Sara Colombo, Yihyun Lim, Miguel Bruns Alonso, Lin-Lin Chen, Tom Djajadiningrat, Loe Feijs, Jun Hu, Steven Kyffin, Elif Özcan, Lucia Rampino, Edgar Rodriguez Ramirez, Dagmar Steffen

Design and Semantics of Form and Movement

DeSForM 2019
Beyond Intelligence

Massachusetts Institute of Technology
Northumbria University NEWCASTLE
HOCHSCHULE LUZERN
POLITECNICO MILANO 1863 DIPARTIMENTO DI DESIGN
TU/e
VICTORIA UNIVERSITY OF WELLINGTON
TU Delft

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TU Delft

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em lyon business school AIM institute

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DeSForM 2019

Beyond Intelligence

Edited by

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Beyond Digital: Designing with Living Things

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October 9, 2019

Venue: Samberg Center, 6th Floor, E52 MIT Campus. 50 Memorial Drive, Cambridge MA 02139.

15.00 Conference Registration

15.30 Welcome & Introduction
• Yihyun Lim, Sara Colombo - *Conference Chairs, MIT Design Lab*

15.45 Panel Presentations: "Beyond Digital: Designing with Living Things"
• Orkan Telhan, *Cofounder, Chief Design & Technology Officer Biorealize Inc.*
• Jiwon Woo, *Biodesigner, Hypha Design*
• Jorge Duro-Royo, *Co-Director, DumoLab*

16.30 Break

16.45 Panel Discussion / Q&A
• Moderated by Scott Penman, *MIT Design Lab*

18.00 Conference Reception

October 10, 2019

Venue: Samberg Center, 6th Floor, E52 MIT Campus. 50 Memorial Drive, Cambridge MA 02139.

8.15 Conference Registration & Breakfast

9.00 Welcome
• Federico Casalegno, *MIT Design Lab*

9.10 Conference Opening Words
• Sara Colombo, Yihyun Lim - *Conference Chairs, MIT Design Lab*

9.30 Keynote Presentation "AI as Tool, Partner, and Inspiration"
• Martin Wattenberg, *Google PAIR*

10.30 Coffee Break

10.45 Paper session 1 - Design Manifestos: What's Next | *Chairs: Sara Colombo and Yihyun Lim*
• Future Forecasting Wicked Problems: A New Framework for Design
Fillippo Sanzeni, Ashley Hall, Paul Anderson *(Royal College of Art, London)*
• Eventual Design for an Emergent World
Nathan Felde *(Northeastern University, Boston)*
• The Decentralization Turns in Design: An Exploration Through the Maker Movement
Massimo Menichinelli *(RMIT University, Barcelona; Aalto University, Helsinki)*,
Priscilla Ferronato *(University of Illinois, Urbana-Champaign)*

11.45 Coffee break

12.00 Paper session 2 - Interacting with Domestic Intelligences | *Chair: Edgar Rodriguez Ramirez*

• The Domestic Shape of AI: A Reflection on Virtual Assistants
Davide Spallazzo, Martina Scianname, Mauro Ceconello *(Politecnico di Milano)*

• Conversational Smart Products: a Research Opportunity, First Investigation and Definition
Ilaria Vitali, Venanzio Arquilla *(Politecnico di Milano)*

12.40 Lunch + Short Paper / Demo Session

• Prosumeristic Publications: alt+yd
Harshali Paralikar, Ajitesh Lokhande *(National Institute of Design, Paldi, Ahmedabad, Gujarat, India)*,

• Swimming Coach: An Immersive Swimming Learning System
Shuo Li, Cheng Yao, Mingxuan He, Qingcong Wang, Ying Wang, Yuyu Lin, Juanli Liu *(Zhejiang University, Hangzhou),* Fan Xia *(Mercyhurst Preparatory School, Erie)*, Leijing Zhou *(Zhejiang University, Hangzhou)*

• Designing Transparent Collaborations - Weave
Gissoo Doroudian *(College for Creative Studies, Detroit)*

• Huxley: Intelligent Book as Essentialist Artefact
David Ramsay, Joe Paradiso *(Massachusetts Institute of Technology, Cambridge)*

• OlfacEnhancer: A Vision-Based Scented Necklace for Cross-Modal Perception and Olfaction Augmentation.
Yuyu Lin, Kai Zheng, Lijuan Liu, Yang Chen, Jiahao Guo, Shuo Li, Cheng Yao *(Zhejiang University, Hangzhou),*
Fangtian Ying *(Hubei University of Technology, Wuhan)*

• APOSEMA: Exploring Communication in an Apathetic Future
Adi Meyer, Sirou Peng, Silvia Rueda *(University College London)*

• HuValue: A Toolkit to Facilitate Considering Various Human Values in a Design Process
Shadi Kheirandish, Mathias Funk, Stephan Wensveen *(Eindhoven University of Technology)*,
Maarten Verkerk *(Maastricht University),* Matthias Rauterberg *(Eindhoven University of Technology)*

• Playing with Systems: Tactile Games as System Prototypes
Tom Maiorana *(University of California, Davis)*

• Attributes of Aliveness: A Case Study of Two Interactive Public Art Installations
Humbi Song, Oliver Luo, Allen Sayegh *(Harvard University, Cambridge)*

• Understanding User Customization Needs: Requirements for an Augmented Reality Lamp Customization Tool
Ana Carina Palumbo, Hella Kriening, Barbara Wajda *(Eindhoven University of Technology)*,
Monica Perusquía-Hernández *(Eindhoven University of Technology; NTT Communication Science Laboratories)*

• Speculating on the Future of Graphic Design in the Age of Intelligent Machines
Sekyeong Kwon, Robyn Cook *(Falmouth University)*

• AI-Stylist: An AI-based Framework for Clothing Aesthetic Understanding
Xingxing Zou, Waikeung Wong *(The Hong Kong Polytechnic University)*

14.30 Introduction of AIM Institute Research Initiatives: Artificial Intelligence in Value Creation
Margherita Pagani, *Research Center on Artificial intelligence in Value Creation - AIM Institute - Emlyon Business School*

14.40 Paper Session 3A - Interacting with Urban Intelligences (I) | *Chairs: Yihyun Lim and Sara Colombo*

• AI-to-Microbe Architecture: Simulation, Intelligence, Consciousness
Dennis Dollens *(Universitat Internacional de Catalunya, Barcelona)*

• Envisioning and Questioning Near Future Urban Robotics
Maria Luce Lupetti *(Delft University of Technology),* Nazli Cila *(Amsterdam University of Applied Sciences)*

• Robot Citizenship: a Design Perspective
Maria Luce Lupetti, Roy Bendor *(Delft University of Technology)*, Elisa Giaccardi *(Umea Institute of Design)*

15.30 Coffee break

15.45 Paper Session 3B - Interacting with Urban Intelligences (II) | *Chair: Scott Penman*
• Towards Transparency Between the Autonomous Vehicle and the Pedestrian
Selin Zileli, Stephen Boyd Davis, Jiayu Wu *(Royal College of Art; Intelligent Mobility Design Centre, London)*
• The Coerced User and the Era of Smart City Dissonance
Guy Cherni, Roee Bigger *(Bezalel Academy of Arts and Design, Jerusalem)*

16.30 Keynote Presentation "How to Design for the Unconscious"
• Matthias Rauterberg, *Full professor for "Interactive Systems Design", Department of Industrial Design , Eindhoven University of Technology*

18.00 Conference Dinner - *Charles River Sunset Cruise Dinner*

October 11, 2019
Venue: Bartos Theater, Building E15 Lower Level, 20 Ames Street, Cambridge MA 02139.

8.15 Conference Registration & Breakfast

9.00 Keynote Presentation: "Adaptive Dynamics: Creating Intelligent Sportswear Experiences "
• Charles Johnson, *Global Director Innovation, PUMA*

10.00 Paper Session 4 - New Interfaces for Complex Ecosystems | *Chair: Davide Spallazzo*
• Drawing Interfaces. When Interaction Becomes Situated and Variable
Ilaria Mariani *(Politecnico di Milano)*, Tommaso Livio *(Thingk)*, Umberto Tolino *(Politecnico di Milano, Thingk)*
• Individual Mid-Air Gesture Sets Informed by Conceptual Metaphors: A Case Study on How Users Generate Mid-Air Gesture Sets to Control Video Streaming
Gulben Sanli Eren *(Istanbul Technical University)*
• A Pedagogy for Noticing – Soma Literacy and the Designer
Stephen Neely *(Carnegie Mellon University, Pittsburgh)*

11.00 Coffee break

11:20 Introduction of Northeastern University Center for Design
Paolo Ciuccarelli, *College of Art, Media and Design - Northeastern University*

11.30 Paper Session 5 - Smart and Multi-Sensory Systems for Behavior Change | *Chair: Lucia Rampino*
• Designing Phygital Activities in a Smart Multisensorial Room: A Collaborative Cognitive Environment for Children with and without Disabilities
Micol Spitale, Agnese Piselli, Franca Garzotto, Barbara Del Curto *(Politecnico di Milano)*
• Recommendations when Designing to Address Procrastination: A Psychological Perspective
Helen Andreae *(Northumbria University, Newcastle upon Tyne; Victoria University of Wellington),*
Abigail Durrant, Steven Kyffin *(Northumbria University, Newcastle upon Tyne)*
• R2S: Designing a Public Augmented Printed Media System to Promote Care Home Residents' Social Interaction
Kai Kang, Jun Hu, Bart Hengeveld, Caroline Hummels *(Eindhoven University of Technology)*

12.30 Lunch

13.15 Participatory Workshop: "The Soma Literacy of AI"
• Stephen Neely *(Carnegie Mellon University, Pittsburgh)*

14.15 Paper Session 6 - Design and Semantics for Health and Inclusion | *Chair: Sotirios Kotsopoulos*
• Nova Creatio: A Clinical Perspective on Rehabilitative Everyday Objects for People with Chronic Stroke
Mailin Lemke, Edgar Rodríguez Ramírez, Brian Robinson *(Victoria University of Wellington)*
• The Semantics of Conspicuity: Design Strategies to Address Conspicuity in Type 1 Diabetes Medical Devices for Adolescents
Madeleine J. Hazelton, Gillian M. McCarthy, Edgar R. Rodríguez Ramírez *(Victoria University of Wellington)*
• Sitting Still: Seat Design for a New Head-Only MRI Scanner
Christy Wells, Edgar Rodríguez Ramírez, Mailin Lemke, Benjamin Parkinson *(Victoria University of Wellington)*
• Designing Research Prototype for the Elderly: A Case Study
Cun Li, Jun Hu, Bart Hengeveld, Caroline Hummels *(Eindhoven University of Technology)*

15.35 Coffee break

15.50 Paper Session 7 - Designing with Humans, Machine Intelligence, and Data | *Chair: Scott Penman*
• Plug-ins Jungle: Algorithmic Design as Inbuilt Dynamism Between Human and Artificial Creativity
Giuseppe Bono *(University College London)*, Pilar Maria Guerrieri *(Politecnico di Milano)*
• Defining a Data Impact Tool for Design Courses
Laura Varisco, Margherita Pillan *(Politecnico di Milano)*, Patrizia Marti *(Università' degli Studi di Siena)*

16.50 Conference Closing Ceremony

October 12, 2019
Boston Brewing & Beyond - Craft Beer Brewery Tour of Boston

Contents

Sara Colombo, Yihyun Lim
Design Lab, Massachusetts Institute of Technology, USA

Beyond Intelligence

Re-focusing on Human Experience in Complex Artificial Ecosystems

Designing Ecosystemic User Experiences

In recent decades, design has faced profound challenges and transformations. The traditional approach to crafting and shaping the tangible world has been challenged by the world's infusion with digital technologies, which have made it smarter, more interactive, and more connected.
DeSForM, the conference on the Design and Semantics of Form and Movement, was undertaken in 2005 as an attempt to foster discussion in the design community around how to design the meaning, aesthetics, and experience of responsive and dynamic artifacts. DeSForM's intent was to *"present current research into the nature, character and behaviour of emerging new typologies of co-designed, content rich, connected and intelligent objects within adaptive systems."* [1]

Those 'emerging new typologies' of 'intelligent objects' have developed and spread over the following years, bringing the rise and formalization of new areas of design research, such as interaction design, user experience, and the aesthetics of interaction. These domains have been widely investigated in the works presented and debated in the past editions of DeSForM.[2]

However, recent technological developments are causing even more rapid and extreme changes than the ones witnessed at the beginning of this century. The emergence of artificial intelligence and machine learning, flexible electronics, virtual and augmented reality, miniaturized and implantable sensors, and hybrid synthetic-biological materials have not only provided designers with new design ingredients, but also generated new cultural and social landscapes in which they must operate.

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[1] https://www.northumbria.ac.uk/about-us/academic-departments/northumbria-school-of-design/research/desform/what-is-desform/

[2] For a full account of the DeSForM past editions, you can access the previous proceedings at https://www.northumbria.ac.uk/about-us/academic-departments/northumbria-school-of-design/research/desform/previous-conferences-and-proceedings/

In this context, designers are called to design not intelligent products *within* adaptive systems, but rather those adaptive systems as a whole. Objects can no longer be interpreted and designed as independent elements, detached from the other components of the complex digital-physical ecosystems they belong to. In such hybrid ecosystems, new distributed intelligences, advanced materials and interfaces, sensing technologies, data, and humans are deeply interconnected and mutually shaped. Their understanding, design, and evaluation demand approaches and tools able to tackle this complexity. Despite this, as these systems become increasingly intelligent, their meanings, aesthetics, and ethics still seem to be overlooked.

Designing *beyond intelligence* means that the design of such complex and smart ecosystems should consider issues beyond mere algorithmic thinking and functionality. Scholars and practitioners in the design field are encouraged to reflect on the connections and mutual relations between the performance of these intelligent ecosystems and their physical appearances, meanings, personalities, and interaction modalities. In doing so, they will be able to address the design of ecosystemic user experiences.

Going 'Beyond Intelligence': New Challenges for Design

In the XI edition of DeSForM, hosted by the Massachusetts Institute of Technology, we explore the implications of recent and emerging technological transformations in the practice of design, with a particular focus on the human experience of these complex systems.

We invited designers, artists, researchers, and industry practitioners to address the need to design for distributed, hyperconnected, and learning intelligent ecosystems, and to investigate how their meanings, experience, and ethics can be approached.

In doing so, we identified a number of possible challenges that we believe are worth exploring in the upcoming years. They refer to i) the growing complexity of the concept of user experience; ii) emerging forms of interaction with human-like intelligences; iii) the ethical implications of digital-physical systems; and iv) the new roles designers should assume in this context.

Experiencing Complexity

As ecosystems of digital-physical solutions become more layered, distributed, and connected, the user experience also grows in complexity. New elements need to be considered, including the meanings of these systems, the multisensory and multimodal interactions they necessitate, and the emotions that such interactions generate.
The tangible manifestations of the systems users interact with are just a tiny part of a huge underlying infrastructure of data, algorithms, platforms, and digital contents. As functions overlap in the same product and digital contents constantly change, physical objects become just the medium for a plethora of meanings derived from multiple connected platforms. What is the role of aesthetics in such dynamic, digital-physical ecosystems? What meanings can tangible forms convey? What new tools and frameworks are needed to design and evaluate the growing complexity of user experience?

Interacting with New Intelligences

Artificial intelligence opens up new frontiers for design, where emerging forms of distributed intelligence become design material. Technological advancements in this field now provide the user with the possibility to have increasingly human interactions with non-human artifacts. Users' interactions with specialized intelligences have progressively taken on the appearance of companionship and assistantship, as seen in the rise of chatbots and social robots. How does artificial intelligence transform artifacts (objects, spaces) and their interaction modalities? How can design give meaning and form to artificial intelligence, when embedded into products? How do artifacts' aesthetics and experience change through AI at home, at work, or in public spaces? This material should be fully investigated in terms of tangible manifestations, social implications, and impact on the design process and the user experience.

Societal Impacts

The above-mentioned transformations surely pose new challenges to design, not only in shaping the tangible forms of these systems, their meanings, and aesthetics, but also in anticipating the consequences they might have on humans at the individual and societal levels. The emergence of AI, robotic solutions, and big data connected with the spaces, objects, and people we interact with everyday will create new landscapes for future generations of designers. This will require designers to adopt new lenses in the design and evaluation of emerging technology, and it will necessitate that designers equip themselves with new ethical paradigms.
How will algorithmic decision making and autonomous systems impact user experience and behavior? How can we design for transparency and reliability? What are the long-term effects of new digital technologies on society?
As systems become smarter, more self-governed, and increasingly embedded into our reality, designers should develop new approaches and methods to consider ethical issues in their practice.

Future Roles of Design

This evolving context calls for new design skills and ways of thinking that go beyond the traditional field of design. How will this domain change, in order to interface with new fields of knowledge such as biotechnology, computer science, AI, and ethics? What are the future roles of design in shaping the growing complexity of the artificial world, where the boundaries between artificial, human, and natural fade? What role can designers play in the multi-disciplinary teams that will envision future systems which are more and more interactive, interconnected, and even unpredictable?

While some of these challenges are just emerging, other issues seem to be already compelling, or will likely be in a short time. This conference invites the design community to reflect deeply on the current and future transformations enabled by technology, as well as their effects on design itself, and on society as a whole. It will take time to fully understand this new landscape and its effects on humans, and to approach it with a critical eye. As some of the works included in these proceedings point out, design is just now starting to react to this transitional moment and to equip itself with new sets of concepts, approaches, and methods to face this changing reality.

DeSForM19 Proceedings

The proceedings from the *DeSForM | Beyond Intelligence* conference are structured to address some of the emerging questions raised above.

Design Manifestos. The first section of the proceedings is dedicated to sharing thoughts on the roles of designers and the meanings of design practice through a series of design manifestos. What are new tools, methods, and frameworks that allow designers to forecast and solve the wicked problems of the future? Observing the current landscape of complex systems and varied forms of intelligences - from artificial machines to synthetic biology - some 'turns' in design practice are identified, which led us to the current state. These manifestos question the role of the designer and the meaning of agency as design practice becomes collaborative at all stages, especially through the use of algorithmically enhanced design tools and artificial intelligence. These questions are expected to repeatedly rise to the forefront throughout the conference.

Interacting with Domestic Intelligences. Perhaps we are more accustomed to interacting with artificial intelligence than we think. Virtual assistants and conversational agents are slowly becoming the norm in domestic settings through the use of smart connected products and social robots. The works presented in this section analyze the current product landscape of domestic intelligences and provide an initial understanding of relationships between form, function, and meaning. As we move into the future of embedded intelligences in our everyday environments, how should we design the shape and interaction modalities of artificial intelligence to effectively translate its function and meaning in an intuitive way?

Interacting with Urban Intelligences. From autonomous vehicles to delivery robots, we will soon, if we are not already, be sharing our urban environment with other intelligent entities. We can no longer opt out from this smart environment experience, and we have no other option but to interact with such systems and provide resources (data) back into their digital networks. Papers collected in this section explore the opportunities and affordances that become available in the design of such environments, as we learn to coexist with various forms of artificial intelligence. From the concept of 'robot citizenship' to that of 'coerced' users, authors suggest new approaches to bring the perspective of urban robots, citizens, and other autonomous systems into the design process.
Shifting our view to the building scale, various forms of intelligence will also become embedded in our architecture. The rise of synthetic biology and the use of engineered microbes as building blocks in urban architecture is opening up an era of hybrid buildings, which function as metabolic systems. Can we simulate nature and create environmentally performative, intelligent, and living buildings?

New Interfaces for Complex Ecosystems. In this plethora of complex ecosystemic experiences, what are the new interfaces for control and interaction? Expanding from voice, text, and gesture-based modalities, what novel interactions can we design for? As we start to build a dictionary of universal interactions with smart products, how shall we explore the semantics of interaction language? Here we explore research in the design of interaction metaphors to represent conceptual understanding of situations (and translation of our language) to communicate intuitively with smart devices. But perhaps before we attempt to design new languages, we should think about methods to reveal and recognize the affordances of technologies in relation to our body, and the aesthetics of interactions it brings.

Smart and Multi-Sensory Systems for Behavioral Change. Although the experiencing human body is the constant in this ever-changing environment of complex ecosystems of intelligences, the designed experience of these systems induces behavioral changes in its users. The papers in this section investigate the effects of the merger of digital experiences and physical environment on human behavior, from creating 'phygital' activities that affect the cognitive learning abilities of children, to mitigating procrastination through designed interventions in built environment and interactive artifacts. Moreover, attention is paid to the experience of caring in elderly living environments through the use of connected technologies. What experiences can we augment with technologies and what should remain as human-driven?

Design and Semantics for Health and Inclusion. Focusing on the health industry, we look further into the semantics and aesthetics of interaction in medical and assistive devices. This topic explores semantic strategies and design criteria to overcome social stigmas in the use of assistive devices, and to improve rehabilitation processes as well as overall user experience.

Designing with Humans, Machine Intelligence, and Data. This final topic brings us back to the discussion on the role of design and the various societal issues designers should consider in their research and practice. What tools and methods can help us to navigate the complexity of data privacy issues in the co-design process? Moreover, as our design software tools become more intelligent and generative, should we rethink the notion of design agency, and invite our software tools to become our creative partners?

Interactive Demos

Short papers and their related interactive demos explore five thematic areas: designing immersive experiences, AI and human collaboration, AI curated experiences, sensory augmentation and communication, and processes and tools for design and awareness.

Immersive Experience. Virtual reality is often used in safety training for hazardous situations or difficult to access environments. What if mixed-reality experiences are used to learn swimming? Can simulated experiences help overcome the fear of water, and bring the experience of swimming to those with limited access to aquatic environments? Along the line of making experiences real, another project explores the 'aliveness' of public art installations, to bring continuous life through embedding real-time responsiveness and audience participation in art experience.

AI and Human Collaboration. Here we explore the design of transparent collaboration between humans and machine intelligences. From graphic design to web contents, and also digital publications, how do we define design agency when algorithms and machine intelligence become active creators of experiences?

AI Curated Experiences. From music to movie platforms, we are accustomed to algorithmically-curated contents based on individual preferences. How about algorithmically-curated clothing suggestions? Can machine intelligence evaluate aesthetics, cultural nuances, individual preferences, and other design elements? Thinking further about human experiences, can AI understand and foresee users' desired engagement level, and curate a holistic reading experience by, for example, selecting appropriate content and creating an optimal ambient sensory environment?

Sensory Augmentation and Communication. Human experience is deeply affected by sensory experiences and social interactions. Can an augmented olfaction device strengthen the link between olfaction, vision, and memory? Or better yet, can we translate our emotions and visually communicate these through an interactive wearable device for the face? Can digital technology and algorithms enhance human communication and social interaction, or is this a false hope?

Process and Tools for Design and Awareness. We close the Interactive Demo section with new toolkits and processes for design and awareness. What are the ways to guide a value-driven design process and the creation of meaningful products? What methods can help unpack complex systemic challenges like climate change, to stimulate discussion and ideate potential interventions?

Future Perspectives

This edition of DeSForM covers a wide range of topics related to designing with new forms of intelligence in complex human-artificial and digital-physical ecosystems. If the trends we are debating at this venue continue to develop, distributed intelligences could potentially affect any designed reality, as well as the experiences that result from users' interactions with these realities.
While design as a discipline is required to develop specific frameworks and tools to tackle the growing complexity of our world, such a diversity of application fields also calls for a collaborative approach with other areas of knowledge. Designers will need to operate more and more in concert with technologists, computer scientists, architects, social scientists, psychologists, and ethicists, as well as policy makers and industry players, in a joint effort to reduce the risks and amplify the positive potential of these transformations. This will ultimately support the type of technological development that is truly centered on and beneficial to humans, both at the individual and societal levels.

Keynotes

Martin Wattenberg
Co-lead, Google PAIR (People + AI Research)

AI as Tool, Partner, and Inspiration

Abstract
How should people relate to artificial intelligence technology? Is it a tool to be used, a partner to be consulted, or perhaps a source of inspiration and awe? As technology advances, choosing the right human / AI relationship will become an increasingly important question for designers. I will show a series of examples--ranging from data visualizations to tools for medical practitioners--that illustrate how AI can play each of these roles in turn. I will then discuss and analyze the considerations that determine which role may be right for which situation.

▶

Martin Wattenberg co-leads Google's PAIR (People + AI Research) initiative and the Big Picture team. His work at Google, with long-time collaborator Fernanda Viégas, currently focuses on making AI technology broadly accessible and reflective of human values. He, his team, and Fernanda have also created end-user visualizations for products such as Search, YouTube, and Google Analytics.

Before joining Google, Fernanda and he founded Flowing Media, Inc., a visualization studio focused on media and consumer-oriented projects. Prior to Flowing Media, they led IBM's Visual Communication Lab, which created the ground-breaking public visualization platform Many Eyes. He came to IBM from Dow Jones, where he was the Director of Research and Development at SmartMoney.com. His work there included some of the earliest pieces of interactive journalism.

He is known for visualization-based artwork, which has been exhibited in venues such as the London Institute of Contemporary Arts, the Whitney Museum of American Art, and the New York Museum of Modern Art.

He has a Ph.D. in mathematics from U.C. Berkeley, focusing on dynamical systems.

G. W. Matthias Rauterberg
Full Professor for "Interactive Systems Design"
Department of Industrial Design, Eindhoven University of Technology

How to Design for the Unconscious

Abstract
We can distinguish human activities as intentional and unintentional, conscious and unconscious, and many more. Most of the modern interaction design in the West relies on conscious decision making of the user. One challenge in the upcoming design of interactive products and systems is how to tap into the unconscious of human behavior. Such kinds of design have to rely on input signals beyond introspection based on human language. These new types of input are bio-signals, video monitoring, deep learning, etc. The presentation will address potential building blocks of the unconscious and related design challenges. I will show potential directions into the future.

▶
Prof. Dr Matthias Rauterberg received a B.S. in Psychology (1978) at the University of Marburg (Germany), a B.A. in Philosophy (1981) and a B.S. in Computer Science (1983), a M.S. in Psychology (1981) and a M.S. in Computer Science (1986) at the University of Hamburg (Germany), and a Ph.D. in Computer Science/ Mathematics (1995) at the University of Zurich (Switzerland). From 2006 till 2015 he was the head of the Designed Intelligence research group, department of Industrial Design at the Eindhoven University of Technology (TU/e, The Netherlands). He has over 450 publications in international journals, conference proceedings, books, etc. His recent research is in the area of entertainment computing, cognitive systems, human-computer interaction, and design science.

Charles Johnson
Global Director Innovation, Puma

Adaptive Dynamics: Creating Intelligent Sportswear Experiences

Abstract
Adaptive Dynamics: Creating Intelligent Sportswear Experiences will discuss PUMA's legacy in innovation for human performance. It will discuss PUMA's journey in integrating the experience of Adaptiveness with digital technology, ecosystem of connected user-experiences, and new forms of intelligences, such as living microorganisms. From track spikes to football kits to automated lace footwear and platforms for customized user experiences, this presentation will address innovation perspective from the industry side, and highlight how PUMA is defining the future vision for sportswear in the current landscape of technological developments.

▶
Charles Johnson has more than 30 years' experience in the sports industry specializing in product strategy and innovation. He has served global brands such as Adidas, Converse and Ralph Lauren both as an employee and formerly through Sports Creative Group, Inc., the New York-based consultancy he founded. He received his formal design training at Carnegie Mellon. In his current role as PUMA's Global Director of Innovation, Charles oversees a network of designers, engineers, material specialists and scientists responsible for bringing life to innovative, performance enhancing products and systems for athletes.

Panel

Beyond Digital: Designing with Living Things

Orkan Telhan

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Workshop

Stephen Neely
Assistant Professor in Dalcroze Eurhythmics, Carnegie Mellon

The Soma Literacy of AI

Abstract

In this short session, Stephen Neely presents methods from theater/music performer training to challenge participants to question the ways technologies engage the actual human reality and notice the variables of experience we are all pre-reflectively attuned to.

Stephen Neely, PhD, Carnegie Mellon Assistant Professor in Dalcroze Eurhythmics, is a teacher, conductor, theorist, musician, and clinician who teaches, lectures, and presents workshops in the fields of design, music, architecture, and pedagogy. He is a dynamic speaker who enjoys traveling to present hands-on workshops and clinics focusing on the overlaps between music, design, the body, esthetics, performance, and experience. He has entertained invitations to present his work in Mexico, Indonesia, China, England, Switzerland, and throughout the USA. An introduction to his research agenda can be found through his TEDx talk and a more thorough discussion in his dissertation *Soma Literate Design–recentering the interstitial in experience*.
"My research focuses on the physical nature of experience and the reflections of the artful gesture in everyday interactions—that is, the ways in which our feeling bodies are necessary components of musical participation and how that understanding presents artful potential in any experience."

Topic 1.

Design Manifestos: What's Next?

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Future Forecasting Wicked Problems: A New Framework For Design

Abstract

Design can be characterized as 'knowledge for future transformation' and is a discipline concerned with developing new products, systems and services that change the future. However, the methods we use for generating foresight are underdeveloped and some gaps and issues remain. This is especially true between more speculative approaches to designing futures and applied industrial approaches. This paper explores these issues in relation to addressing wicked problems in design, specifically the emphasis on qualitative methods and how these lack measurable indicators of problem improvement. The use of mixed methods offers possibilities for combining the power of abductive thinking generating alterative visions of the future alongside quantifiable improvements. We review methods for future forecasting in other fields including economics and business management and explore how these can be transposed into design practice to address some of the issues raised. A proposal is made to achieve this via an interdisciplinary mixed method approach by instigating a process of gap analysis within a new design futures framework.

Keywords

Future Forecasting, Wicked Problems, Design Methods

1. Introduction

The argument for future forecasting in design is based on the following semantic difference between 'prediction' and 'forecasting': predicting refers to announcing future events and making prophecies; forecasting is about making calculated hypotheses and suppositions about what could happen in the future using qualitative or quantitative information from the past or present. The importance of thinking about the future and preparing for it has grown in the last decades, due to the increasing awareness and number of complex and undefinable problems. These are issues which cannot be solved with a miraculous solution, simply because the problems are too complex and dynamic for solutions to be proposed before we begin to tackle the problem. Examples of wicked problems include opiate addiction, obesity, climate change, anxiety. Further, we recognize that the issues of climate change are composed of a complex interacting set of wicked problems.

The type of future forecasting we focus on here is specifically aimed towards supporting the improvement of wicked problems tackled via a range of design methods by designers or those trained in design methods from a range of disciplines. These include traditional design fields such as industrial design and service design but also those working in health, energy, social, transport, ICT and other fields.

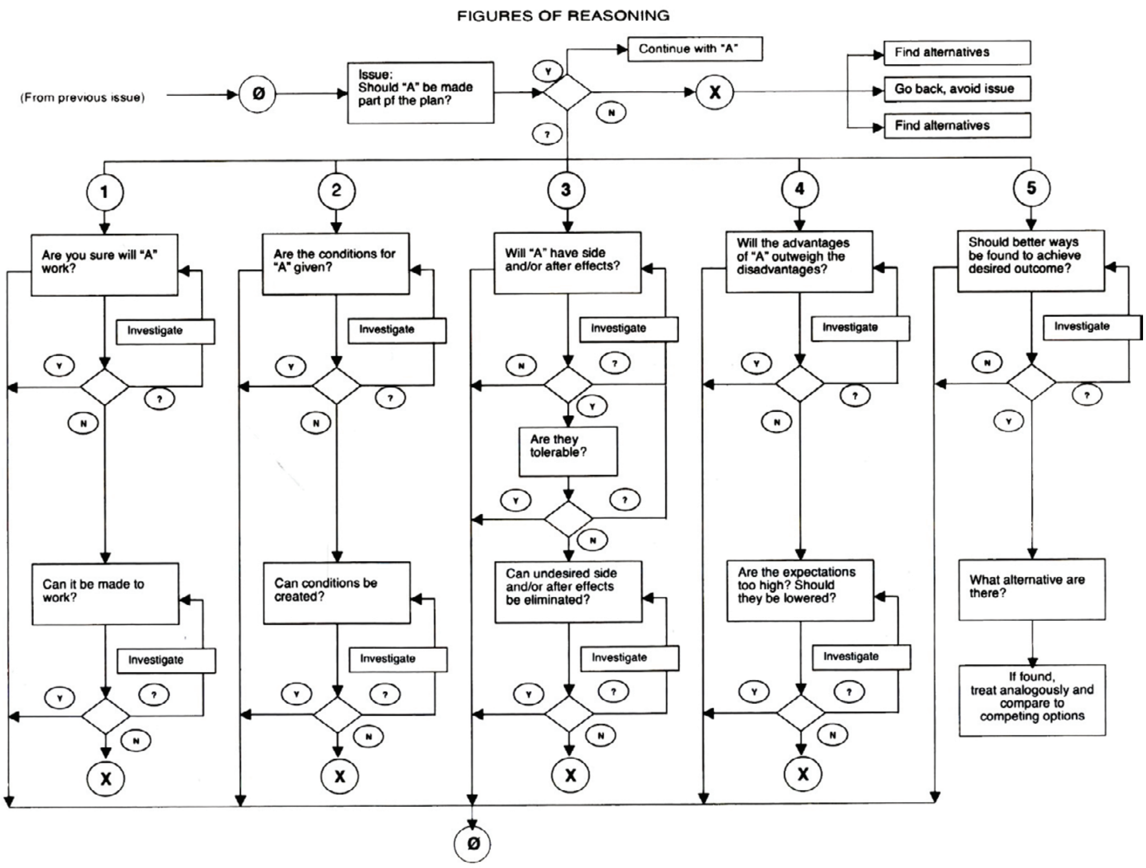
Rittel and Webber called these types of issues "wicked problems", in contrast to "tame problems" which can be approached and solved using known analysis paradigms and decision-making processes. A wicked problem is a complex and troubling situation, which refuses to be fenced and described with a unifying definition and requests interdisciplinary solutions [1]. Figure 1 shows a diagram from Rittel's 'The Reasoning of Designers' and is clearly aimed at generating a flow diagram to tackle complex problems. However, the type of information being processed (qualitative/quantitative) is omitted. Buchanan argues that design, is inherently suitable for tackling wicked problems since it has a potentially universal scope, which is inevitably narrowed down into a subject, emerging from the observed issues and problems [2].

1.1 Designing for the Future

The field of design is focused on changing the future: two early historical examples are Buckminster Fuller's 1956 course about Comprehensive Anticipatory Design Science, which was aimed at systematically foreseeing future crisis [3] and Papanek's Design for the Real World, which pioneered the field of sustainable design by citing the adverse effects on the environment of designing products [4].

Other established approaches to exploring possible futures are discursive design, fictional design and its extension - speculative design and critical design (SCD). As the name intends, discursive design is aimed at the creation of products – intended in the broadest meaning possible – which aim to facilitate discourse and debate in design practice [5], fictional design creates

Fig. 1. Rittel's flow diagram from the reasoning of designers (Source: Rittel, H. (1988). The Reasoning of Designers, Arbeitspapier zum International Congress on Planning and Design Theory in Boston, August 1987)



suspension of disbelief through “profitable”, “desirable” but not necessarily “buildable” diegetic prototypes [6]. Dunne and Raby [7-9] broadened this second method by framing the prototypes in society and by stressing out their ability to critique the very development of the technologies involved. They use extensively the concept of Future Cones (Figure 2), initially introduced by Hancock and Bezold [10] in 1994 as part of a WHO future of health report and later more commonly referenced by Voros [11], which projects possible, plausible and probable futures and creates an opportunity for constructing a preferable future.

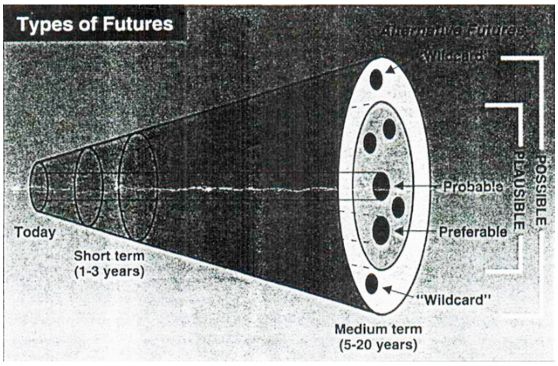


Fig. 2. Futures cone (Source: Bezold, C. and Hancock, T. (1994). An Overview of the Health Futures Field. WHO Consultation, July 19-23.

Although initially conceived as a critique to the over-use of science fiction elements in design, the speculative/critical approach is grounded in the researcher’s previous experiences, rather than the context in which the provocation will take place: two notable examples are the project *Foragers* by Dunne and Raby [12] and Burton and Nitta’s *Republic of Salivation* [13]. The first was commissioned by the South African organization Design Indaba to explore the future of farming and represents future Caucasian individuals struggling to find food in an over-populated world. As sustainability designer Cameron Tonkinwise imagines in one of his *Science Fictions About Critical Design* [14], this project might incur some malcontentment if, for example, it would have been exhibited in post-ebola Liberia. In *Republic of Salivation*, Burton and Nitta envision a future in which food scarcity and hunger is resolved in a centralized and government-led rationing system, which assign nutrients based on the worker’s job. Although it resonates with being a possible future dystopia in some European countries, this project would simply be an exercise about recent history in other countries, such as China, Brazil or even post-war Italy.

Another approach that looks at designing for the future specific to the field of HCI is Reflective Design [15]. Based on Critical Theory, this reflective approach questions the unconscious assumptions in HCI by outlining a series of principles to be considered when the designer designs interactions with technology. Although these principles can be used to design "better answers" [16] for existing and circumscribed problems, this method does not lend itself to addressing wicked problems.

This fictional and speculative approach to the future, although it may contribute to the creation of stimulating and entertaining narratives in some geographical areas of the world, is rooted in abductive reasoning [17-19], where the designer projects an alternative view of the future world hence creating a difference. It can be argued that the mere act of projection changes the future by offering an alternative that may be adopted. As argued above, wicked problems are fluid issues that cannot be solved with a preemptive solution. Hence, forward-looking yet reductionist design practices, such as discursive, fictional and speculative design, are ill-equipped when charting a plan of action to tackle them. These future generation methods are aimed at inspiring debate and consciousness-raising for the consideration of the different types of future that we may create. However, they do not claim to solve the issues raised. Speculative critical design deliberately positions itself away from industrial practices and is often exhibited in museum contexts in a situation where feedback loops for tackling wicked problems are weak. Whilst we can see exciting provocative and insightful future projections that often visualize future wicked problem scenarios these leave a significant gap in addressing wicked problems. Improving wicked problems requires the integration of a means to assess the changes that have taken place either by gathering quantitative data or by qualitative assessments throughout the design process.

Research in the fields of economics and business management has employed extensive forecasting techniques to explore uncertainty in the future and describe the outcomes of decision-making processes [20]. The methods employed rely either on qualitative insights or quantitative analysis [21]. It has been demonstrated empirically that either method if employed alone, yields uneven and inconsistent results, but the forecast accuracy greatly increases when the two methods are combined in a meta-forecast [22-23]. In their comprehensive review about the advantages and disadvantages of quantitative and qualitative forecasting methods, Bunn and Wright concluded that the literature on forecasting is overwhelmingly supporting the idea of combining multiple outputs, to increase the forecast's accuracy, its communicability to third parties and its defensibility from criticism [24].

Although some examples of using qualitative and quantitative methods in interdisciplinary teams exist, we found very little focus on over-arching frameworks that are specifically tailored for design-led action in addressing wicked problems using mixed qualitative and quantitative methods throughout the process. We propose to transpose the interdisciplinary integration of intuitive and computational methods common in other fields into the practice of designing for the future through a process of gap analysis, to address wicked problems.

1.2 Core Assumptions in Future Forecasting

In order to assist in the development of a framework to integrate qualitative and quantitative methods throughout a wicked problem improvement process we note here a number of assumptions that function to focus our thinking:

1. The ultimate aim of future forecasting is to improve the welfare of humankind, of all animals, plants and the biosphere. This is achieved via the systematic exploration of possible alternative futures: the probable (what is almost sure), the possible (what can be), the plausible (what might be) and the preferable (what ought to be). However, future forecasting is not merely about depicting possible future scenarios: it is the strategic approach on how to reach (or avoid) each one of those scenarios.

2. The future of a wicked problem cannot be stated with absolute certainty. It is inevitable that a certain degree of uncertainty will persist until the forecasted event has passed.

3. Total and organic forecasts are utopic: there will always be some aspects of a problem which were not thought of or deemed essential to address especially as many wicked problems are viewed by diverse stakeholders who may see the problem in very different terms. Furthermore, it is impossible to forecast sudden unexpected impacts and Black Swan events.[1]

4. Interdisciplinary teams, composed of experts in diverse subjects need to work together to produce possible solutions. Lee Fleming demonstrated that in these conditions the outputs, even though not very relevant most of the time, have higher chances of being breakthroughs. For instance, missile guidance systems used by the United States Army in the Sixties were invented during the Second World War by a team composed of Hedy Lamarr (an actor) and George Antheil (an avant-garde composer). Their technology became the precursor to modern radio standards, such as Wi-Fi and Bluetooth.

5. Providing forecasts to policy-makers, innovation units and public and private institutions will help them to formulate new social, economic and management policies. These new policies, in turn, will change the future, wearing away the forecast's accuracy.

2. Compasses and Maps

Generally, there are two kinds of forecasting methods: *qualitative* and *quantitative* [20][25]. The former is sometimes used if there is no data available on the researched topic, or if the data has little or no relevance to the researcher's focus. The latter is used if there is relevant data to assume that events from the past will continue to happen with little variation in the future. When using future forecasting techniques designers overwhelmingly base their methods on qualitative approaches and when data is used it is generally adopted to provide starting points and provide a semblance of rigor from which to base forward looking creative processes. It is much less evident that designers employ data and quantitative methods in partnership with qualitative throughout the wicked problem process in a way that each provides a feedback loop for the other.

[1] Term indicating situations and events which appear in a random and unexpected fashion, such as the 2008's financial meltdown and the dot-com bubble in 2001.

2.1 Qualitative Future Forecasting

Qualitative future forecasting is based on individual or group creative methods focused on the problems addressed. Due to the high level of experiential individual and group based focus this method is often referred to as 'judgmental' [20]. Inevitably, these methods are leveraged based on an 'expert' focused mindset. Qualitative forecasting is employed when it is deemed that the future will not behave in the same manner as the past. A good example is the Australian Government's decision in 2011 to enforce companies to use dark green on cigarette packaging, in an effort to increase public health by reducing tobacco consumption [26]. Qualitative forecasting is helpful when a large amount of specific and local data is scrutinized to discern patterns which will not be flagged using a quantitative approach, as they require a more nuanced sensibility to be recognized. For example, when a construction company decides which kind of housing it has to build in a specific neighborhood, it generally seeks help from an expert on the local population, to better understand the demographic and cater to their needs. Compared to quantitative forecasting, there are two distinct advantages in using this method:

- It enhances the capacity to anticipate changes in patterns, grounded on the knowledge of experts in the field.
- It gives the flexibility to use both specific, diverse and non-numerical sources, which possibly enhance the forecast's quality since statistics cannot capture all the localized and individual nuances which may be highly significant.

Since this method is rooted in *informed opinions* and not quantifiable data, there are some caveats, vis-a-vis quantitative methods. A study conducted by Lawrence et al. [27] highlights that the information used in judgmental forecasts are partial and biased to a certain degree, since the data used as a starting point for the analysis is selected without specific criteria and a fixed probability weighting system.

2.2 Quantitative Future Forecasting

Quantitative forecasts are often linked to specific disciplines and are developed to address a defined and focused situation but, overall, they can be categorized as Extrapolative, Explanatory or Simulations.

Extrapolative Methods. These methods assess how the series of observations made until a specific moment in time will continue to evolve in the future. They strictly use information already known to the forecasting team, and do not help in determining what factors can modify or impact the observed course. Consequently, it is possible to extrapolate trends and past seasonal cycles. Usually, extrapolative methods are based on time-series data [28], which are used when trying to forecast an event which is changing dynamically through time [29] such as the stock value of the market.

Explanatory Methods. These methods look at *explanatory variables* [28], such as the prices of specific goods, and assume that these variables have an explanatory relationship with other independent variables. This model usually includes a third variable, called error, which represents the randomness in the system [28].

Simulation Methods. Simulation methods are based on analogies: a *mechanical analogy* could be a crash test held to verify a car's behavior in an accident. A *mathematical analogy* could be an equation describing the behavior of a flock of birds. A metaphorical analogy could be the use of a neural system to describe the working of a computer and a game analogy is used when the player's interactions are symbolic for the interactions inside of society [30].

2.3 Combining Forecasts

Combining multiple forecasts deriving from the same method family is a useful procedure to achieve higher accuracy in the overall results [31]. This process of combining results requires an interdisciplinary approach, which leverages on the porous nature of social networks [32][2]. Ronald Burt [33] argues that the higher the homogeneity of thought in a group, the more access to different points of views and perspective

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[2] This figure of speech is derived from an interview with former CEO of the French company Rhône-Poulenc: "le vide (literally, the void) has a huge function in organizations. [...] If you do not leave le vide, you have no unexpected things, no creation" [34] [35].

the people which are part of multiple groups have, empowering them to have more options to think about and synthesize. They can see more broadly, select data and insights and synthesize them effectively in their practice [34][35].

Combining Qualitative Forecasts. Thus, it is evident that the starting point for an effective forecast is the group of people which constitute the team tackling the issue, the stakeholders involved and their social capital. The complexity lies, therefore, in selecting the appropriate person necessary for the specific context.[3] Combining various qualitative forecasts can be achieved using various methods, such as the questionnaire-based Delphi, the more visual Futures Wheel or the better known and used Scenario Making.[4]

Combining Quantitative Forecasts. The analysis has to be done in ways that ensure repeatability of the process, such as an arithmetic average. In fact, it has been demonstrated by Robert T. Clement [37] that the simple average can perform as well as more sophisticated statistical methods. The 'magic number' of forecasts to combine has been empirically demonstrated by Makridakis and Winkler [38] when they calculated the error reduction of multiple forecasts combined: most of the error reduction was achieved after combining five different forecasts. A good example of combining forecasts is the work of Lobo and Nair [39]. They analyzed the quarterly earnings forecasts for 96 different companies between 1973 and 1983, employing two separate qualitative methods and two quantitative extrapolations to justify their projections. By combining the judgmental outputs, they lowered the Mean Absolute Percentage Error (MAPE) by a total of 5.2% [39].

3. Future Forecasting for Designers

Despite the advantages future forecasting offers in terms of risk mitigation, efficient planning strategies and preemptive decision making in the context of economics and business management, the concept has its limitations, as extensively addressed by van Vught [40] and Khan and Mann [41]. The pitfalls of qualitative methods stem from logical fallacies (that is, those which depend on the human factor) and are a byproduct of an underlying fallacy deriving from Hegel's historicist approach [42][43]. His arguments are grounded on inductive reasoning, which states that if it is possible to observe a certain regularity in a limited number of situations, it is feasible to formulate a generic statement which implies the future repetition of that particular instance [44]. This mental framework alone is questionable, as argued by David Hume and Bertrand Russell[5] [45]: they evidenced the complete lack of any logical argument on which it is possible to base the assurance that future experiences will resemble in any way an already experienced phenomenon. On the other side, an approach to future forecasting which relies solely on computational and quantitative methods can impoverish the design activity by reducing the ability of abductive reasoning to identify alternative futures, in effect it can radically reduce divergent thinking [46]. An improved mental framework for the designer can be suggested by the mixed use of quantitative and qualitative approaches. If quantitative and qualitative research is seen as a continuum, where qualitative-driven research is mainly "constructivist-poststructuralist-critical" and quantitative-driven research is post-positivist [47], the mediation of the two is given by pragmaticist and pluralist approach to the future [48].
To summarize we have argued that traditional design approaches to future forecasting are under-powered in not fully leveraging the capabilities of quantitative methods integrated throughout the creative process of addressing wicked problems. Existing methods from speculative critical design are powerful ways of visualizing alternative futures but have weak feedback loops and were into originally intended to tackle wicked

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[3] It is important to stress that social capital is not a prerogative of a selected group of people, such as lawyers, scientists or politicians: it lies in those structural holes in the fabric of society, as Burt describes them [38][39].
[4] For a thorough review of qualitative forecasts and how they can be combined, see Glenn & Gordon's Future Research Methodology [36].[5] Russell made evident the fallacy of inductivist reasoning with the famous chicken example: "We know that all these rather crude expectations of uniformity are liable to be misleading. The man who has fed the chicken every day throughout its life at last wrings its neck instead, showing that more refined views as to the uniformity of nature would have been useful to the chicken".

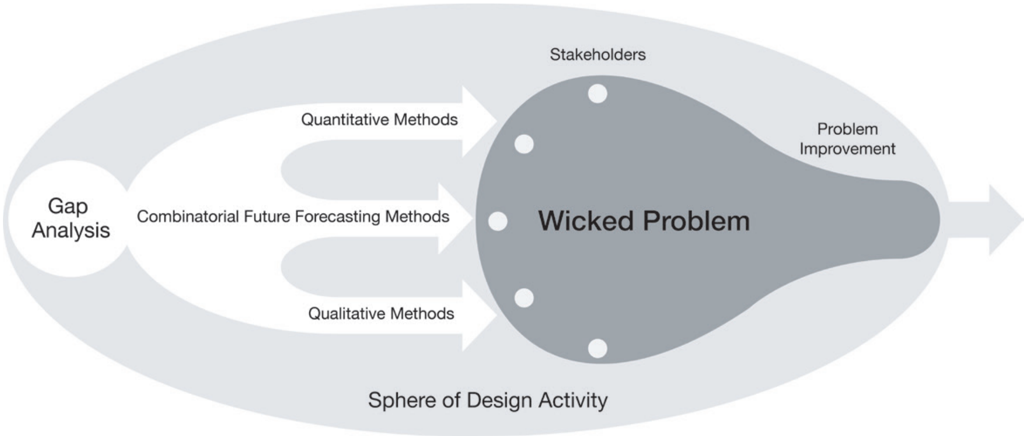

Fig. 3. Diagram illustrating the main interacting elements of the proposed new design-led future forecast framework for tackling wicked problems.

problem directly.

3.1 A New Framework

We propose a new framework for addressing wicked problems using mixed quantitative and qualitative methods leveraging creative design methods. The framework has a number of interacting elements initiated via first identifying a gap in capability for tackling a wicked problem. Gap analysis is a term borrowed from William Burley's research in biological diversity [49]. He defines a gap analysis as a simple concept, which can be described as a continuous loop between:

1. Defining and classifying various elements of biodiversity in a specific area;
2. Examining the preservation systems already present in the territory;
3. Determining which elements are either underrepresented or absent from the initial assessment;
4. Setting guidelines for the next conservational effort [49].

This could be transposed in the design practice by:

1. Defining any number of qualitative future trajectories;
2. Quantitative analysis of datasets and determining trends stemming from it;
3. Determining the discontinuity elements between the two;
4. Setting design principles and constraints for the project.

The diagram in Fig. 3 structures the main elements of the proposed new framework which functions as follows:

The framework proposes an approach to wicked problems from a mixed methods perspective via employing quantitative, qualitative and combinatorial methods to future forecast thereby increasing the forecast's accuracy and its communicability to a variety of involved stakeholders. The synthetic process proposed consists of a gap analysis, where different future trajectories deriving from the different methods employed are mediated by individuating any discrepancies resulting from the different processes. The envisioned design solution or intervention is then steered continuously by the feedback loop given by its own impact on the problem in question via qualitative and quantitative data and insights .This framework is proposed explicitly for designing and wicked problems; therefore, it is intentionally not structured as a series of steps to follow and implement: depending on the problem at hand, the stakeholders included, the available datasets and the level of access to experts in the field, different processes and outcomes are to be expected.

Further research which grounds the framework in a specific wicked problem is needed, so that it can be adapted and tested in a specific instance.

4. Conclusion and Future Steps

Introducing the proposed qualitative-quantitative framework for future forecasting aimed at tackling current and emerging complex challenges seems to be a promising step towards the development of a systematic method for resolving wicked problems. Reflecting back on the definition provided by Rittel and Webber, it becomes clear that the use of mixed techniques of future forecasting could be a desirable method to scan the boundaries of a given problem initiated via a combinatorial strategic design approach. However, since future forecasting is often considered to be an aleatory art without the ability to define the future, its task is not to dictate specific lines of action, but to chart possible outcomes. Therefore, future forecasting as presented in this paper is another method available to the designer to systematically create routes to action.

One of the challenges for our proposed approach is the dominance of qualitative approaches in design and the mistrust, misunderstanding and lack of exposure to the value of quantitative methods. Moreover, many designers consider data driven conclusions that hold central truths to be illusory. While we believe there is significant value to considering this approach, the disciplinary methods preference in design is also a serious consideration. We have also highlighted the inclusion of some cybernetic concepts including feedback loops and there is also potential in further exploration of the relationship between wicked problems and black box technologies and how these problems could be addressed by a new category of mixed methods for future forecasting incorporating qualitative and quantitative feedbacks.

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Eventual Design for an Emergent World

Abstract

Are we at a punctuation point in the evolution of design practices? The ascendance of modern design practices, over the last 100 years, to popular and pervasive application, is fraught with questions about benefits and limits. In light of persistent social injustice, political strife and looming ecological danger, a more extensive accounting of the work of designers is needed, if only to craft a proper manifesto for proceeding with our work. By extrapolating recent trends in the evolution of design practices, a meta-practice of "eventual" design is envisioned, to call attention - *beyond form of artifacts, process of service, and quality of experience* - to the entailments, actions and etiquette of events, and their eventual consequences. The "event" is identified as a fruitful entry point for forensic reconnaissance into causes, effects and consequences in this *terra incognita*. An event lab and instrument are sketched, with intentions to 1. identify aesthetic causes, social effects and systemic consequences of design; 2. formulate a common etiquette between and amongst people and with technology; and 3. model and monitor interdependence and sensitivity within the logistics of our human project and ecology of living systems to avoid detrimental or disastrous consequences.

Keywords

Design, Consequence, Events, Aesthetics, Etiquette

1. Introduction

Design, in essence, is a kind of wishful thinking combined with audacity and ingenuity. As designers, given any evidence of the worlds we inhabit, we can, with classic "blues" mentality, recite a list of ills, flaws and shortcomings that dismay. So, when we contemplate a new approach to design, consistent with our times, it is instinctual to not look away from past disasters and present dangers of human making and doing. But it is axiomatic that we imagine optimistic goals.

Design is also a kind of guessing game in which the guesses include ideas about the remote existence of the "other"; ideas that are presumptuous and biased by personal experience; ideas that use anecdotes and asymptotes to conjure archetypes and prototypes with impunity, and are realized with a peculiar ingenuity and determinism.

Design is also often conflated with deciding. Origami provides a clarifying metaphor: While folding moves determinedly toward an explicit exclusive formal expression by deciding, designing opens new possibilities of form, by cutting. Design prototypes first subvert and violate the norm, before assimilation of the preferred is replicated.

While design is often cited as a means to goodness, beneficial change, and betterment of life, there is a dark side to this noble tradition; this speculative studio practice of intentionally making mistakes and fixing some of them; this mutative operation with putative benefits. It seems imperative, as we proceed, to not ignore the penalty of misunderstanding each "other" and conflicts inherent in the rise of a single species to dominate nature with "human" nature.

Modern design principles have had tremendous influence over the last one hundred years on most design practices and arguably constitute a major cultural force shaping infrastructure and implements of the modern world. But as demands and desires of one species threaten the existence, natural resources and habitable environment of other species, we risk epic eventual calamity. Philosopher Stanley Cavell said it well as "our capacity to do harm has exceeded our capacity to do good." [1]

Designers and their clients, largely absolved of liability, are nonetheless instrumental in delivering this moment. Even conscientious designers invoking methods of social and environmental science in their research lack sufficient means to understand or account for derivative, long-term, far-reaching or unintended consequences. The question goes begging: How should we account for the shortcomings, limitations and constraints of design practices?

Designers have been, and remain, active and integral to capitalism, industrialization and globalization. Flaws in capitalism, however, exacerbate disparity and rupture the fabric of everyday life. Excesses of human habit and density of human habitat proceed toward depletion and saturation of our ecology. Corruption and regulation distort and circumvent intended results. Design happens.

Sublimated violence inhabits our infrastructure. Errors that can rapidly propagate unknown risks, persistent threats and real danger to living systems have a new velocity: the speed of light. Digital connectivity accelerates toward ubiquity throughout the logistics of our human project. Interdependence amongst humans, and with and within technology, grows, both tantalizing and ominous.

In the late 1980s, the entire national telecommunications infrastructure in the United States faced total collapse from a cascade of errors spawned from a single typo in one million lines of code. How will we avoid catastrophes of such proportions as the cybernetic future expands like the universe and evidence of its constitution fades?

Every single material object belies the violence of its origins, its production and eventual dangers of its use, abuse, distribution, abandonment and ultimate interment. Manifest, latent, buffered or muted, violence constitutes a real terror of our existence and needs a remedy. Is there a link between error and terror we do not see?

Questions face designers (and their clients) as to whether existing design processes can be applied to this emergent world or even address failures from the past. Can we better understand the social and ecological consequences of "designing" the world? Can we resolve this emergent crisis with social justice or ecological reciprocity? Can we even eliminate or mitigate violence with acts of human kindness? More crucially, can designers address how people treat each other and our living ecology or will we continue to primarily serve a mass marketplace of individual wishes? If we are at a punctuation point in evolving design practices, can designers adopt new goals that subvert their own process, progress or success?

We are Much Obliged. Is it too late to accept the greater role of citizen designer exemplified by the utilitarian legislator Benjamin Franklin, and too soon to be the universal citizen Buckminster "Start with the universe" and "If the results are not beautiful, I know I am not done" [2] Fuller? Now is always the opportune moment to crack the code of design, reveal its potential and reform our praxis. As anyone who has planted a tree knows, the best time to plant a tree is twenty years ago.

The second-best time is now.

2. Manifesto Destiny?

The recent surge in popularity of design has prompted multiple declarations of the power of design to produce beneficial change and one noble attempt to write a manifesto to enact the idea that "All people deserve to live in a well-designed world." [3] Design principles and practices are being celebrated with an invitation to "prototype the future" [4] and dozens of exhortations to innovate, disrupt and change the world. "Utopia Toolbox" [5] catalogs an illuminating collection of such ambitious initiatives. Even the United States Army has incorporated a doctrine of design into its arsenal of weapons to wage persistent war. "In a dynamic and multidimensional operational environment, design offers tools vital to solving the complex, ill-structured problems presented by persistent conflict." [6]

A Bit of Personal History. Fifty years ago, as an impressionable young design student, I spent an inspiring day with R. Buckminster Fuller who told us the goal of design was to "make the world work for 100% of humanity, in the shortest possible time, through spontaneous cooperation without ecological offense or disadvantage of anyone." [7]

We clearly have yet to accomplish that goal.

Within short months of my infection with Fuller's enthusiasm, I was drafted into the army, ostensibly for the vile war in Vietnam. I rapidly learned some hard lessons about freewill, individual agency, large-scale forces in lethal conflict, destructive power of well-designed weapons and above all, a spectrum of human behavior well beyond my childhood experiences. Even an aesthetic difference, between the hard kick from the recoil of an M-14 rifle and the easy burping nudges from an automatic M-16 rifle, signaled a profound change in my possible relationships to other humans; that signature of a new tragic sense of "self," a "medium," and a realization of the recondite remoteness of the "other."

Something happened. Something broke within me. I mutated.

As a consequence, I became a cynical pragmatist, maybe even a realist. My activism tempered, my idealist fantasies buried, (but latent in every subsequent design consideration) I became host to perhaps an ideal mental brew for pursuing the intelligent response to uncertainty and opportunistic risk management that design, of necessity, becomes.

Design Practices Evolve. What was, in the 19th century, a choice between utility or decoration became, in the 20th century, a focus on synthesis of form and function. By the 21st century, digital tools for design were amplified by revolutions in computing and communication capacity. A fascination with interaction and distribution erupted, permitting designers to develop integrated systems of products and services for "personal" experiences through media design practices.

Since, as Eva Horn has written, "Media are not only the conditions of possibility for events—be they the transfer of a message, the emergence of a visual object, or the re-presentation of things past—but are in themselves events: assemblages or constellations of certain technologies, fields of knowledge, and social institutions." [8]

Old, New (Now), and Eventual. Two lists (see below) of trends in design practices, shared with me by Hugh Dubberly, were the impetus for my speculations on design practice over a decade ago. Extrapolating emergent aspects of design from those two lists spawned the notion of the "eventual". The question of what happens as a consequence of what a thing is and what it does, provoked the idea of turning the attention of designers from objects to events to better understand cause and effect, especially in social behavior.

In the old dominant design paradigm, heroic solo product designers worked on the composition of editions of static objects in a fixed locus (node) using information drawn from computers. They sought simplicity, if not for the sake of the relationship of form and function, at least to make manufacture for massive consumption efficient. Decisions and control followed a top-down hierarchy.

In the new (now), then dominant, design paradigm (in the golden age of the Internet and web) teams of service designers used improvisation and continuous updating of dynamic links to invent experiences using persuasive communication. They embraced and exploited complexity, if not for the sake of tighter relationships of form to belief, at least to enrich interaction and fascination with screens. Decision-making and control

	Old	*New (Now)*	**Eventual**
Product as	*object*	*experience*	*behavior*
	static	*dynamic*	*liberal (as in liberating)*
	node	*link*	*mesh*
Focus on	*information*	*persuasion*	*transformation*
	computing	*communicating*	*conversation*
	with	*through*	*within*
Key skills	*manufacturing*	*interaction design*	*etiquette design*
	product design	*service design*	*social networks*
Process	*seek simplicity*	*embrace complexity*	*achieve sophistication*
	solo or hero	*team*	*community*
	top-down	*evolutionary*	*metabolic*
	editions	*continuous updating*	*anticipatory*
Technique	*composition*	*improvisation*	*performance*

Table 1. Terms in the first three columns (below) are from a memo about design my colleague Hugh Dubberly wrote. They compare Old and New aspects of design. Extrapolating from those two lists and integrating the results yielded my initial notions of eventual design and etiquette.

were an evolutionary collective process.

My wishful emergent paradigm proposes, that communities of etiquette designers would use cybernetic conversation to instigate liberal (liberating) behaviors within a mesh of social networks. They would embed sophistication in their design of etiquette, if not for the eventual goal of transforming living systems, at least to improve relationships between semiotic form and social performance. Anticipation would supersede decision-making and control would yield to contextual eventualities and metabolic entailments of events.

Events, Appearances, Performances. Slavoj Zizek postulates an event as when "effects appear greater than apparent causes." [9] An eventual design practice would juxtapose events to consider long and short-term causes, effects and possible consequences, not simply what is or can be.

Events disclose how people choose to invest their attention and how that attention turns into obligations, agreements, appointments, and thereby into actions of life. The salient design question is, "…and then what happens?" Events also significantly occur at and comprise the intersection of information design and experience design practices.

Turning Attention. Can designers invent and deploy a "macroscope" [10] to reveal and mitigate inherent conflicts between nature and human nature? Can the cultural currency of attention find parity or equity with the social currency of trust? Can we conceive and design a common public etiquette for civil society to comprehensively emerge? Can social or ecological justice even be design goals?

It is now possible to trace the events of media from sources to uses and track media incidence to individual experience. Behavioral insights from data-mining permit design of systems to surveil, anticipate, inform and influence individual experience. It may now be possible to assess the impact media have on relations between people.

It should be possible for designers to deploy diagnostic and forensic design research as a reconnaissance of new cultural territory to learn how the spectrum of etiquette between and amongst people can become an index to social justice or design errors. Perhaps this can extend to measuring our collective treatment of our planet's ecology?

It is just barely imaginable that such sophisticated design of media could ultimately engender sustainable beneficial relationships between and amongst humans. However, it does seem feasible to move the attention of designers from the millisecond events between a person and their instant messages, games and signals to other events occurring between and amongst people and to potentially map the consequences of human choices and actions to living systems and nature over deep time. What other success could be more meaningful to civil society?

3. Etiquette

How we behave toward others is a spectrum that ranges across confluence, collaboration, cooperation, coordination, competition, conspiracy, conflict and coercion. Perhaps a spectrum from fear to love can serve as an index to human treatment of our ecology of living systems; our global common ground?

The writer Guy Davenport recalled Jane Kramer saying that the French “preferred a common etiquette to a common ground.” [11] This comment crystallized the idea that social justice in denser diverse populations will require a more sophisticated understanding of the “other” and how to integrate valuable differences in each “other” into society. Adjusting our design scope to examine events opens a portal into how form and significance pass across social synapses and have subsequent or derivative consequences.

Civil society requires, or rather, obliges each individual to acknowledge the value and protect the freedom of the “other.” An understanding of “kind” and a common etiquette of kindness is required for negotiation and integration of valuable differences to replace strife and conflict. The real mandate for change of design practice comes from accepting this moral accountability for consequential events of design decisions. Can designers seek such a noble goal when elements of living systems are so complex?

4. Framing, Forming and Informing a New Design Practice

Conceptually framing the study of events and the eventual can begin with the "welkin" - the sky we share. Under that sky, the watershed of earth symbiotically grows fuel for life. The equation of life we work within is reciprocity or kinship between logistics of the human project and ecology of living systems. At heart, our concern is action and reaction, between people, and between human nature and nature.

Do we control that symbiosis or will technology beyond our intelligence intervene and mediate living systems?

Logistics. All of human history can be described as a logistical project to support the growth of the human population. An archaic and useful definition of logistics as “what must be known for the conduct of war” [12] helps us see that human project as intrinsically lethal and violent. How we prosecute the human project could be described as a kind of war against nature and struggle against natural forces. But it is actually within us, within the context of evolution. Will we govern our logistics by design, by sentient technology or have we lost even the capacity to govern technology by logic, or ourselves by law or common sense?

Ecology. Our common ground is finite. Our capacity for meanness and kindness seems unlimited. Witness the plight of indigenous hunter-gatherers whose lands are confiscated with the rise of the nation-state. They occupy boxes of concrete that are hot in the summer and cold in the winter. With the arrival of subsidized and mandated provision of electricity, they obtain refrigerators. With refrigerators, they obtain soft drinks. With a diet of soft drinks, they obtain diabetes, further decimating their population. This in all of ten years out of thousands living sustainably. The spectrum of etiquette includes ecologic cruelty.

Kinship. When James Grier Miller, instrumental in formulating behavioral science, wrote “General Living Systems Theory,” he was inviting the social sciences to find a way to join with the natural sciences to better “understand the facts of life.” [13] He invoked cybernetics as a tool for accomplishing that and, more importantly, identified and defined a systems approach to the natural ecology that permitted examination of how society might achieve civilization in concert or kinship with nature; a kinship monitored within events. Kinship and Kindness. Kindness is a social solvent. Kindness also requires a study of difference. To integrate valuable differences in situations or events one must understand kind. Kindness may turn out to be crucial to the survival of the fittest when we consider our social interdependence. Behavioral economics might explain our neglect.

Aesthetics. Beyond physical reflexes, humans have evolved and embody a system of signs, the semiotics of everyday life, as a counterpoint to the physics of everyday life. These signs mediate between the metabolic and cybernetic systems which govern everyday life. The aesthetic goal for individual and social experience would be for events to dissolve into timeless moments. For this, we need to better understand the link, the kinship, between aesthetics and etiquette.

Timebase over Database. As a time-based meta-practice, eventual design would work by coordination, configuration and sequencing of events; with temporalities, appointments, assignments, and notions of subjective and elastic time. All of the qualities and paradigms of time delineated by Olga Ast in "Fleeing from Absence" [14] enter into consideration. Events can act as armatures for prototyping ideal living systems, but how can we account for all the entailments of events?

Technological Feasibility. Bruno LaTour said it: "New innovation will be absolutely necessary if we are to adequately represent the conflicting natures of all the things that are to be designed…visualization tools that allow the contradictory and controversial nature of matters of concern to be represented." [15] At a minimum we might reform architectures of computation and communication to employ parallelism, connectome mapping, record/playback, fuzzy and three-state logic, data valencing, metabolic processing, photonic switching, fractal zooming, depiction morphing, consideration spacing and pacing, sociocratic programming, blockchain accounting, link typing, quantum computing and sensitivity modelling in an event laboratory *larger than the experiment*.

Temporal Nominal Annotation. The construct of the *tenome* I imagine could begin to monitor a temporal membrane across which stories are told, lives are lived, and histories are narrated. While the genes and memes circulate in matter and memory, their intersection in time as social interactions might be marked in a *tenome*. A carefully annotated *tenome* could locate and score the interstitial event, where media disappear, and exchange of cultural and social values takes place.

The site of exchange could even permit value to be extracted by a mediator, the way a bitcoin miner is compensated. Knowing what to do next; the *etiquette*, [16] or reading choices offered by the "ticket" could emerge from data within the tenome.

Templates of *tenomes* (see below) would be a possible way of marking time, annotating situations and mapping scenarios for deliberation, analysis and sharing insights. (Binary systems, *which now tend to "eat their young,"* should evolve such consideration space/time to more naturally integrate with lives, as lived, of human beings.)

For Example. When the replacement of the decayed planks of a park bench is connected to a decision to plant a tree decades in advance, and the construction of the bench permits this repair to be a social event; a sense of continuity and community ensues; a natural order is preserved and enjoyed.

When that kind of knowhow and understanding is conveyed over generations, a sophistication is embedded in the designing and deciding that subdues violence. A pragmatic, yet noble transaction occurs when preparedness has replaced planning

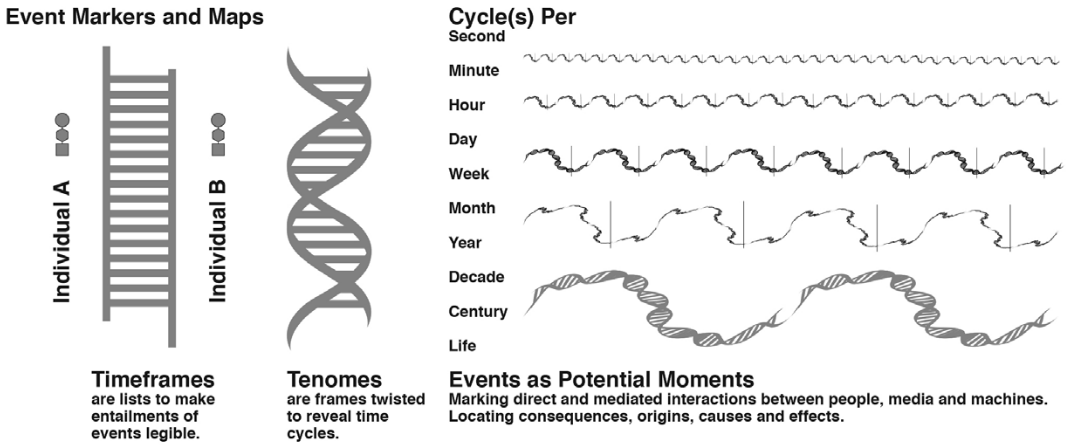

Figure 1. Schematic of a method for marking a time-base as events between sender and receiver. Entailments of the event listed, and time cycles twisted into time frames assist in seeing chronology, sequence or series. Parallelism would reveal potential correlations.

and the eventualities of nature are respected and accommodated. The persistent practical question is simply, "…then what happens?" or "Great, now what?"

5. The Goals of Eventual Design

Eventual design is proposed as a meta-practice to address situations of human experience *between* and *amongst* people within the logistics and ecology of an emergent world. Its praxis is a holistic investigative approach to design of mediating form, that begins within an imaginary, but necessary, *School of Behavioral Arts,* where all disciplines or practices exploring, employing and deploying the human body convene. There, a study of form and function, form and belief and form and behavior, seeks to understand life as a performance and discover essential, optimal and eventual relationships between form and fruition.

Identifying. Events link cause and effect. Events hold clues to quantum entanglements. Events signify and illuminate life. Events, from geologic to nanosecond, mark time. Events convey cultural signals. Chains of events link deep history, inheritances and influences.

Mediating. Form affects behavior. Designing *form that mediates between people* can establish and enhance etiquette. The test? If the interface, artifact, experience, behavior feels rude, it is rude.

Monitoring. Relationships between the logistics of the human project and the ecology of living systems over deep time can be registered as interdependent and assessed for consequence, and eventualities located.

When in the Course of Human Events. Fuller likened design to electricity, writing "We cannot define it, but we can *measure* its effects." [17] Yet despite recent advancement of design research, we seldom measure effects or aftereffects of design, nor do we have useful metrics for effects we observe. Instead, we rely on market forces to reward and punish the work of designers.

The emergent situation of the present world poses challenges neatly articulated by a truly global explicitly and implicitly violent force, the U.S. military as: "Globalization, technological diffusion, demographic shifts, resource scarcity, climate changes and natural disasters, proliferation of weapons of mass destruction, and failed or failing states." [18] Add density of human habitat, and ubiquitous digital connectivity to compress reaction times and accelerate recoil. Any design renaissance that alleviates yet untreated problems of the planet will require a sophisticated reconnaissance of actual and potential consequences. A quantum shift of attention from object to event, from information database to human time-base, offers a way to seek and evaluate such correlations, causes, effects and consequences.

You are Invited to an Otherwise Future. Ideally, designers would develop formal systems that advocate, enable, distribute and sustain social justice; where inherent conflicts of human nature within our common ground are resolved; where the form and content of infrastructure, artifacts, and appliances establish, inform and evolve a common universal etiquette that reconciles human nature with other wisdom. The daunting complexity of living systems, our growing interdependence as humans, and with technologies that animate and emulate life, constitute our event laboratory.

I cordially invite you to enter.

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The Decentralization Turns in Design: An Exploration Through the Maker Movement

Abstract

This article recollects paradigms and turns in the Design research and practice integrating several contributions and elaborates a new proposal arguing that the current changes are not about a single shift from one center to another, but rather the decentralization and distribution to several new centers becoming thus a system of Decentralization turns in Design. This system is structured with eight turns: Do It Yourself approaches to Design, Open Design, Network Science approach to Design, Distributed Manufacturing, Design and Locality, Design and Decolonization, Posthuman Design, Design, Data, Software and Artificial Intelligence. These eight turns are transforming design practice and research along eight dimensions (meta, who, what, where, how, tools, process, scale), here explored through the context of the Maker Movement.

Keywords

Decentralization, Design Turns, Maker Movement, Posthuman

1. Introduction

The understanding of the evolution, revolutions, general dynamics and changes in the history of science is a crucially strategic endeavor. In this sense, one of the most influential contribution was elaborated by Kuhn [1], who theorized that science evolves through revolutions based on paradigm shifts that move the focus from one center to a new one, transforming how science is done and understood and generating new eras in science. Besides epoch-making paradigms science presents also turns, which are smaller-scale changes that take place more as parallel and overlapping [2, 3] and can be considered a product of their own time. At different levels, decentralization is a crucial element of the history of science. This paper aims to contribute to this discussion regarding Design, by tracing a first exploratory timeline of paradigms and turns in the design research and practice, and by identifying a further turn that takes place now. Therefore, it proposes the extension of these turns not by showing the displacement from one center to a new one, but by distributing the center to several new centers in what is can be then described as a set of *Decentralization* turns in Design. Moreover, the identification of such new turns is based on eight turns bringing decentralization to design along eight dimensions. Although these dimensions have several different roots and also applications, this paper describes them in the specific context of the Maker Movement [4, 5]; as one of the more recent evolution of the Design practice and with extended implications, it offers examples for all the identified turns. Based on this context, this paper aims to answer the following research question: What are the decentralizations that have been emerging in the design research and practice, and how they can possibly characterize new turns in Design? In order to answer that, this research explores with a literature review the previous turns in design, and elaborates a coherent system of turns in Design and in the Maker Movement.

2. A Review of Paradigms and Turns in Design

The identification of paradigms and turns in Design might have less tradition than in other disciplines. While some authors provide an overview of timelines of different paradigms and turns, others develop single turns that show their underlying research and practice, exploring the role of designers and users, and also of the methods and theories applied. Such paradigms and turns present changes in design practice, roles, processes and concepts, and we focused specifically on the proposals that focus on agency by shifting who design and how.

One of the main contributions in the identification of paradigms in design can be found in the four economic paradigms identified and described by Gardien, Djajadiningrat, Hummels, and Brombacher: the Industrial, Experience, Knowledge and Transformation economies [6]. This framework is mainly focused on companies and how they can innovate in order to keep up with paradigm changes. In the *Industrial Economy*, mass production and a modernist machine aesthetic are based on efficient design activities that are objectively measurable and follow a linear rational problem-solving process. In the *Experience Economy*, differentiation is created through branding as a way to enable users to belong to subcultures with a plurality of diverse styles. The work of designers here extends beyond object-centered thinking to the total user experience and follows two approaches to processes: reflective practice and user-centered design. In the *Knowledge Economy*, an overflow of brands and the emergence of the remix culture of online communities enable users to reach self-actualization through a DIY remix of subcultures into individual custom subculture: belonging happens through a personal remix of one own's identity. Companies create value through an open innovation process based on communities of users with an open design, co-created and participatory approach. Now the works of designers is in orchestrating open innovation through algorithmic thinking, data visualization and creative coding. The *Transformation Economy* is the latest and still emerging paradigm, where concerns about pollution, global warming and wealth disparity push the work of designers towards understanding societal values and foster reciprocal value creation with a systemic approach to local solutions through platforms that enable plural and radical approaches.

In terms of turns, although design researchers have already identified turns in design in the past [3, 7], there is not a consensus in their definition, identification, and meaning of the word "turn" in the design field. We consider a starting point for the study of turns in design the paper of Marttila and Botero [3], who identified four turns related to "co" in co-design: Usability, Sociability, Designability, and Openness. For them turns are more parallel, overlapping, mixed and connected than paradigm shifts. In other words, a turn is a device for communicating the identified changes. The *Usability turn* can be considered the first turn in Co-design, and it has a clear emphasis on the user and the use situation. It provides an impulse to the development of the concept of Human Centered Design (HCD) and constitutes the basis of research and literature in Human-Computer Interaction (HCI) [8]. Here, the user can be described as a consumer, and the primary purpose of design is to make them consume the final result of the design process. The second turn is described as the *Sociability turn* and it is characterized by the attention to the relationship between peoples' practices and to facilitating stakeholders' contributions [3, 9, 10]. Moreover, the Sociability turn defines design collaboration as enacted through organized events (e.g. workshops) initiated by experts, in which users are considered stakeholders who are not merely passive consumers, instead they become more active and form partnerships [11], supporting the development of practices like co-design and participatory design.

Therefore, Design acquires a broader notion, involving activities that support people's wishes to become active participants and contributors in personally meaningful activities [12], which characterize and develop the *Designability turn*. Moreover, users need to be empowered "to act as designers" [13], which is related to the concept of Meta-Design. In the Meta-Design approach, users are seen as potential designers by extending, improving and appropriating design, while designers are the ones in charge to create social and technical infrastructures to enable new forms of collaboration. This differs from the *Openness turn*, that is solely based on the adoption of digital technologies and the rise of the Open Source Movement, enabling new forms of organization and distribution of resources through sharing and collaboration [14]. New spaces and conditions for practice can be developed regarding the openness of projects, the rise of new practices and the sharing of knowledge and information, enabling new forms of collaborative interactions. Moreover, it allows end users to share projects and access to digital fabrication technologies to prototype and manufacture products locally [15–17]. The openness of design changes and challenges some of the current paradigms of design practice, such as: authorship, and the idea that every design project should end with a commodified and final outcome. Two main strands can be identified in the practice and literature on Open Design: a predominant one focusing on design artifacts in which the emphasis is on the openness of publicly available designs (e.g., blueprints as documents), and a broader approach to open-ended design activities and practices.

Other authors propose single turns instead of a timeline of turns, such as the Semantic, Openness and Peer-to-Peer, Systemic and Posthuman turns. Krippendorf [7] describes the *Semantic turn* in design as a shift in designing artifacts that moves the center from how artifacts ought to function to what they mean to those affected by them: the design of an artifact entail more than just its form and aesthetic, it is also connected to users' beliefs, values, needs, and emotions. The *Systemic turn* is distinguished from others in terms of scale, social complexity, and integration. By integrating systems thinking and its methods, this turn extends Human-Centered Design towards complex and multi-stakeholder service systems [18], an aspect that is also related to the idea of layers and interdependence of different turns. In the Openness and *Peer-to-Peer turn* Menichinelli adds the Peer-to-Peer (P2P) and Meta-Design approaches to the *Openness turn*, considering how design can adopt open source and P2P practices and how it could use its tools, practice and resources for implementing open source and P2P practices [19]. Within the context of this research, this turn becomes relevant since it openly proposes decentralization as both an explicit core value and objective. The meta-design approaches detailed in this turn explicitly use design tools and approaches not just for operating within decentralized systems, but also for creating them. The importance of decentralization is here an inheritance of the origin of these phenomena from Internet-based organizations and its historical decentralized architecture elaborated by Baran [20]. In the *Posthuman turn* described by Forlano, design is a way to resist to binary categories and integrate humans and the non-humans as social constructions, which is connected to the development and use of new technologies and a new understanding of agency [21]. Posthumanism criticizes the anthropocentrism, extending the limits of the human also to the ethical, social, and political sphere in which humans operates. The agency of artifacts distances the centrality of humans in design research and practice, moving towards a more complex system of interactions between human and non-human actors. Moreover, this comprises how socio-technical systems can be socially constructed, but also how they can shape society. Therefore, not only it discusses the interactions between human and non-humans, it is also a way to break the notion of subjectivity (subjectivities and identities constructed through race, class, gender, sexuality, and ability) in Design.

3. The Decentralization Turns in Design and the Maker Movement

Several turns in Design have emerged in the last decades, sometimes overlapping and sometimes disconnected among them. Some of these turns are now increasingly integrated because of the recent technological, social and economic changes, bringing an additional displacement to the ones documented in the previous section. To better understand the possible changes and opportunities that can be related to decentralization, as an integrated and transitory set of turns, we analyze how this unfolds in the relation between the Maker Movement and the Design practice and research. In this context, the Maker Movement is not seen as the only cause of this new turn, but more as one of the causes and one of the effects of such turn at the same time, both an outcome and a catalyst of these changes, and the context that inspired this research and the reflections.

Through this analysis, we aim to identify what are the clear forces towards the decentralization in design, divided by eight turns and eight dimensions in which the effects decentralization takes place. We propose to call it as *Decentralization turns*, as it represents a clear force towards decentralization, multiplied by the integration of several turns and the extension of them. The deep changes behind this turn are aligned with the evolution of the design research and practice, which has recently moved its scope from single users to local and online communities, from isolated projects to complex system of solutions, and from harmful and misunderstood impact on the environment to a long-term, inseparable, aware and unavoidable blending with it.

We argue then that this is not just a *Maker Movement* turn but a thorough, complex and articulated phenomenon. Therefore, the Maker Movement and its integration with Design research and practice can be where all the recent decentralization processes are meeting, showing that there are wider and more profound implications than just the use of 3D printing technologies and informal education and design. Within this context, the system of Decentralization turns in Design can be identified in eight distinct categories: 1) *Do It Yourself (DIY) approaches to Design*, 2) *Open Design*, 3) *Network Science approach to Design*, 4) *Distributed Manufacturing*, 5) *Design and Locality*, 6) *Design and Decolonization*, 7) *Posthuman Design* and 8) *Design, Data, Software and Artificial Intelligence (AI)*. Depending on what is decentralized in the design research and practice, these categories can be analyzed along eight dimensions: a) *meta* (shifting elements to the meta level), b) *who* (changing whom of the different actors have agency), c) *what* (changing what is designed), d) *where* (displacing the location of design activities), e) *how* (transforming methods and approaches), f) *tools* (changing the tools adopted), g) *process* (transforming processes), h) *scale* (changing scale of the design initiatives). This structure, displayed in Table 1, is a first approach at assessing the level of decentralization in design projects and activities, depending on how many turns and dimensions are decentralized. Within such *Design Decentralization Score* (DDS), each turn is equivalent to 12.5% of a full decentralization; if we consider both turns and dimensions, each cell in the table represents instead of 1.5625% of a complete decentralization.

As a starting point, the turn of *DIY approaches to Design* (1) is a foundational point that challenges who is the designer; the boundaries between amateur and professional designers are increasingly blurred [22–24]. Following the pioneering example of Enzo Mari [25] makers but and designers embrace and promote this turn for the development of projects [26]. Moreover, the DIY approach has been applied by both designers and makers to the production of new resources and materials [27]. This turn also brings changes to where design is done (e.g. at home or in a makerspace), and what tools can be used in a nonprofessional environment, often pointing out how design practice can be part of the informal economy [28].

The turn of *Open Design* (2) is an extension of the first one, as developing projects independently is often based on the sharing of projects, tools and documentation, including the Openness, Openness and P2P turns. After the pioneering work of individual designers like Ronen Kadushin [29] and of experimental digital platforms like Thinkcycle [30], now Open Design is a

Table 1. The Decentralization turns in Design: turns and dimensions

	meta	who	what	where	how	tools	process	scale
DIY Design		■		■		■		
Open Design	■	■			■	■	■	■
Network	■		■		■			■
Distributed Manufacturing	■			■	■	■	■	
Locality		■		■				■
Decolonization		■		■	■			■
Posthuman	■	■			■			
Data, Software, AI	■	■	■		■	■	■	■

common practice thanks to makers and well established platforms like Thingiverse [31].

The often collaborative and collective dimension of Open Design brings the category of a 3) *Network Science approach to Design*, mainly for research purposes at the moment, with the aim of uncovering how the social interactions influence design processes and projects, for example platforms such as Github [32] or Thingiverse [31]. Network analysis is typically implemented in order to understand 1) structural dependencies within products and systems, 2) communication, cooperation and competition in design processes, 3) social, economic, institutional environment of design processes [33].

The often distributed nature of Open Design initiatives brings the increasing relevance of a 4) *Distributed Manufacturing* ecosystem of Fab Labs, Makerspaces, craft workshop, micro-factories and other digitally connected places where digital fabrication and traditional processes enable the manufacturing of open projects [4, 5, 15, 16].

Distributed Manufacturing systems are not only a digital layer that erases the local differences, but enhances them, as several examples of maker initiatives that re-evaluate local traditions and craft show [34]. Several examples of projects designed with and for digital fabrication have been collected [35], and an interesting case is Circular Knitic by the artists Varvara Guljajeva and Mar Canet, an open source digital knitting machine [36].

In this category, the Maker Movement further promotes the work on 5) *Design and Locality* of previous design initiatives [37, 38]. This turn focuses not only on users and markets for developing products and services, but on the local conditions, communities, economies and cultures and work at improving them at the same time. An example in this case is the Fab Loom [34, 39], a traditional Peruvian loom by Walter Gonzales Arnao redesigned and fabricated with digital technologies which enables collaborative processes in its development, usage and dissemination.

The role of locality in design brings the importance of *Decolonization* (6) in its approaches, which further extends the previous turn by strongly focusing on the empowerment of local communities through projects that can develop a design approach following the local culture [40]. This turn is emerging in several maker initiatives [41] but it is however less explored, and further research should clarify if and when the Maker Movement is really advancing decolonization, or instead proposing a new form of technological and cultural colonization, or both at the same time for the moment. An example of this can be found in the many initiatives of indigenous communities for building drones for community mapping activities that aim at reclaiming ownership of their territories against government and companies [42]. Drones are an iconic project in the Maker Movement, and not only makers and designers are using them, but also designing, fabricating and releasing them openly as Noumena did with the NERO project [35], who then also deployed it in Costa Rica for the 3D scanning of pineapple plantations in collaboration with local makers [43].

Further along this direction, the *Posthuman design turn* (7) supports emergent critical race, gender and decolonial theories. Therefore, Posthuman in design changes the perspective of what is agency, who has agency, and how it can shape interactions. In the Decentralization Turn, posthumanism shifts the agency from the human who was placed in the center of the design actions, and takes into the consideration the locality and different agents – like technology, the environment and other entities as also capable of shaping interactions. In the Maker Movement, this approach often takes place with work on synthetic biology projects that enables living organisms to produce materials and artifacts; makers have already started coupling this with open source 3D printers [44, 45].The decentralization of the role of human actors towards non-human ones in terms of agency is also connected to the increasing connections among 8) *Design, Data, Software and AI*, where software is not just a tool any longer but a creative actor in the generation of projects [46, 47]. While Generative Design approaches have been around for decades, with the digital fabrication technologies and the attitude provided by the Maker Movement designers like MHOX are increasingly treating software as a design material that acts semi-autonomously [48].

4. Conclusion

Based on a critical reflection on the literature, this research explores different turns in the Design research and practice. We propose not a new turn, but a set of turns called the Decentralization turns which represent a clear force towards decentralization along the integration and extension of the previous turns. As an initial step towards its development and better understanding, we propose a set of decentralization forces, divided by eight turns and eight dimensions. We use the Maker Movement as the starting point, context and example of the preliminary analysis of these forces. This proposal aims at contributing more insights, approaches and practices to the Design research and practice, highlighting emerging possibilities and their architecture. However, further analysis is necessary in order to verify and suggest new modes of operation regarding distributed, hyperconnected, and complex intelligent ecosystems. The next steps can be directed towards a) the exploration of their impacts on the design process, user experience, social consequences, and the role of designers, b) the validation of the proposed score through the developing a composite index based on multiple data sources and capable of integrating the eight turns and dimensions [49] in order to measure the level of decentralization. Finally, as consequence of the lack of consensus on the concept of turns and paradigms in design, there is not a strong theoretical background: a more rigorous analysis of turns and paradigms in design research and practice is necessary.

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Topic 2.

Interacting with Domestic Intelligences

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The Domestic Shape of AI: A Reflection on Virtual Assistants

Abstract

Artificial intelligence is more-or-less covertly entering our lives and houses. In this context, virtual assistants such as the renowned Amazon Alexa and the products that embed them, are the most representative of the first wave of materialization of artificial intelligence in the domestic domain. We focus on these products, studying their tangible form and appearance as well as the interaction modalities of 10 domestic virtual assistants already in the market or close to be. Our analysis highlights two main approaches in terms of shape: on the one hand AI is embedded into common home appliances – usually speakers – while, on the other hand, robot-like assistants are taking ground. Concurrently, we portray a still immature reflection on this issue from a design perspective. We highlight a frequently poor translation of functions into tangible shapes as well as a lack of reflection on interaction design basics, such as: input and output modalities, feedback systems and functions discoverability. The subsequent discussion frames the results in a broader reflection about shape, function and meaning paving the way to alternative paths to follow for the design of future home virtual assistants.

Keywords

AI, Interaction Design, Home Virtual Assistants, Tangible Forms, Interaction Modalities

1. Introduction

Aware that the world is gradually moving towards the *Ubiquitous Computing* that Weiser envisioned in 1991 [1], and computation is spreading throughout the physical space and across multiple devices to build environments that help people in their ordinary activities [2], we want to frame the transitional period we are experiencing, looking for a path to follow in design research and practice. In particular we look at those products we consider representative of the first wave of materialization of AI in the domestic landscape, namely virtual assistants. Today, conversational AI-based agents such as Amazon Alexa, are spread in 100 million houses according to Amazon's SVP [3].

If studies have been carried out on the UX of conversational agents [4] and on how Machine Learning (ML) is/can be integrated into the UX [5, 6], the design discipline still has not investigated how AI and its skills have been materialized into objects. This aspect is the focus of the paper that analyses those products specifically designed to act as domestic virtual assistants.

The aim is to initiate a discussion in the design domain on the tangible appearance of AI-enabled virtual assistants, focusing on the shape these objects have, on how they embody skills and interact with people.

1.1 AI-enabled Virtual Assistants: an Analysis

For years AI has been covertly pervading systems and devices that we use daily, but recently, the exigence to state the existence of AI technology resulted in specifically designed products. As a consequence, domestic multi-purpose assistants, materialized the smartness of AI in the shape of smart speakers that can learn through continuous conversations with their owners. Furthermore, in the last years, affordable domestic robots, has entered the market opening a frontier that is closer to the idea traditionally associated with AI: that of sentient robots able to simulate human behavior.

These applications exemplify a double interpretation of AI, which has been animating the scientific debate for years: on the one hand, McCarthy's position focused on the creation of a super brain capable of simulating human behavior while, on the other hand, Engelbart's position based on the amplification of human potential through AI [7].

Taking this dichotomy into consideration, we analyze here ten devices integrating AI agents (Figure 1), the only in the market with the characteristics listed in the following. They are (i) multipurpose home assistants with no other distinct goal (i.e. elderly assistance, etc.), (ii) specifically designed as first-party hardware, (iii) already commercialized or coming in the near future and (iv) able to control other smart home appliances. In case of families of products, we only considered the first released in their latest version.

The investigation on domestic virtual assistants starts from the analysis of their aesthetics of interaction [8], as evidence of AI embodiment. It encompasses physical appearance, use and interactivity, in preliminary considerations. The study here presented does not aim at evaluating the user experience of the analyzed products, but to portray the state of the art of domestic assistants, aiming at stimulating further reflections.

Hence, neither UX assessment protocols [9] nor usability tests [10] have been employed to analyze the declared features. Products have been evaluated through official videos and documentation from their producers. A method considered suitable, given the aim of the research and that some of the products are still not in the market.

Table 1 lists the products analyzed (arranged by release date of the first model) and crosses the basic parameters we considered for the analysis: (i) physical appearance, (ii) input and output modalities, (iii) feedback systems and (iv) discoverability [11] of functions, specifically considering how proactive those artifacts are.

Fig. 1. Pictures of the analyzed domestic assistants (authors' graphic elaboration of official producers' images)

These parameters have been chosen to analyze and describe, in a very basic manner, the selected products from a product/interaction design standpoint.

A choice motivated by authors' main hypothesis about domestic virtual assistants. Acknowledging the great market success of some of them, this paper aims at showing how immature they are in some respects and at encouraging designers to take on a leading role in identifying a language and a meaning, beside a form.

2. On the Embodiment of Virtual Assistants: A Review

Physical Appearance. Domestic virtual assistants share quite similar appearance in terms of main colors and materials. They cover the grayscale with white being the most used color, a choice that may be inspired by sci-fi imaginary. On the other hand, black and grey derive from traditional hi-fi aesthetics, underlying their main functionality as speakers. Plastic is the predominant material, while fabrics are getting ground, seeking a better integration within the domestic environment.

Shape is the most significant feature. The review highlights two main formal paths: on the one hand, there are smart objects following simple and mainly regular shapes; on the other, assembled *bodies* are built according to the geometric addition of solids [12], in four cases looking for a characterization as human/animal like shape with a recognizable *head* and *body*. The separation of formal outcomes also highlights a different functional purpose, giving proof of the fact that the intended tasks have a relationship with the final shape: smart speakers are the first embodiment of AI, and as such a natural outcome for a *speaking technology.* Home Pod, for example, is totally focused on audio

Table 1. Comparative analysis of home virtual assistants

DEVICES		*Amazon Echo*	*Google Home*	*Mji Tapia*	*Asus Zenbo*	*Jibo*	*Apple Home Pod*	*Emotech Olly*	*InGen Dynamics Aido*	*Home Connect Mykie*	*Samsung Galaxy Home*
Year of production		2014	2016	2016	2017	2017	2018	2018	2019	tba	tba
PHYSICAL APPEARANCE	Simple Shape	●	●	●			●				
	Assembled solids				●	●		●	●	●	●
	Main Color & Material	B/G, F	W+G, P	W, P	W, P	W+G, P	W/B, P	B, P	W, P	W, P	B, P
DISCOVERABILITY	Proactive			●				●		●	
	Non Proactive	●	●		●	●	●		●		●
INPUT	Voice	●	●	●	●	●	●	●	●	●	●
	App	●	●	●	●	●	●	●	●	●	●
	Buttons	●	●	●	●	●		●	●	●	
	Touch Surface		●				●				●
	Touch Display			●	●	●			●	●	
	Vision (camera)			●	●			●	●	●	
	Touch					●			●		
OUTPUT	Other Device Action	●	●	●	●	●	●	●	●	●	●
	Audio	●	●	●	●	●	●	●	●	●	●
	Video			●	●	●			●	●	
	Movement			●	●	●		●	●	●	
FEEDBACK	Lights	●	●		●	●	●	●			●
	Voice	●	●	●	●	●	●	●	●	●	●
	Movement			●		●		●			
	Display			●	●	●			●	●	

Colors: B=black; G=gray; W=white. Materials: F=fabric; P=plastic.

quality and it looks like nothing but a speaker. On the contrary, devices aiming at establishing a social contact assume a more anthropomorphic shape. For instance, Aido is thought of as a butler and its height and shape nurture this concept. So, functions highly influence the general, formal configuration of the object, also in terms of dimensions. Speaker-shaped assistants are nothing more than discreet ornaments, while those with social qualities increase to the dimensions of small home appliances or become bigger, in case of a closer human simulation.

The possibility of movement may contribute as well to the embodiment of function: Olly has neither a simple shape nor an anthropomorphic one, but its movements nurture a sense of social connection.

Behavior and Discoverability. AI assistants are based on ML, then evolving according to their owners' preferences is a common feature. Again, what influences the behavior of domestic virtual assistants is their main purpose, once more underlining the distinction between smart speakers and domestic robots.

Most of the assistants, namely smart speakers (Amazon Echo, Google Home, Apple HomePod, Samsung Galaxy Home) and, surprisingly, some robot-like assistants (Zenbo, Jibo and Aido) have a non-proactive behavior: they are unobtrusive and respond only when prompted. On the contrary, three assistants are also proactive and suggest information, activities or contents to their users according to their habits, mood or expected necessities. To better perform their proactivity, they integrate a camera (or more), so that they can relate on more data to foster their suggestions: they not only evaluate noises or routines, but they also read body language and can understand what their users are doing. Furthermore, they can recognize and be triggered just when their users are passing by. The highest point in terms of empathic interaction and proactivity is represented by Olly, which develops and manifests its own personality according to its interlocutor's one. The discoverability of non-proactive objects is really low, and most of their functions remain obscure to the user. This is the case of Alexa: it has thousands of skills, mostly created by third-party developers, but rarely known and used [13].

Interaction. The investigation on interactivity has been limited to *input, output,* and *feedback* modalities, referring to Saffer's *Systems Design* [11]. The main inputs and outputs are vocal, highlighting one of the most important achievements of AI towards a *more human* interaction. Indeed, Natural Language Processing (NLP) has improved to the point that it can easily understand human requests and answer accordingly. This is the main premise for the rising of digital assistants, which represent the best evidence of this technological accomplishment.

Another feature that all of the devices still share as an input is a through-app interaction: its functionality ranges from basic setup to complete functions (especially for all the smart speakers). Moreover, they also have buttons to perform specific activities: a mute-microphone button and, respectively, volume up/down buttons or touch surface. On the contrary, robot-like assistants only need the starting one as they have a touch display as a face. Additionally, proactive devices take advantage of their cameras to read body language and gestures as inputs. While, finally, some of them (namely Jibo and Aido) emotionally respond to touch inputs as a *result of being cuddled.*

In terms of outputs, all the assistants allow the interaction with other home appliances, and the providing of audio contents: web researches, music, podcasts, etc. For the devices having a display or a projector (Aido and Mykie), video contents are also an output, which can be a reproduction of internet sources or an enriching characterization of what they are saying or doing.

Movement is another possible output: it can be the result of a request – dancing (Jibo) or moving across the rooms (Aido and Zenbo) – or just a reinforcement for communication – moving up and down while counting push-ups (Olly).

What is more relevant in an interpersonal-simulated interaction, though, is the feedback system. Relying on [14]'s framework to analyze human-product interaction, it results that AI-enabled assistants offer almost no inherent feedback, as physical actions are required in a very limited manner; then only functional feedbacks (corresponding to the described outputs) and augmented feedbacks characterize the current domestic assistants. In particular, lights, verbal utterances, movements and displays reveal the internal state of the object while the function is processing. Almost all of the objects use lighting systems to show their current status, especially the speaker-based assistants, whose choreographies remind those they already have on other devices (for example, it is the case of Google Home bouncing dots). It is to be noticed that – except for Galaxy Home – all the brands have opted for colorful lights, that become particularly expressive in the Olly's custom-built circular LED display: it really underlines the effort of creating a patent communication system through lights.

Another typical feedback of digital assistants comes from their voice: whether in a rigorous or more confidential way, with a robotic or person-like tone, these devices let their users know if and what they have understood before they provide the requested content. This kind of feedback is especially positive in the interaction with anthropomorphic assistants as it gives the impression of being engaged in an actual conversation with a companion, and not just being talking to a machine.

For the devices having a display and being able to move, those are great occasions for feedback: natural and fluid movements can follow the activity or stress the awareness of the robot in its being addressed to its user – for instance turning its *head* towards the one who is speaking. Displays, instead, are used to show the bot's more or less abstracted eyes, which animate in relation to the user's inputs. Those feedbacks are the most effective in providing a natural interaction, as the machine appears more alive, expressing its own identity. An aspect that is strongly related to feedback, and highly influences the interaction, is feedforward [14]. In the example of virtual assistants, the user (and potentially the designer and/or programmer) does not know what will happen after making a request. In many cases (s)he can only imagine or expect a certain outcome, while one can be absolutely sure of the more usual interactions (through app or buttons) and of the basic and routine commands that (s)he has performed various times. Otherwise, the output of the interaction is unpredictable and – additionally – not immediate: two aspects that may hinder the perceived quality of the interaction.

3. Reflections on the Embodiment of AI-Enabled Assistants

The discussion of the formal outcomes cannot be separated from the main functions of the object. As remarked, the shape derives from *use* and from the relationship that the devices have with their *context*. Except from its inclusion in the name of some products, the concept of *home* has been poorly taken in consideration while designing the appearance of those objects. All of them are devices that can be freely set in any environment, and still have not created a connection with our domestic reality: a condition which may contribute to make people perceive them as aliens in their houses. Perhaps, a closer relationship could help users to understand the assistant's benefits more easily. In the meantime, they are interpreted according to their similarity to other, known, objects, or to the abstract expectations that the speculations of our culture have encouraged. Then, it does not come by chance that the most common use of speaker-shaped intelligent assistants is to play music [4], despite the introduction of NLP features opened novel opportunities. On the other hand, devices with a humanoid figure are commonly defined as companions or home managers.

Then, coming to their functionalities, it emerges that users prefer few known commands that actually transform the intelligent assistants into mere executors of routines, especially talking about smart speakers. Hence, the multiple skills they have are rarely used, as discussed by [15] and confirmed by [4] through quantitative and qualitative analysis of use of Alexa. The study by [13] underlines that discoverability in smart speakers is a big issue for designers and it proposes possible solutions to overcome the problem, including context awareness and proactivity. This condition of poor discoverability and weak affordance [16, 17] may be due to a deficiency in the embodiment of the skills into tangible products, which often mark a rejection of sensuous curiosity and pleasure [18–20]. In fact, when executing actions, users are prevented from experiencing their inherent effect. In particular, [14]'s framework may be employed to pursue a more intuitive interaction. In order to strengthen its quality, the authors suggest restoring natural couplings between actions and reactions according to six different factors. At the moment, the most promising and easy-to-integrate solutions are related to the *expression* of interaction: the output modality could be a reflection of the conditions in which the request is performed, such as the user's mood or the moment of the day [21]. Currently just three of the analyzed devices (Olly, Mykie and Tapia) feature these functionalities, but it could give true value to the overall interaction and utility of the assistants and, possibly, inform their shape.

One hypothesis is that a humanized aspect and behavior can make an AI-enabled device truly appear like a domestic assistant. Probably its association with a human being sets the conditions for a more natural interaction and makes it simple to imagine that the object has covered skills and it is likely to have a proactive role in our daily life. Yet, we are incline to anthropomorphize everything [21], and functions – made explicit through proactivity –, shape and movements are what actually seems to facilitate users in terms of discoverability and, therefore, interaction. Furthermore, the behavior of those devices characterizes them with well-defined identities.

In the light of this reasoning, another consideration can be pointed out: a distinctive trait of some anthropomorphic assistants is what defines them as mutuality of influences systems [18], meaning that they are sensitive to *perceptual crossing.* It is not only the user who has to perceive the object of interaction, but it also has to sense the individual who is going to trigger it, preparing and giving notice of this awareness. In this way the interaction becomes expressive, embodied and responsive, even without the use of an interface.

Deeper connections between shape, abilities and behaviors should be developed according to a more mutual relationship between objects and people, trying to understand what it is really about.

Facing the complexity of these devices and their role in the ordinary life, another issue designers must reflect on is the materialization of a great amount of skills, especially if the only means of interaction is conversation. In fact, most of the analyzed assistants feature a companion app to be accessed through smartphone, allowing the personalization of the product as well as a traditional browsing of the skills. Yet it contradicts one of the premises for a natural interaction: getting rid of interfaces to make the mechanism of the artifact directly available to the system users [22].

Undertaking the same direction, a similar, and perhaps less intuitive, interaction is allowed by the devices integrating a tablet as head, which can be actively used for input and output. An arguable solution that entails an evidently poor investigation about the meaning of interaction.

Analogously, the use of voice as main tangible manifestation of the intelligence behind domestic assistants does not automatically make them real conversational agents, nor it makes it easy to exploit their potential. This condition is made evident by the choice of every producer to integrate added input systems ranging from simple buttons to cameras and complex nested menus to be browsed through bespoke apps. In other words, the conversational agents are frequently thought of as the tip of an iceberg that should make interaction more human and friendlier but, actually, they are still in need of a better definition.

4. Future Design Scenarios for Virtual Assistants

The first wave of materialization of AI into the domestic domain, as described in the introduction, is still profoundly immature in terms of function, language and meaning [23].

Designers are called to manage the coupling of form and ever-increasing functionalities, finding a compromise between expressing them or keeping them implicit. The current situation still mirrors the dichotomy animating the discourse within the field of AI. On the one hand, products like smart speakers materialize AI into aesthetically appealing objects inhabiting our houses. On the other, objects with varied shapes aim at being perceived as valuable humanoids to help in ordinary life. A dichotomy that permeates all the aspects – with regard to physical appearance, behavior and interaction – analyzed in the study and betrays a still immature reflection from a design perspective, and the need to find an original language.

Even though the argumentation only considers few initial parameters and presents limitations better addressed in the following, some preliminary considerations may arise. The impression is that the field is still experiencing that period of drunkenness that characterizes the introduction of every new technology [24]. Domestic assistants seem to be in the toy phase having to find their actual contact with reality [25], and design should take a leading role in guiding a human-centered transition towards meaningful products. Present perspectives lead to the integration of AI discourse into the Interaction Design field. In particular, they share the goal of fostering a more natural interaction, going beyond display-mediated interfaces.

Then, translating AI in a tangible and domestic form, according to a human-centered and holistic perspective, shape cannot be separated from function and meaning. From what seen, AI-enabled objects could simplify their functional structure so that, from a tangible point of view, the interaction could be more immediate and significant in terms of experience and utility. In this sense, we could be facing three main scenarios: (i) virtual assistants could evolve as self-standing objects, maybe with more specific and limited functions that better translate into a clearly recognizable form; (ii) they could become more accurate humanized robots, taking the role of actual people at service of others; or maybe, (iii) they could be completely dematerialized and spread across other existing appliances and devices throughout the physical environment, with a sensibility for their location and proximity to each-other, accomplishing the ideal of *Ubiquitous Computing* [22]. The latter, in turn, may open further enquiries about the embodiment, regarding its scale (product or environment) and the way the augmented functionality will be expressed.

Clearly, the study presents several limitations. It takes into account a small sample of products, even if they represent the totality of those responding to the selection criteria. A broader study may include the entire range of products of the producers here analyzed and, eventually, third-party hardware integrating AI agents. Furthermore this initial argumentation, starts from the fundamental traits of a product, but may expand triggering a discussion about current physical materialization of AI that may comprehend other design matters like UX, or interdisciplinary reflections like social/psychological implications, as the emotional response they may nurture through interaction, as well as experimental studies.

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Conversational Smart Products: A Research Opportunity, First Investigation And Definition

Abstract

This paper approaches the topics of Conversational Design and Conversational Interfaces (CUI) from a product design perspective. While this topic is more widespread in HCI and UX design community, there is a lack of insight coming from product design. Given that the integration of CUIs and assistants into physical products have the potential to impact product design practice, the paper introduces the term Conversational Smart Products (ConvSP). It analyzes the topic of Conversational Design and the construct of "Product Smartness" and presents a framework to define and analyze ConvSP. The research aims to delve into ConvSP characteristics, deepening how the conversation can be embodied in the product, and how the physical attributes could work in synergy with the verbal dimension. Through a case study research conducted on a selection of 30 existing products with CUIs, insight is collected on four different topics. On product smartness and personality; on the level of physical embodiment of the conversation; on request/response design; and on the tangibility of conversational inputs and outputs. A descriptive definition of Conversational Smart Products is given. Broadly, the research aims to investigate what the role of product designers in the development of ConvSP could be.

Keywords

Conversational Interfaces, Smart Products, Conversational UX, Product Design, HCI

1. Introduction

The idea of building machines capable of behaving and dialoguing as human beings has influenced Artificial Intelligence (AI) since its emergence as a field of research. Since the release of the vocal assistant Siri in 2011, Natural Language Interfaces (NLI) and assistants have become a focal point in both academic and industry research. There are several Conversational User Interfaces (CUI) able to mimic human, turn-based conversation and to use natural language in written or spoken form [1]. Their aim is to provide for a more natural and immediate interaction.

CUIs have become increasingly widespread and integrated into physical smart products. This will have an impact on the practice of product design, especially for consumer electronics. The topic of conversational design is gaining importance within the Human Computer Interaction (HCI) community [2] and from the point of view of User Experience (UX) Design. In particular, there is a drive to formalize "Conversational UX Design" as a distinct discipline in UX Design [3-4]. There is a current lack of research on this phenomenon from the perspective of Product Design. Therefore, the paper introduces the term "Conversational Smart Products" (ConvSP), and it delves into their characteristics. It discusses the results of an analysis conducted on 30 existing products with conversational interfaces. It offers product design insight and presents a working definition of ConvSP.

This paper is part of ongoing research aimed at understanding what could be the role of product designers in the development of conversational smart products. It gives particular attention to how products embed CUIs and how the physical attributes could work in synergy with the verbal dimension during the interaction.

The structure of the paper is the following. Section 2 describes the meaning of the term Conversational, illustrates the different conversational interfaces, and outlines how Design is approaching the topic. Section 3 deepens smart products and their characteristics. Section 4 presents the research topic of Conversational Smart Products. Section 5 explains the case study research carried out on 30 existing products with CUIs. Section 6 discusses the results, and emphasizes four main topics.

2. Conversational Interfaces and Conversational UX

"Conversational AI" is a term used in Artificial Intelligence to represent the study of techniques aimed to create software agents that can engage in natural conversational interactions with humans [5]. The term is historically used applied to interfaces to describe systems that display human-like characteristics and support the use of spontaneous natural language in the form of text or voice.

Conversational interfaces include [1]:

Chatbots. Chatbots are computer programs that process a natural-language input of the user in text form and generate a textual response to the user. Their history goes back to the 1966 with ELIZA, the first chatbot developed at MIT by Joseph Weizenbaum. Chatbots can include visual elements and rich interactions [6]. Chatbots are currently being tested for forms of "Conversational commerce", brand engagement, and integrated in messaging platforms [7].

Vocal interfaces (VUI) are based on a similar technology but have the added complexity of dealing with speech inputs and outputs [8].

Virtual Personal Assistants (VPA) - also called personal butlers or AI assistants - are programs integrated in a device, operating system or app, that can take over a multiplicity of tasks for the users. Assistants are "super bots" that facilitate and manage multiple services [6]. They have a personality and a character, like Amazon's Alexa and Apple's Siri.

Embodied Conversational Agents (ECA) are agents in form of animated characters on screens. Their aim is to simulate face-to-face interaction with human-like agents that use their bodies in conversation [9].

"Conversational User Interfaces" (CUI) is one of the terms used to identify Natural Language Interfaces. Cathy Pearl, Head of Conversation Design Outreach at Google [8], states that the term *Conversational Design* should only be used to identify those systems in which interaction can go beyond one turn. This because human conversation is bidirectional and turn-based. During the conversation, each participant can take the initiative, exchange information, and keep memories of the past turns of the interaction. Machines instead are not always able to keep this memory and go beyond simple one-shot requests, therefore simulating a conversation. For the same reason, Porcheron et al. [10] propose the term "request/response" design to describe interaction with VUIs.

Hall [11] instead uses the term Conversational with a broader perspective. According to her: "taking a conversational approach to interaction design requires applying the deeper principles of how humans interact with one another". A truly conversational system should manifest conversational qualities at a deeper level, not only as a façade.

This research uses the term Conversational because it does not focus on the linguistic capabilities of the agent but refers to the emerging discipline of Conversational UX Design. User Experience (UX) is an emergent discipline that focuses on encompassing all aspects of the end user interaction with companies, their services and their products. It is a multidisciplinary field that considers the entire user journey. Usability and User Interface (UI) design are merely subsets of this concept [12].

Conversational UX design means being able to create experiences that work like a conversation.

Moore et al. [3-4] consider it necessary to define it as a distinct discipline in UX Design. This is because human conversation is a complex system that requires a different skill set/background compared to the development of other interfaces. Designers must become conversation experts and draw knowledge from different disciplines that study human conversation such as Discourse Analysis, Interactional Sociolinguistics, Conversational Analysis, Automatic Speech Recognition (ASR) and Natural Language Processing research (NLP).

The constant increase in products' processing capabilities and connectivity facilitates the diffu-sion of smart products with conversational interfaces. For this reason, Conversational UX De-sign should include contributions from a Product Design perspective.

3. Smart Products and Product Smartness

Smart products are a product category that represents internet-connected consumer electronics. Other terms such as intelligent products and connected products have been used to describe the same concept. These objects are reshaping industry boundaries and creating entirely new industries, raising a new set of strategic choices and disrupting value chains [13]. Then, what makes a product smart?

Rijsdijk and Hultink [14] define product smartness as a construct consisting of seven dimensions: autonomy, adaptability, reactivity, multifunctionality, ability to cooperate, human-like interaction, and personality. The level of smartness of a product depends on the extent of its capabilities in one or more of these dimensions. However, these functionalities must be obtained through the use of Information Technologies (IT) for the product to be described as "smart". Although a universally accepted definition of "smart product" does not exist, the term identifies objects that share some common technical characteristics. Different authors propose definitions and technical requirements [15-19].

Smart products share three main characteristics. They are cyber-physical, networked, and with computational intelligence.

Cyber Physical [19]. Smart products blend hardware and software. They are physical objects with a digital representation. Interaction is a key aspect, and it can occur through multiple, multimodal interfaces. For example, there could be a direct interaction with the product combined with an external web application.

Networked. Smart products are networked and uniquely identified. Internet connection makes them part of a larger network of things, people and services. They can communicate with users and/or with other objects. Connectivity can take three forms, that can be present at the same time: one-to-one connection, one-to-many, many-to-many [12]. These connected products are part of the so-called "Internet of Things" [20] and are enhanced by a strong service component [21].

With Computational Intelligence. In contrast to the passive nature of most products, smart products display autonomous and proactive behaviors [15-16]. This blurs the boundaries between product design and robotics, and it leads to reconsider the notion of product agency – that is the ability to act and produce effects according to an intention [22-23]. Computational intelligence may be located in the object (edge intelligence) or even completely outside the physical products, e.g. in the cloud [18]. Computational intelligence enables products to be context-aware, personalized, adaptive and anticipatory. These four characteristics derive from the literature on Ambient Intelligence (AmI), a technological vision developed in the late nineties that envisioned environments infused with technology, sensitive and responsive to the presence of people [24]. Smart products were seen as the building blocks of Ambient Intelligence [17].

The four aspects of computational intelligence according to AmI are briefly summarized here.

Awareness. In products, awareness can occur in several forms. User-Awareness means that the system is able to recognize and memorize users and their preferences. Contextual-awareness refers to the ability to detect what happens in the environment and to infer user intentions according to the situation. Self-awareness means that the product has and generates new information and memories about itself, its use and purpose. Cultural awareness means that the product is socially appropriate. For example, a talking toy that uses a language appropriate to the children's age.

Reactive, Adaptive, Anticipatory. Reactiveness is the ability to quickly react to events and environments. Adaptability is the ability to use data to respond and adapt behavior over time, even according to user needs and desires. An anticipatory product can proactively anticipate users' plans and intentions [16], and suggest actions.
Thanks to these features, smart products offer opportunities for envisioning new functionalities and interaction. They raise new challenges for their design, such as designing interactions distributed across multiple devices, in which the focus of the user experience is the service and not the product itself [25].

4. Research Perspective: Conversational Smart Products (ConvSP)

Smart products with conversational interfaces and virtual assistants are becoming widespread. McTear, Callejas & Griol [1] explain that the rising interest in conversational interfaces depends on five main factors: (1) the renaissance of AI as a field and advances in language technologies; (2) the emergence of the semantic web; (3) the improvement in device technologies; (4) increased access to connectivity; (5) the interest of major companies. In addition, platforms and libraries [5] support the phases of design, prototyping, and development of CUIs. For example, the design software Adobe XD added in 2018 the possibility to simulate voice interactions in interface prototypes.

CUIs are a topic of interest for Human Computer Interaction (HCI). In 2018, Clark et al. [2] did a systematic review on the status of speech interfaces in HCI. The study found that current research in HCI converges on nine topics. These include studies on user/system speech production, comparisons on different modalities of interaction, investigations on people's experiences with personal assistants, and studies aimed at generating design insight. Their research highlights the lack of design related work and research, outside usability testing and theory-based research.

This research addresses the topic of CUIs from a product perspective. In particular, it has three main objectives.

O1: it aims to define "Conversational Smart Products" (ConvSP) and their characteristics;
O2: it aims to deepen how conversation can be embodied in products, and how the physical attributes could work in synergy with the verbal dimension during the interaction;
O3: broadly, it wants to investigate what could be the role of product designers in the development of Conversational Smart Products.

Literature from the disciplines of Human-Computer Interaction, Artificial Intelligence, and User Experience Design contributed to investigate the theme of ConvSP. In HCI, it was given relevance to the subject of speech interaction and *Tangible Interaction*. Tangible Interaction is an umbrella term denoting systems that rely on embodied interaction, tangible manipulation, physical representation of data, and embeddedness in real space [26].
Tangible interaction is a promising field of research for smart connected products. The study of Tangible Interaction applied to the Internet of Things has been called "Internet of Tangible Things" or IoTT [27], and is seen as a way to facilitate the control and understanding of IoT objects.

Design researchers are already studying the use of sensory language to communicate information and engage users during user-product interaction [28]. One of the research hypotheses of this paper is that non-verbal, tangible elements could work in synergy with the verbal dimension, and help users to overcome some of the limits of voice-interactions. For example, one limit is that voice is not always the most natural interaction option, or the most socially appropriate. Another issue of VUIs is that users may not know or remember what all the tasks that the system can perform are, because those are not visualized on a display. That is why chatbots and virtual AI assistants rely on menus and visual elements, like buttons and cards, and smart speakers integrate screens.

5. Analysis Framework and Case Studies Selection

As conversational products are getting commercially widespread, the first step of this research consisted in a preliminary analysis based on case studies. Exploratory case studies are an appropriate method to inquire little known, poorly understood issues, and whenever the research subject is still emerging. The aim of the investigation was to define ConvSP and gain possible insight for further research.

A framework of five main characteristics was outlined to analyze existing products. The framework is the following (see Table 1).

Type of Conversational Interface (CUI)	Vocal User Interface (VUI), Chatbot, Embodied Conversational Agent (ECA), Virtual Personal Assistant (VPA)
Level of physical embodiment	Remote, Environmental, Embedded
Type of conversation	User or System initiative, Task-led or Topic-led conversation. Conversation goes beyond 1 turn
Input and Output modalities	Text, Speech, Tangible interaction
Product smartness	Autonomy, Reactivity, Adaptability, Multi-functionality, Cooperation, Awareness, Personality

Table 1. Framework for the analysis and definition of Conversational Smart Products

The Type of Conversational Interface (CUI) includes VUIs, Chatbots, ECAs and VPAs. This criterion aims to identify which are the most frequent, and to get insight on how Assistants (VPAs) are integrated in products.

Level of Physical Embodiment of the CUI. Fishkin's taxonomy [29] was the starting point to determine where and how conversation takes place in the product. Fishkin proposes a frame-work to analyze the tangible interfaces according to their level of physical embodiment. He distinguishes between four levels of embodiment. "Full" embodiment occurs whenever the output device coincides with the input device. "Nearby" embodiment is characterized by the output taking place near the input object. "Environmental" embodiment consists of the output being around the user and *non-graspable*, like sound. Embodiment is "Distant" if the output happens remotely, such as on another screen or in another room. Based on this framework, three different levels of embodiment for conversation were defined. Conversation is "Remote" when the input or output happens elsewhere. It is "Environmental" when it uses sound and speech. It is "Embedded" when the conversation includes aspects of tangible interaction with the product.

Type of Conversation. Conversation was analyzed in respect to three aspects. The first one is initiative. User-initiative means that the user can do one-shot queries and open-ended prompts, while System-initiative means that the system directs the dialogue with slot-filling prompts [1]. The second aspect is the purpose of the conversation. A Task-led conversation aims to accom-plish a task, while a Topic-led one aims to discuss and exchange ideas [6]. Finally, there was an attempt to check if the conversation can go beyond a turn of interaction [8].

The input and output modalities of the interaction of user and system were deepened to to see if they were only textual and verbal, or if they included tangible interaction.

Lastly, the **construct of product smartness** was applied to assess whether these products possess the characteristics identified in the literature. Selected product smartness criteria integrate Rijsdijk and Hultink's categories and the principles of Ambient Intelligence described in section 3 of this paper. The seven criteria are: Autonomy (independent action and proactiveness), Reactivity (direct-response to environment and events), Adaptability (over time), Multifunctionality, Cooperation with other devices, Awareness (contextual, of users, of self, of cultural principles), and Personality (having a credible character).

5.1 Selection Criteria and Data Collection

The investigation was carried out on a sample of 30 products with conversational interfaces, or compatible with voice assistants, launched on the market in the last 3-4 years. One requirement was that there would have to be sufficient online material to evaluate their interaction through video and reviews. For this reason, concepts and research projects were discarded. The product selection comes from the most recent tech fairs (i.e. CES 2019, 2018), official lists of products with built-in and compatible assistants (i.e. Alexa, Google Assistant, Siri, Bixby), tech blogs and blogs specialized on conversational interfaces (i.e. Chatbots Magazine, Voicebot, Wired, Tech Insider, etc.).

The 30 case studies belonged to different product categories. They included: a TV remote, camera, door lock, earphones, food scale, commercial robot, light bulb, microwave, musical keyboard, printer, smart clock, fridge, smart outlet, shower, smoke alarm, thermostat, vacuum cleaning robot, washing machine, 2 light switches, 2 smart toys, 3 smart displays, 6 smart speakers.

6. Results and Discussion: Conversational Smart Products Characteristics and Definition

Products were analyzed according to the framework described in section 5. The alluvial diagram in Fig. 1 summarizes the case study research in numbers, and highlights the relationships between the different aspects of the framework.
Research findings are summarized in four main topics.

On Product Smartness and Personality. The construct of product smartness proved useful to evaluate smart products. All the analyzed products possessed one or more aspects of smartness. Most of the products (18 p.) possessed three to five aspects at the same time, eight products possessed just one or two, while four possessed six or seven.

Smart products are networked, and through connectivity enable different modalities of interaction. Therefore, Cooperation is the most frequent aspect of product smartness (28 out of 30 products), followed by Multifunctionality (23 p.) Awareness & Adaptiveness (18 p.), Autonomy (15 p.), Reactivity (11 p.) and Personality (6 p.).

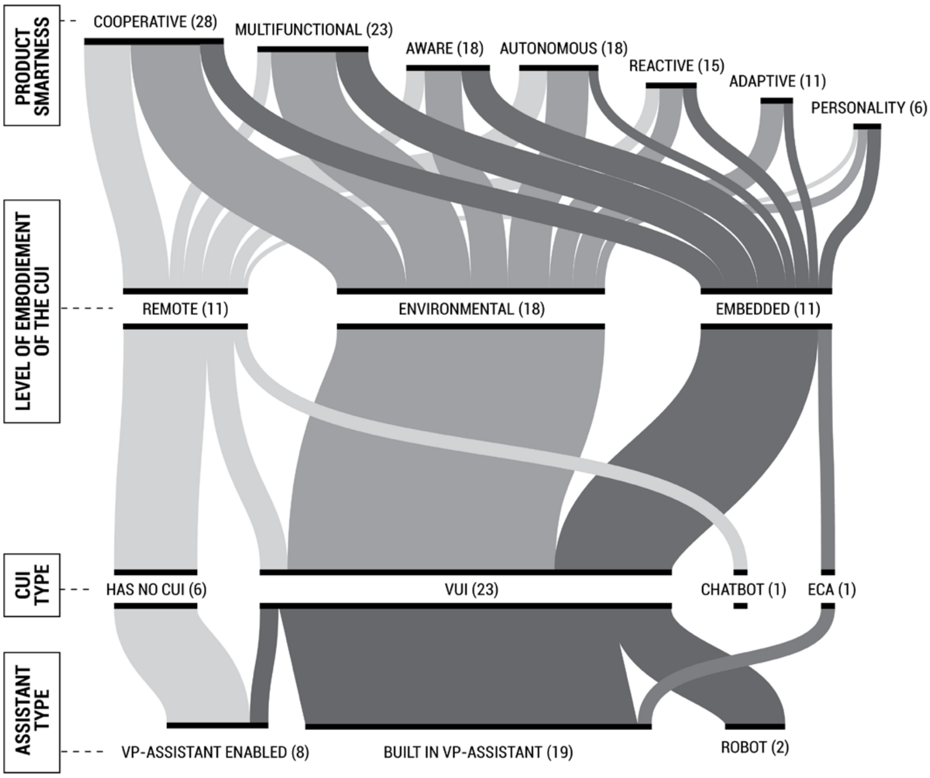

Fig 1. The alluvial diagram summarizes the case study research in numbers, and highlights the relationships between the different aspects of the framework.

The aspect of personality, while relevant in the design of digital conversational agents and interfaces, it is scarcely present in commercial smart products. It is more frequent for such products to attempt to engage users in topic-led conversations, as done by robots, smart toys, and smart speakers with specific purposes, like teaching languages and playing with children. Most of the examined products integrate existing voice assistants (i.e. Alexa, Google Assistant) and do not create another proprietary character.

Level of Physical Embodiment of the Conversation. Conversation happened mainly in an environmental, intangible way (18 products), most frequently through the use of voice inter-faces (23 p.). In 11 products, conversation took place remotely, according to two types of situations. In the first one, the input or the output of the conversation was given to or from another device. For example, a smart TV remote acted as the speech input, but the output in the form of voice, text, and actions took place on the TV screen. In the second situation, products were simply "VPA assistant-enabled". The products did not integrate CUIs. External assistants, in the form of smart speakers of apps, received and processed the commands, while the product only performed actions. Conversation had no impact on the shape of those products. This characterized smart locks, smart outlets, printers, vacuum cleaners, showers, and smart light bulbs. In 11 cases, the products directly integrated the conversation with some tangible elements. Among those, four products used embedded screens to support the conversation. In two cases of robots and smart toys, the conversation was in fact "embodied" by the product through a character.

Voice interfaces were the most frequent CUI (23 p.). Only one product used a chatbot: a washing machine with a chatbot assistant on a dedicated app. Only one smart speaker used an Embedded Conversational Agent: an animated cat, displayed on a screen mounted on top of the device.
Since smart products increasingly embed screens, it is possible to integrate other kinds of CUIs beyond VUIs. Graphical User Interfaces (GUI) could use the metaphor of conversation in their interactions. This could be useful for those products that guide users in complex procedures.

Conversation Insight: Request/Response Design. It was challenging to clearly evaluate the details of the conversation through videos and indirect references. Initiative was left to the user in the majority of samples (29 products), while it was directed in the case of a washing machine controllable via chatbot. Interactions were short and in form of commands. As stated by Porcheron et al. [10], this can be referred to as "request/response design", since there is no real conversation.
Without practical tests, it was not possible to clearly define if the products were able to go beyond the first turn of interaction, as in the definition of Conversational Design given by Pearl [8]. It depends on the capabilities of the conversational agent. The communication capabilities of those products that have built-in assistants will acquire more conversational skills as the assistants are further developed. On the contrary, it is hard to define as Conversational those products are compatible with assistants but do not have CUIs themselves. This has been taken into account in the definition of ConvSP.

On Tangibility and Conversational Input & Outputs. The research shows that there are a few aspects of the conversation that are embodied in the product. The first is the "invocation" of the agent, the way in which users can "wake up" the product and start interacting with it. In five products out of 30, the voice interaction could only be initiated by pressing a physical button. This is also seen as a privacy measure, to ensure that products with VUIs are not always "listening". In seven cases, screens were used to support and enrich the conversation. This is particularly true for smart speakers, that are progressively turning into smart displays. This opens up possibilities for multimodal interactions that blend voice interaction and Graphical User Interfaces.

During the conversation, feedback in the form of animated light effects was used to communicate with the user that the agent was listening and producing a response (in eight products). There could be the opportunity to design multimodal feedback that synchronizes to the content of the conversation. For example, the feedback could change in case of greetings, confirmations, and errors. Another opportunity is to design ways to aid users in remembering and visualizing the available actions and commands that the product supports.

6.1 Working Definition of Conversational Smart Products (ConvSP)

Given the findings of this first investigation into existing products, the working definition of the ConvSP is as follows:
ConvSP are physical, networked products, augmented by a digital counterpart.
They possess one of more aspects of product smartness in the form of Autonomy, Reactivity, Adaptability, Multifunctionality, Cooperation, Awareness, Personality.
They embed Conversational User Interfaces (CUI) in the form of Vocal User Interfaces (VUI), Embodied Conversational Agents (ECA), Virtual Personal Assistants (VPA), and chatbots.

There are three levels of physical embodiment of the CUI. It is “Remote” when the input or output happens elsewhere, “Environmental” when sound and speech are used, and “Embedded” when there the conversation includes tangible interaction with the product. A ConvSP must clearly display or suggest through its physical form and feedback, that is conversationally enabled.

7. Conclusions

This paper approaches the topic of Conversational Design and Conversational Interfaces (CUI) from a product design perspective. It introduces the term Conversational Smart Products (ConvSP) to describe those physical products that embed conversational interfaces, and offers a descriptive definition.

Broadly, this work is part of a research that aims to investigate what could be the role of product designers in the development of conversational smart products. The paper proposes a framework for the analysis and definition of Conversational Smart Products which considers the type of CUI, the level of physical embodiment of the conversation, the type of conversation, the input and output modalities, and the overall product smartness. It begins to investigate how the conversation can be embodied in the product, through a case study research conducted on a selection of 30 existing products with CUIs. A limit to the present study is that it only investigates smart products using indirect resources such as videos and reviews. Therefore, the evaluation of the interaction may not be complete or completely correct.

It is a preliminary study that proposes four different topics that can be relevant in the design of ConvSP.
The first point is that ConvSP possess one or more aspects of product smartness. The aspect of personality is more relevant for those products that engage in topic-led conversations, such as robots and smart toys.
The second point is that interaction with ConvSP is mostly environmental, and happens via VUI. Since smart products embed screens, there is space to integrate other kinds of CUIs, such as chatbots and ECAs, and to design Graphical User Interfaces (GUIs) that use the metaphor of the conversation.
The third point is that the ability to converse strictly depends on the conversational agent. Therefore, products with built-in assistants will have the most advanced capabilities. Products that are only “assistant-enabled”, without any impact on the product, can hardly be considered as conversational.
The fourth and last point is tangibility. There are different elements that show potential for tangibility: the design of the “invocation” of the agent, the design of the system’s outputs, and the design of systems to guide users in remembering and visualizing the available actions and commands.

Further research could explore the firsthand experience of designers that are already involved in related projects, with the goal of investigating their role in the development of ConvSP. Other activities could include practical tests with ConvSP, and design activities aimed at exploring how physical attributes could work in synergy with the verbal dimension.

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Topic 3.

Interacting with Urban Intelligences

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AI-to-Microbe Architecture: Simulation, Intelligence, Consciousness

Abstract

This paper probes questions of how big machines—buildings—can function as hybrid metabolic/AI organisms. Focusing on AI, artificial life (ALife), and microbial intelligence I look through the lens of Ludwig Wittgenstein's *Tractatus* and Alan Turing's algorithmic plant simulations to source modernist theory for biointelligent architectures. I'm using scant records and testimony interpreted through each thinker's writings, architecture, and/or simulations. This text is then a device for considering ways-of-being within, and ways-of-thinking about, theory/practice for the fusion of biological-to-biosynthetic intelligences (microbes, plants, animals, AI, machines.) Resulting theory thereafter supports the development of bioremedial environmental cleanup addressing climate change. My proposition then deploys biomimetic and laboratory data to nurture metabolically driven intelligences partnered with AI in the production of architectures. That ontological pathway stems from machine learning, bio-surveillance, and digital simulation at object, agent, and urban scales. Accomplishments in neural net AI and synthetic biology stirred me to question earlier breakthroughs in relation to current experimental practices. Subsequently, I link and hybridize emergent design proposition to AI, ALife, and biological intelligences as unities for environmentally performative, intelligent buildings.

Keywords

Metabolic Architecture, Artificial Intelligence (AI), ALife, Alan Turing, Ludwig Wittgenstein, Computational Simulation.

1. Propositions Toward Metabolic Architectures

Research strategies to regulate exploratory sets of generative design actions are called upon here for reasoning the inclusion of AI, synthetic life, and bio-algorithmic generation into the production of metabolic architectures. These exploratory tactics underwrite hypothesizing biointelligent buildings as parts of nature. Therefore, to link theory and observation I evolve strategies for the investigation of matter and forces starting with symbolic languages to sort types of intelligence.

Specifically, concepts-terms such as "atomic facts," "form," "objects," "substance," and especially "picture" — autonomously inhabiting Wittgenstein's *Tractatus* — are appropriated for research organization. His philosophy suits design analysis reinforced when the Vienna house [1] he designed for his sister is decrypted to acknowledge *Tractatus* logic I analyzed in "Calculating Turing, Thinking Wittgenstein" [2]. Likewise, for this paper, the Wittgenstein House stands as a pre-

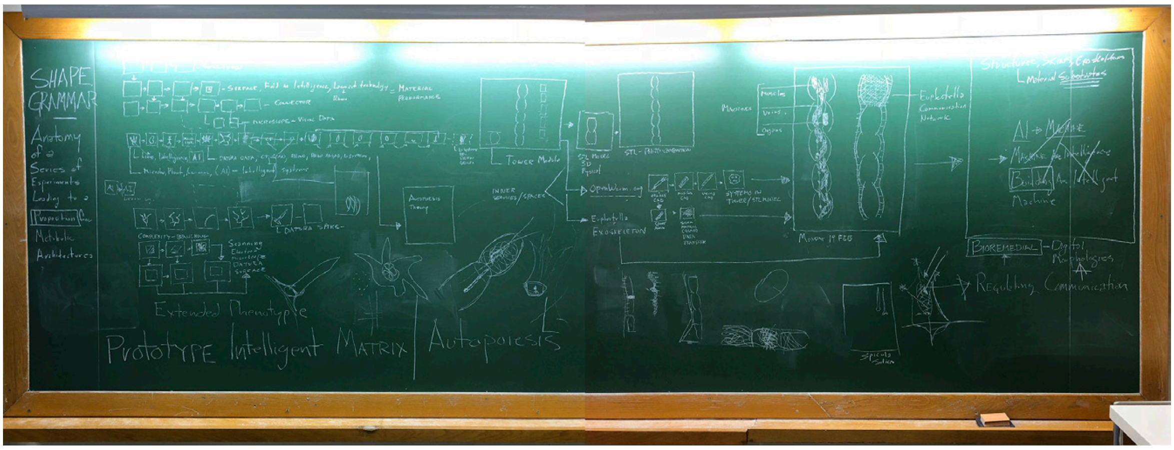

Fig. 1. Brainstorming. Theory for plotting application and methodology for metabolic buildings involving microbe/plant/animal/machine intelligences organized on Wittgenstein's ***Tractatus*** and Turing's Morphogen propositions. Drawn for the 2018 Metabolic Architectures Studio, UIC. Dennis Dollens.

computer agent balancing thinking and design practice to enact theoretical propositions in architecture.
In the above framework, Wittgenstein's philosophy guides design-research, especially when joined by notions of extended cognition [3], extended phenotypes [4], and Turing's algorithmic botany [5]. That mix is used to prompt theoretical organization to motivate AI-to-microbial [6] design conceptualization. Such organization enables metabolic and AI linkages through Wittgenstein's logic and Turing's simulations to illustrate relationships for theories of intelligent buildings. In the same way, designers may configure objectives for their own projects, observations, and strategizing research procedures for metabolic architectural [7. 8].

The result of *Tractatus*-prompted reasoning may be used to diagram design visualization theory enabling architects to consider: (i) the synthesis and mutability of life, matter, and forces, (ii) differing typologies of intelligence existing in microbes, plants, animals, and some machines for (iii) algorithmic simulation. All three areas have parallel interactions in Turing's [9] research that complement *Tractatu* [10] precepts when used as foundational logic for AI-managed, metabolic architectures. Turing/Wittgenstein reformulations thereby suggest pathways over which buildings may be designed as living technology [11. 12].

Together, Wittgenstein's propositions and Turing's computational tactics enable design brainstorming [Fig. 1] to frame programs of investigation. That research may then reveal biological attributes of living organisms suited to architectural simulations and models. Viewed through propositional tactics, the Wittgenstein House [1], designed approximately ten years after his book, is a built idiom — the logic of the *Tractatus* resolved in tectonic form: book-to-building, mind-to-matter. Mind-to-matter scrutiny — mixing modes of autopoiesis [13] and extended cognition [3] — further situates the house in a relationship with intelligence, language, and visualization.

2. Typologies of Microbe, Plant, & Animal Intelligence

Metabolic architecture — formulated through propositions — articulate cognitive states supporting mind-to-matter design enactments. It seeks biological performance by questioning technological ways to extrapolate sensory biointelligence from nature. For example, asking: How can designers observe biological intelligence to enact architectural bioremediation? And, if remedial strategies are sourced in nature: How can architects employ theoretical procedures to interpret an organisms' intelligence and appropriate it to monitor environmental toxicity? Such questions become recursive — referencing history and philosophy to evolve thinking and data appropriate to building design. The designer may then set objectives receptive to living metabolic operations involving the hybridization of AI, microbe, and synthetic biology.

In this phase, aggregates of AI/microbes may be studied as cellular-intelligent agents challenging architects to harness carbon dioxide (CO_2) sequestration. First design explorations are organized through biology via autopoiesis (*auto* = self, *poiesis* = making) [13] interpreted to validate organisms (microbes, plants, animals) as intelligent system unities. Theorized by autopoiesis, organisms may be composite unities coupled with computational technology. Such simulations echo Turing's plant observations for algorithmic performance [14] and his theories of machine intelligence [15].

Shadowed by cybernetics, design research is linked to biology, biology is linked to code, and code is linked to generative architecture. That architecture awaits new questions formulated after Turing asked: "Can machines think?" [9]. From Turing's starting point, designers may fast-forward observations and data to contemplate intelligent systems programmed through computational biology. In such cognitive-to-computational processes, *Tractatuslike* corollaries emerge as tools [Figs. 1. 4] to determine design research methodologies situating metabolic buildings as human-extended phenotypes [4. 16].

3. Hybridizing: Nature/Intelligence to Machine

Observation of nature's biochemical processes reveals that cellular agents — microbes and plants — can be integrated into synthetic materials or ALife provisioned for architectural components/facades. The resulting metabolic architectures operate as hosts for cellular, living organisms communicating between urban infrastructures and dynamic ecotones. For such hybrids, an architect needs biological data [Fig. 4] visualized and/or rendered in code to simulate microbial living habitats that, until now, have been genetically programmed only by nature [17]. Such observations and programming presuppose subsystems invoking collective microbe behaviors that designers (working with biologists), must coax into an alliance with AI in order to ask: Can buildings bio-technologically remediate pollution? In response, post-Turing questions take for granted that intelligent bio-façades could incorporate, for example, AI-monitored bacterial colonies (e.g., biofilms) in order to convert toxins to energy by feeding on CO_2 in ways pioneered by oil-spill cleanup.

The thinking behind botanic algorithmic programming and the exchange of metabolic data will enormously increase when AI and synthetic life are genetically cooperating and reproducing in living matter found in nature [6. 26]. Existing examples preview beneficial bacteria living in animal architectures built of beeswax, wasp paper, biofilms, termite mounds, and human-made adobe. Biocellular-AI may equally be modeled upon, or paired with, microbes and plants to take residence in, and perform from buildings and urban infrastructures that track pollution while metabolically consuming specific toxins.

4. Turing/Wittgenstein

By extrapolating from Turing's theories and programming, I repurpose biology-to-code investigations through which he simulated aspects of matter, life, intelligence, and machine processing [5. 7]. Procedurally, the lineage stems from his observations of living organisms extended to implant functions from nature into coding. This meshes with how Wittgenstein [10] used propositions to argue the "case" as the world and, in this text, when the *Tractatus* is culled for

Fig. 2. L-system Grown Plant/Microbe BioTowers. Left to Right: PagodaTower, BioTower, and MicrobeTower, Barcelona. Dennis Dollens.

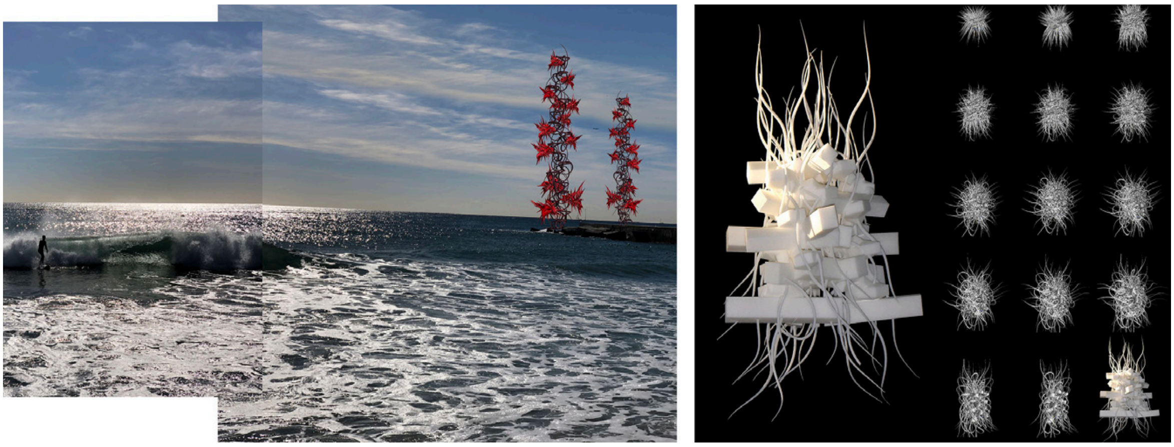

Fig. 3. Left: *ferox*Towers are theoretical experiments whose function investigates hybrid AI/microbe atmospheric carbon capture collaboratively enabling options for bioremediation to produce energy at levels of cellular homeostasis. 2018-ongoing. Right: ArizonaTower STL & Animation Sequence. L-system plants generated as roots, branches, and seedpods — with the seedpods programmed as polysurface rectangles and the roots grown into a branching superstructure. Dennis Dollens.

design research logic. Extrapolated data, or mind's-eye pictures in Wittgenstein's sense, are then available to researchers for cross-system investigations in which biochemical signals appear as potential codes for heuristic AI to learn or decrypt. In my *case*-world experiments, algorithmic generation and morphological materialization [Figs. 2. 4] merge to help analyze teaching/research pathways over which metabolic architectures may source intelligences from nature for use in buildings [7. 8. 14].

5. Biological Observation as a Design Operation

Design research observations, channeled through 3D scanning and SEM imagery [Fig. 4] thus parallel the *Tractatus*' first line: "The world is everything that is the case" [10]. Designers evolve individual *case*-worlds when data is retrieved from organisms and applied to design — inarguably a realm of human cognitive nature. In this situation, scientific procedures supplement material and environmental data to support design research. That research facilitates inducting ALife functionality and behaviors into building materials. Following preliminary designs — data and imagery from microscopes and scanners [7. 8] — further detail the translation of insights [Figs. 1. 4] from nature in order to program AI/microbe material candidates into fablab productions and/or agents [Fig. 3].

To unpack the above paragraphs requires us to: (i) theorize technology, ecology, architecture, and computation in terms of bio/synthetic and metabolic propositions [Fig 1]. Doing so positions us to conceptualize AI enhanced with animate intelligences targeted for generative architecture while (ii) tasking resultant theory to support programming bioarchitectural homeostasis engaged in climate, soil, and water restoration. Those two processes integrate networks of living (cellular organisms) and AI to (iii) envision metabolic intelligent buildings [Fig. 2].

The above bio-to-building dialectic [7. 8] enables us to characterize intelligent architectures as potentially sentient and autonomous. One possibility is then to capture airborne CO_2 through the actions of AI/metabolic machines performing intelligent analysis of toxins executed by microbes in biomechanical systems [Fig. 3]. Sentience, routed to architectural functions, algorithmic simulations, and cellular performance illustrates how metabolic machines could give rise to new species of design and architecture [Fig. 3]. Emergent propositions thereafter expand territories of experimental theory in queries such as: If metabolic/AI buildings sense, experience nature, and make decisions through collective microbial life, do they experience artificial consciousness? [18. 19].

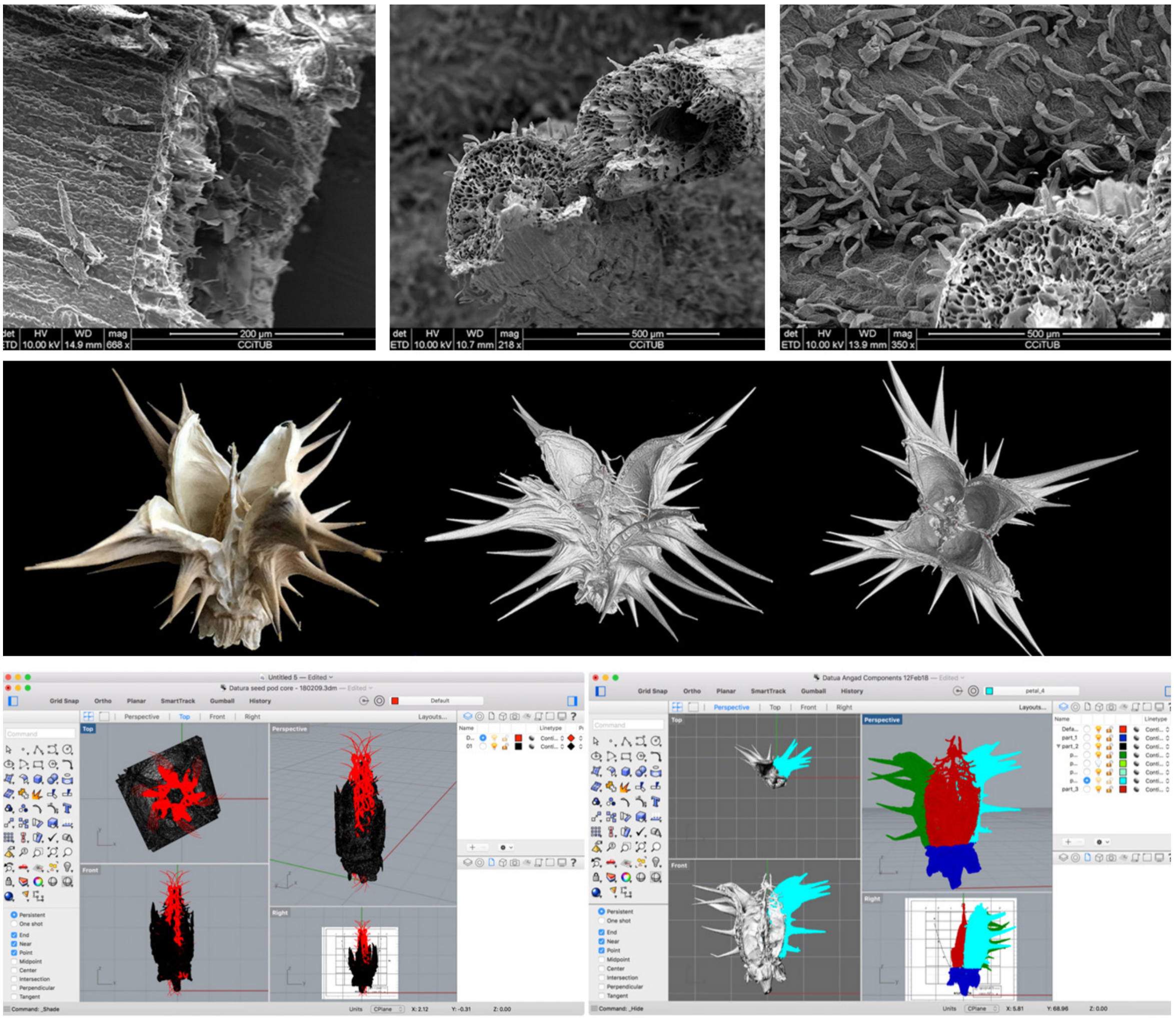

Fig. 4. *Datura ferox* Data/Image Sets. Top: Scanning Electron Micrographs of ***Datura ferox*** seedpod spikes. Middle, left: ***Datura ferox*** dried seedpod followed by two images of 3D-CT scans. Bottom: Rhino3D screen shots. Imported CT scans for carbon-capture pod development of (See: Fig. 3 Left). Dennis Dollens.

6. AI Anticipates DNA Turing Machines

From such interrogations — not frequently probed, yet lurking behind, for example, Google's AlphaGo, [20] — I anticipate ontological nature-to-machine unity. Such questions are credible after Google's AI succeeded at learning, playing, and winning Atari video games, beating world champions at the Game of Go, and triumphing over human and machine chess players [21. 22]. Still other questions arise because programmers do not fully understand the learning processes their codes engender in machines. We/they may ask: Are some species of AI existentially thinking? [23]. Associatively: Is a subset of neural net AI approaching cognitive abilities? — abilities humans have traditionally considered exclusive to themselves and, in a lesser register, to a few animal species [19. 24].

These questions do not suggest a one-to-one microbe or plantlike parity with deep learning or reinforcement learning AI. Rather, I point out quorum sensing [17] potential for genetic biotechnologies [12] to prompt computationally originated sensing in living/synthetic cells capable of next-generation inheritance and reproduction. (According to *Interface: The Royal Society* — prospects include theoretically successful DNA Non-Deterministic Universal Turing Machines [25. 26. 27]. Such molecular-scale machines would be compatible with quorum sensing and neural net

AI and could eventually be edited into living cells to enable DNA computing [26. 27]). Here then, metabolic buildings with active DNA intelligences, could be viewed as biosynthetic AI/ALife agents achieving microbe cognition long after Turing, but still consistent with his algorithmically simulated drawings and theoretical writings [5].

To be clear, I am saying that Turing/Wittgenstein theoretical propositions may now be considered members of intelligent nature. They are phenomenal agents-of-thought licensed in philosophy, mathematics, and cognitive science [3]. Propositions of this phenomenal order (metabolic/living/AI intelligences) figure as agents of thinking [28] — facilitators from human cognition as it evolves new typologies of intelligence — in this text's *case*-world — as metabolic buildings and/or cities. Agents-of-thought, manifested through the *Tractatus*, are accordingly selected as design axioms for generating prototypes that consequently exist as extended phenotypes [4. 16].

7. Can Buildings Think?

However jarring, constructed species — neural net AI and ALife [11. 12. 27] — extend Turing's question, "Can machines think?" [9. 14. 28] His question (and Wittgenstein's too [29]), if answered positively, gives support to the proposition that buildings, as big machines, can think. Design-research goals can then be perused for ontological unity connecting ways-of-being / modes of debate / types-of-intelligence / responses-to-climate change / and requirements-of-design. As a result ontological cohesion aligns research with places, tools, and nature as aspects of design contextualizing the extension of our cognition [3] in *case*-worlds. That process creates a framework for contemplating hybridized machines, AI, and (some) microbes as environmental sentinels — new species of metabolic intelligence and artificial life [12].

Metabolic architectures are thus first ideas, then propositions (or codes) developed in design from deductive exchange between phenomena, material, computation, nature and the architect. In this lineage, propositional analysis is *realized* descending, not only from the *Tractatus*, [10] but also from Latin *res* (thing) as in *res extensa*; as well as idea found in *idein* (to see) from Greek. The quandary — things seen cognitively — or cognitive things (*res cogitans*) — underpins design (ideas, propositions, prototypes) embodied in matter/tools for thinking about metabolic architectures. Applied to Turing, we need only look at his plant-to-algorithm drawings and printouts [5] to comprehend that he seized on nature's intelligence and physical growth for mathematic language and resulting digital simulations.

For design theory, this text's *case*-world is in service to algorithmic simulation begun when Turing translated plant attributes to programming [15. 28]. Simulation then enters our framework, not only through Turing but also through Wittgenstein's term to "picture" (*res + idein*). Similarly, propositions can be generative orders of simulation — Latin *simulationem, simulare* to underpin thinking and designing as thought prior to coding.

Turing simulated parts of nature in computation appropriate to philosophical design/machine/intelligence debate. From that scenario, we confront results of the verb *simulate* and the noun *simulation* to communicate ranges of life/cognition. Simulations, for such usage, are thus human-extended phenotypes [4. 16]. They are concept/objects of thought as cognitive or computed numbers realized (built) as thinking machines/buildings constructed in the world [3]. In autopoietic [13] terms, they are participants in cognitive-to-physical domains (the *case*-world) that here includes Wittgenstein's theory of picturing [2. 10] incorporating language and design/construction realized in symbolic logic (philosophy) and the built Wittgenstein House [1. 2].

To give bearing to this paper, I see Turing as the agent from whom we learned how to simulate nature with algorithms (e.g., his reaction/diffusion theory [5. 15]) as computational extensions of our thinking [3]. Those lessons later brought fourth code-to-simulation languages (e.g., L-systems) for today's output whereby seeing (*res*) and imagining (*ideate*), translated mathematically, drive machines/AI to simulate nature. With such ancestry in mind, I evolve models [Fig. 2] using methods Turing pioneered. After extending his botanic observations for computational biology to CAD/CAM, I use laboratory and fabrication machines to visualize and build-out data resulting in various scientific, technological, and design pathways for metabolic architectural practice [14].

Consequently, by subscribing to precepts of Dawkins's [4] and Turner's [16] extended phenotypes, I justify intermingling observations of organisms, matter, and forces. Thereafter, metabolic architectures are propositional descendants of Universal Turing Machines [25. 26] and/or botanic algorithms [5] theorized in *The Chemical Basis of Morphogenesis* [14] and *Morphogen Theory of Phyllotaxis* [27].

Natural functions such as phyllotaxis in fir cones or daisies, borrowed by Turing for his programming and drawings are now culturally and technologically absorbed. However, they may be further recast — computationally resimulated and biofabricated for metabolic systems (living technology) not possible in his time [Fig. 2]. In that context, a paradox appears whereby we simulate nature in an act of intelligent/phenomenal nature itself. Subsequently, at junctures of observation other questions arise: If neural net AI can simulate or partner with life, can it contemplate itself as conscious? [19]. Or: Can bioAI convince multicellular systems (microbes/plant cells) that its onboard intelligence is a part of their living milieu? [12. 17. 18. 19].

8. Conclusion

Different iterations of neural net AI along with biological and synthetic life intelligences — are being developed and or decoded in laboratories around the world. Plant intelligence and communication predicated on signaling and biochemical reaction/diffusion are equally subjects of research [17. 31. 32]. We should therefore interrogate composite bio/AI systems [33] and dialectics [34], not through vague notions of sustainability, but through climate stabilization collectively underwritten by theories such as autopoiesis [13], extended cognition [3], and extended phenotypes [4. 16]. Thereby, designers investigate nature to pair with learning AI and/or living intelligence that address questions of how big machines — metabolic architectures — can function like organisms eradicating pollution while monitoring violations against nature [35. 36].

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Envisioning and Questioning Near Future Urban Robotics

Abstract

Robotic services, which have started to appear in urban environments, are going to transform our society. Designers of these robots are not only required to meet technical and legal challenges, but also address the potential social, political, and ethical consequences of their design choices. In this paper, we present a workshop format with its related tools intended for enabling speculation about such possible futures and fostering reflection on potential socio-ethical implications that might support/oppose these futures. We report the results and discussion of one particular workshop case, in which the implementation of two particular robotic services for a city was envisioned and questioned, i.e., surveillance and delivery of goods. By discussing the results, we illustrate how such a workshop format might be beneficial for setting the agenda for a more conscious design of urban robots and orienting future research towards meaningful themes related to the emerging coexistence scenarios between citizens and robots.

Keywords

Future Scenario, Urban Robotics, Robot Capabilities, Robot Implications, Robot Conceptualizations, Design Workshop

1. Introduction

Provided by the advancements in sensor technologies, artificial intelligence, and smart materials, designers now have the opportunity to take on the exciting challenge of working with intelligence as a design material that can be used in form giving practices [1]. The idea of automata, which has been an object of speculation and pretense since the ancient times [2], can now be translated into tangible entities that are autonomous, intelligent, and might behave out of our direct control. The enthusiasm that may characterize this emerging design space, however, often tarnishes the contingent need for understanding how these novel autonomous artefacts and related services are transforming our society, and whether the future we are shaping correspond to our needs and aspirations as community [3]. Attributing reasoning abilities and autonomy to artificial artefacts, in fact, asks not only to meet technical and legal challenges, but also to address the possible social, political and ethical consequences of such a choice. In particular, automation and artificial intelligence need to be addressed and designed responsibly in public environments like cities, which are becoming more and more crucial as contexts for technological innovation [3-4].

The complex nature of coexistence scenarios emerging from the diffusion of these artefacts, hence, point out the need for systematically envisioning how these near futures might look like. In this regard, the design discipline can play a proactive role by providing methods and tools for supporting speculation about possible futures, fostering reflections on potential political structures that might support these futures, and enabling a more conscious shaping of intelligent and autonomous artefacts [5].

With the aim of embracing this call to action, we present a workshop format developed within the context of the *"Things as Citizens"* research project from Delft University of Technology, as an approach to investigate near future scenarios of coexistence between people and autonomous artefacts in the urban environment. In this paper, we refer to these artefacts as robots, but it may be argued that the same reasoning and investigation may apply also for other autonomous or intelligent artefacts that may not be conventionally considered as robots, e.g. automated traffic lights. Given this intent of encouraging the envisioning of possible near futures and reflecting on recurring ethical dilemmas, a workshop format for "*envisioning & questioning"* was crafted and used in various academic and non-academic events.

In this paper, we report the results and discussion of a particular workshop in which we tackled two robotic services for a city, i.e., surveillance and delivery of goods, with non-experts. By discussing these results, we illustrate how such a workshop format might be beneficial for providing a barometer for the "state of the people" with respect to the practical and ethical considerations of living with robotic services, setting the agenda for future projects and orienting future research towards meaningful themes related to the emerging coexistence scenarios between people and autonomous artefacts in the city.

2. Envisioning and Questioning workshop format

The *Envisioning and questioning* workshop and its related toolkit resulted from a combination of methods and knowledge already familiar in fields like participatory city making, speculative design and responsible AI.

The field of participatory city making includes many toolkits developed for enabling collaboration among different actors, and therefore, was very rich to borrow from. We designed a set of materials (in particular, the Key Interactions Board, Critical Review Board, and Clustering Board) by referring to the consolidated design ideation toolkits meant for envisioning scenarios (e.g. [6-7-8]) and workshop formats for facilitating dialog [9-10] and eliciting values [11-12] among different stakeholders.

We involved speculative design in the customization of the materials and the workshop format to enable reflection. As mentioned earlier, our work is dedicated to the investigation of possible near future cities in which people will cohabit with robots. In particular, we refer to the work of Auger [13], who suggests that a crucial aspect for crafting speculations and dealing with the domain of the possible is to create *perceptual bridges*. These consist in a carefully crafted combinations of audience's perception of the world and the fictional elements, which can be achieved by designing artefacts that are familiar and provocative at the same time. Following the author's suggestion, we crafted our workshop format by analyzing the context of smart cities and its main developments and trends with the intent of building a sense of familiarity and plausibility, and at the same time, we introduced some provocative characteristics in the form of robotic services. In fact, we presented the novel automated services as initiatives of the Rotterdam municipality, which attributes rights and responsibilities to robots.

Finally, the provocative component used for fostering the speculation was defined by current debate and literature about the responsibilities related to the spread of AI and robotics. We examined the current debate about the attribution of rights, legal personhood, and citizenship to robots [14-15-16-17] and employed these as an inspiration when describing the robots in the Things Cards, as well as raised these issues during the discussion phase at the end of the workshop.

The resulting materials and the workshop format, which we refer as *Envisioning and Questioning* workshop, was then used in different contexts, including: education (for supporting a master thesis about an intelligent bike with agency), an academic conference for facilitating the envisioning and discussion of near future robotics for children (IDC workshop by Charisi et al. [18]); and non-academic conferences for discussing the potential opportunities and challenges of robotic solutions for near future cities (Border Session Lab, The Hague, 2018; Drive Festival, Eindhoven, 2018; ThingsCon workshop, Rotterdam, 2018). In the following sections we report the procedure and results of the last workshop carried out during the ThingsCon 2018 Conference. This particular workshop was selected because of its specific focus on urban robotic services (main interest of the Things as Citizens project) and for the completeness of the documentation.

2.1 ThingsCon Workshop

The workshop was organized as a two hours activity, including an introduction presentation on the theme and practical activities carried out by the participants. In this occasion, the toolkit was customized to envision and problematize two main kinds of robotic solutions that are likely to widespread in near future cities, namely delivery robots and robots for surveillance (Fig. 1). In fact, there are already cases in which these two services are already being tested (e.g., Starship Technologies, Marble, Dispatch, Knightscope).

The proposed robotic services were presented through the Things Cards, containing a description of the robot's tasks and functionalities together with an illustration of the robot. These were introduced as an initiative of the city, which grants rights and responsibilities to these artefacts because of their contribution for the public. By emphasizing rights and responsibilities of robots, we aimed at addressing emerging problems of social roles and possible controversial relationships between humans and robots.

Participants. The workshop was attended by 9 people (7 female; 8 aged under 30). The participants were: 1 professional computer scientist, 1 experienced design researcher, 1 young design professional, and 6 design master students.

Process. The workshop was organized in six main steps:

- *Group formation and introduction to the robotic services.* Participants were invited to split in two groups, where they received a Thing Card describing one of the two robotic services, delivery or surveillance.
- *Ideation of key interactions.* The two groups were invited to think about what might be the key interactions among the robots and people in the city when the robot is seen as a member of the community with rights and responsibilities. Participants were

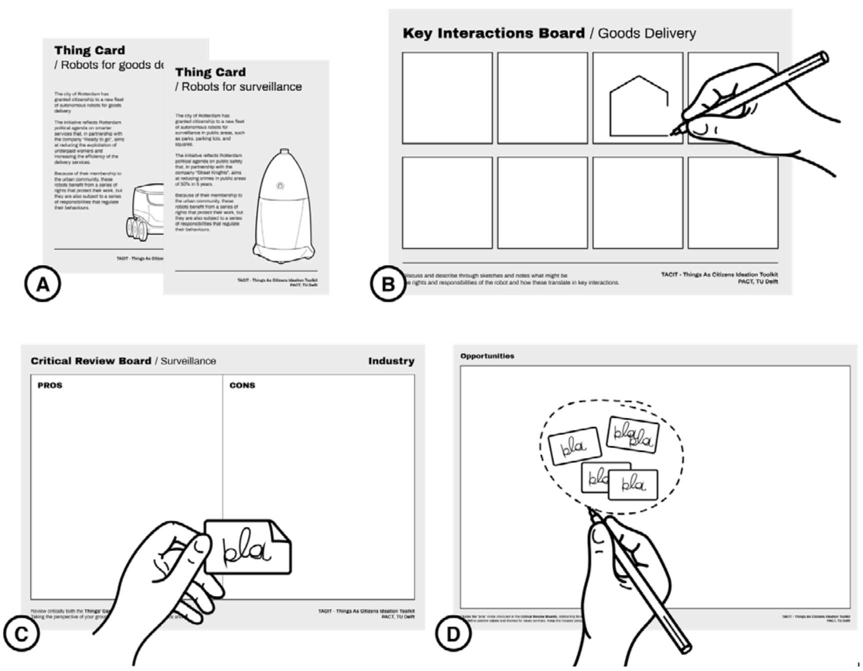

Fig. 1. Workshop materials: (A) Things Cards, sheets with a description and illustration of the proposed robotic service; (B) Key Interactions Board, A4 forms with white boxes for illustrating and taking notes about the possible key interactions and situations related to the proposed services; (C) Critical Review Boards, A3 forms with two sections for pros and cons where participants can put their notes sticking post-it; (D) Clustering Boards, A2 forms where participants were invited to collect and group the post-it about pros and cons and take notes of the emerging topics.

invited to describe their ideas through sketches and notes on the Key Interaction Boards.
- *Presentation and discussion.* Participants were invited to present their ideas about key interactions to the rest of participants who were invited to discuss them.
- *Critical review of the services and interactions.* All participants were invited to review both services and the related ideas of interaction. In this reflection phase they were invited to take notes on Post-its about the opportunities and challenges they could identify in each service, taking the perspective of citizens, industry or government. The Post-its were organized on the Critical Review Boards.
- *Clustering.* Participants were invited to take all the opportunities and challenges and cluster them according to the theme they related to. Participants were asked to abstract the specific notes into more generalizable topics.
- *Discussion and recap.* The reflections emerged during the clustering were summarized by two participants, one for the opportunities and one for the challenges, and the organizers recapped the activity.

3. Results

The materials produced through the ideation of key interactions (Fig. 2), the critical review and the clustering (Fig. 3) were reviewed and discussed both in loco with the participants and a posteriori by the authors with the intent of extracting insights. The two different discussion activities also correspond with the two potential functions of this workshop's results. On the one hand, the participants had the chance of identifying and discussing a series of emerging opportunities and challenges related to the specific cases presented in the workshop. This indicates that the workshop format would be useful for *setting an agenda* for collaborative work to be carried out between the citizens, government, and technology developers (e.g. focused on the actual development of a delivery or surveillance robotic service). On the other hand, the critical review of the results performed by researchers a posteriori was a useful way of generating knowledge for research in the area of responsible urban innovation and design. By interpreting both the explicit results that were reported in the clustering boards and the implicit results encoded in the situations represented in the ideation of key interactions, it is possible to identify meaningful and sensitive topics to *orient future research.*

In the following subsections we report a summary of the topics emerged from the participants' work and reflection, organized and discussed in three macro-themes identified by the authors through their subsequent analysis.

3.1 Data Related (In)abilities

Participants discussed the robots' distinct ability to go to places that humans may not go and see things that humans cannot see, using a large array of sophisticated sensors and processors, which significantly increases their capacity to collect and process personal data. They emphasized how, through these data, companies,

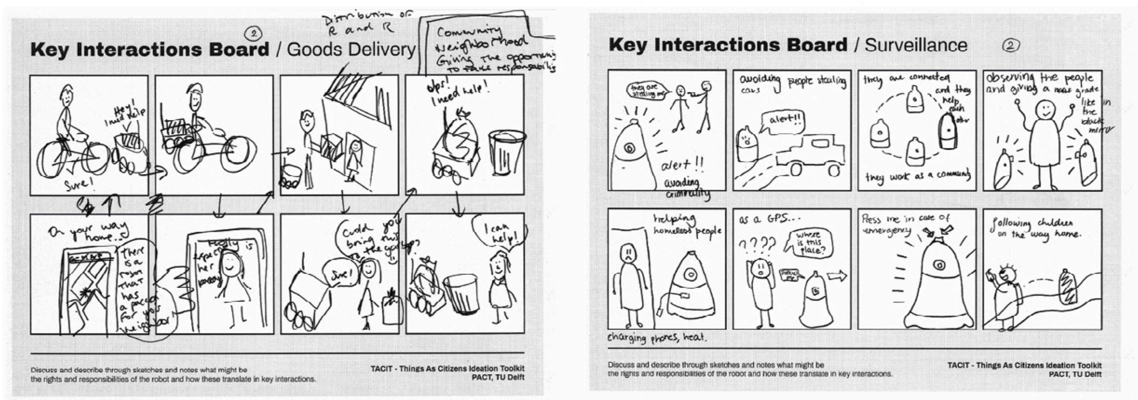

Fig. 2. Results of the ideation of key interactions. On the left: interactions with goods delivery robot. On the right: interactions with surveillance robots. In both cases, participants illustrations show how the robot's role may go beyond its main function and provide additional benefits for people.

Fig. 3. Participants engaged in the clustering phase of the workshop and final clustering boards.

government, and citizens gain new capabilities.
For example, surveillance robots may increase the autonomy and independence of citizens. As envisioned during the workshop, children or elderly could be accompanied to their homes while being guarded from security threats by the robot identifying anomalies in its environment. This may provide them greater freedom to move around, knowing that they have a personal guard that will prevent problematic situations.

Despite this opportunity, however, participants largely stressed how such abilities also come with their own challenges, mostly in relation to privacy. Even if the surveillance robots are not meant for law enforcement, they can easily turn into Big Brother kinds of control, not only steering the citizens' activities, but also nurturing the feeling of being observed and evaluated. The participants envisaged situations such as the robot gathering information about citizens from their social media and using it identifying potentially "troublesome" people, the robot observing people and giving them a grade as in the TV series Black Mirror, or the robot anticipating crimes by using prediction algorithms and machine learning. Or given that these robots might well be financed by the governments or particular companies, the robot may be programmed to nudge the citizens into specific "government approved" behaviors. In other words, *the ability that the citizens gain* regarding to mobility may sometimes be *hindered by the "disability" they simultaneously inherit* regarding their privacy and freedom. There could be slippery slope towards authoritarian robotics, which might cause the citizens deliberately avoiding the robot.
Although less controversial, the participants also raised concerns regarding the delivery robots' potential to use the collected data for offering improved services. Functionalities such as face recognition to unlock the robot, detection of customer location for dynamic delivery, access to purchase history for a personalized service, and detection of the customer's age as a security check to deliver the parcel or not, were all envisioned as opportunities for a better service, yet come with the cost of invading privacy. Thus, the question here is whether the increased efficiency in delivery and the improvement of safety are great enough to justify the resulting restriction of the individuals' privacy and liberty.

Another issue that was discussed during the workshop was related to robot networks and flocks. While citizens may think of surveillance and delivery robots as single entities that autonomously operate in the city, it is more apt to think of them as networked devices. They can share the data they collect with other robots or control other smart devices in the city, such as traffic lights or self-driving cars. The participants envisioned scenarios where a flock of robots coordinate their actions to "catch" a criminal. However, if the mechanics of this data exchange is not understandable, it was discussed that the robot-robot communication would alienate and frighten the citizens. Again, the pragmatic benefits of having robots must be balanced against the people's right to data transparency.

These discussions point out how data, which is often referred to as a new design material and loaded with large promises for improved services and human experiences, may actually became a disabler. Especially if associated with the idea of autonomous robots that can roam around public environments, the capability of collecting and managing data can indeed represent a source of discomfort and negative attitude in people.

3.2 Beyond the Tool Paradigm

As expected, the workshop highlighted when designing robots for public environments, such as cities, not only is it essential to make the robot perform its tasks effectively, but also to consider other forms of *interactions that go beyond the mere function*. The robot, in fact, is usually expected to comply with social norms and human habits. What unexpectedly emerged from the workshop, instead, is how such non-task-oriented interactions becomes prominent if the robot is discussed in terms of citizenry relationships. Both in the case of delivery and surveillance robots, participants envisioned and critically discussed possible emerging roles of the robots which, because of their membership to the urban community, are expected to perform some kind of action that we may consider socially relevant. The participants conceived situations that involved positive interactions where people felt responsible to take care of the robots and vice versa, as well as negative ones which could compromise robot safety. In the following subsections, we illustrate two types of human-robot interactions that go beyond the primary robot function: *mutual care and self-defense.*

Mutual care. Participants conceived many situations in which fully autonomous robots ended-up needing a bystander intervention. These situations included robots breaking down, getting stuck, or even being damaged and vandalized by people. In these cases, participants envisioned an active role for human bystander who may intervene if the robot calls for help or even offer their help voluntarily, such as in a scenario where a citizen spontaneously cleans up a robot from spray paint. Interestingly, these "help scenarios" only occurred in relation to the delivery robots. This may be due to the nature of the task of these robots. Delivery robots are a service with an immediate practical benefit to the citizens, whereas surveillance robots would most probably be imposed on them by the government or companies (e.g., shopping malls, airports, etc.) evoking an uneasiness that comes from being observed and judged.

In many of the scenarios that the participants crafted, the robots also "returned the favor" in some ways or provided services that can be seen as forms of care towards humans. For example, participants envisioned situations where a delivery robot carried a first aid kit and contacted police in case of an emergency, or offered to throw trash in the dumpster after making a delivery. Similarly, other participants thought of surveillance robots could help tourists to find a place to stay or help homeless people to charge their phones or provide heat. In these perspectives, the robot becomes a social actor.

Self-defense. The participants also envisioned situations in which robots may be exposed to vandalism and violence, generating a reason for the robot to defend itself, e.g. by contacting security or carrying weapons such as built-in taser shocks. Participants were mostly problematizing the situation in these types of interaction scenarios, rather than taking a positive or negative position. In doing so, they compared the robots with the security officers, who are allowed to carry weapons for self-defense. This comparison raised a discussion that questioned to what extent it is appropriate for the police to have weapons during public demonstrations for example, and if we could expect the same right to apply to robots. But in this case, the participants reflected on whose legal and moral responsibility it will be, if a robot's self-defense action turns out to be harmful for the humans or break the law.

3.3 Practical Advantages vs Socio-Ethical Challenges

The discussions during the workshop stressed the robots' practical potential for improving the human performance in terms of efficiency, reliability, and economy, and therefore, improving the quality of life in urban environments. Nevertheless, both in the ideation and the clustering phase, we noticed how participants were counterbalancing the reflections on practical advantages with discussions on socio-ethical challenges.

The potential practical benefits of the robotic services—such as the opportunity for having more personalized delivery services or reducing risk of violence, crime rate and police budget—were constantly counterbalanced by several concerns. For instance, a recurring concern was that the possibility of having more efficient services might come again at the expense of privacy. A particular discussion was focused on if the delivery robots should know the content of the packages they carry. Some participants considered this to be acceptable in some scenarios, such as when a robot transporting alcohol is received by a minor at the door. Should the robot deliver the contents to him? Or, should it be able to detect the persons' age and decide accordingly? Similarly, the surveillance scenario raised several ethical concerns, especially in relation to the possibility of the robot's misjudgment and false accusations. Some of the participants created scenarios in which the robot pointed at innocent people due to its wrong data analysis algorithms, people misusing the robot (e.g. a person wrongfully accuses a neighbor because of an ongoing dispute), or after being hacked.

In addition to these issues, the participants also pointed out several advantages for companies, such as being exempted from following employee rights and overcoming issues typically related human employees, such as substitution in case of absence or paid leaves like pension, maternity, or holiday. But at the same time, they stressed how these are directly related to prominent issues of partial or complete replacement of tasks currently performed by a human being and consequent job loss.

Furthermore, the physical presence of a robot was also considered to create challenges for the city and impact the physical urban environment. The complexity and unpredictability of public spaces such as streets and sidewalks can cause malfunctions and collisions, the robots can crowd the sidewalks, or the presence of robots can force the city to alter its layout of buildings and roads for more efficient performance.

4. Discussion and Conclusion

The results of the workshop indicated how the format met our dual interest in facilitating the envisioning of possible near futures enabled by emerging autonomous systems, while fostering reflections on potential ethical dilemmas. Both in the ideation and clustering phases, we noticed how the participants' discussions moved from very practical solutions to critical questioning of the possible consequences and controversial situations resulting from having robots providing services in the city. In a very short time frame, the workshop enabled the participants to elicit themes that we can acknowledge as relevant and topical for the current discussion in the fields of urban robotics and technology ethics.

For instance, the participants extensively explored the themes related to human-robot relationships, such as (1) human vandalism towards robots, acknowledged in academia as a crucial issue [19] which can create a barrier to the robots' diffusion in cities [20], (2) the open debate on how far the robots should be allowed to protect themselves from theft or vandalism [21], (3) the robots' ability to perform social rituals as enablers of long-term relationships [22], and (4) possible relationships of mutual care resulting from the social roles played by robots [23].

Similarly, the participants' reflections on the potential implications of robots also recall topics largely addressed in public and scientific debate, such as the potential flexibility and customizability of robotic services as breakthrough solutions for particular contexts (e.g. access to services from very remote locations [24]); or possible negative drawbacks for people (e.g. being subject to monitoring without consent [25], injuries [26], or job loss [27]) which lead to discussions about design protocols to prevent them [21-28].

This effectiveness versus legitimacy dilemma also frequently emerged during the workshop in relation to data and privacy. This is another prominent discussion in the techno-regulation for robotics literature particularly about who is deciding what data is collected, with whom it is shared, the purposes for which the data is processed, and the necessary security measures that need to be in place [21-28-29].

Although most of this discussion covers topics that would be recognized by researchers in the field of urban robotics, what is particularly noteworthy is that these discussions were not raised by the workshop organizers, but by the participants who were experts in neither robotics nor ethics (although they obviously shared an interest in the topic of the workshop). Thus, the workshop resulted to be a particularly valid tool for enabling a meaningful conversation among non-experts on complex topics. We will continue conducting the same workshop among populations with diverse backgrounds such as social scientists, ethicists, municipal employees and robotics engineers in order to capture an even larger sample of issues that might help identify new directions in the future of urban robotics research.

Furthermore, in our opinion, the workshop can add two additional contributions to the existing debate about near future urban robotics. On the one hand, different from other kind of investigations that often remain on a speculative level, this activity enabled participants to ground their reflections on very practical examples and to situate ethical concerns into daily life practices, rather than extreme situations. On the other hand, through the discussion of controversial situations emerged from the envisioning activity, participants moved from discussions of practical implications to reflections on values and societal implications that go beyond the specific case of robots. As in the case of self-defense which led participants to talk about the appropriateness for police to defend themselves when engaged in public demonstrations, the problem of privacy related to the purchase of particular products such as drugs, and the controversial case of delivering alcohol to a minor and the question of whether it should be a responsibility of the personnel who is performing the delivery to discern if it is appropriate to deliver a product or not.

These two aspects, i.e. reflections grounded in concrete examples and discussions on the socio-ethical implications, summarize the dual nature of designing for near futures with autonomous systems. In fact, also in the three main themes emerging from the reflection on the results, we noticed how considerations of practical opportunities and limitations should constantly be counterbalanced by reflections on the possible socio-ethical impact that the envisioned robotic services might have.

This dual nature, we consider, should be reflected in the designer's approach, through a co-presence of a pragmatic and an idealist mindset. Designers are more and more asked to simultaneously understand and deal with new technological capabilities, reframe the conceptualizations of artefacts and technology, and envision the potential impact of their actions on a both specific and societal level. By embracing these dimensions, designers can engage in a constant dialogue with technical disciplines in order to develop a deep understanding of the potentials and limitations of technology, and with humanities, especially with philosophers and social scientists, in order to abstract from situated interactions towards socio-ethical reflections and questions of values.

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Robot Citizenship: A Design Perspective

Abstract

This paper suggests robot citizenship as a design perspective for attending to the sociality of human-robot interactions (HRI) in the near future. First, we review current positions regarding robot citizenship, which we summarize as: human analogy, nonhuman analogy and socio-relationality. Based on this review, we then suggest an understanding of citizenship that stresses the socio-relational implications of the concept, and in particular its potential for rethinking the way we approach the design of robots in practice. We suggest that designing for robot citizenship (in the terms suggested by this paper) has the potential of fostering a shift from a logic of functionality to one of relationality. To illuminate the direction of this shift in design practice, we include and discuss three robot concepts designed to address and rethink present HRI challenges in the urban environment from a relational perspective.

Keywords

Citizenship; Design Practice; Urban Robotics; Human-Robot Interaction; More-Than-Human City

1. Introduction

Current technological advancements in the fields of Artificial Intelligence (AI) and robotics have stirred a lively debate about the nature of human-nonhuman relationships and how these may be regulated. In this debate, designers often find themselves caught in between sensationalist attributions of citizenship to humanoid robots such as *Sophia* [1], and more pragmatic initiatives that contemplate the attribution of legal personhood to robots, such as the European Parliament Resolution of *Civil Law Rules of Robotics* [2]. Attempts to regulate human-robot relationships through the typically human construct of citizenship as a congruent set of rights and responsibilities can also be observed in other, more mundane cases. The widespread and unregulated presence of delivery robots in San Francisco, for example, has raised a series of social concerns to which the city has responded with a strict regulation that limits the number of delivery robots moving freely around the city [3]. In contrast, the state of Arizona has responded to similar concerns by giving the delivery robots the same rights as pedestrians [4] as a way to make them comply with the same rules.

Although robots have yet to populate the urban environment *en masse*, unresolved challenges concerning their social desirability and responsibility [5-8] call for a deep reflection on what attributing citizenship to robots may lead to. This, in turn, compels us to rethink future urban environments as more-than-human entanglements of human and nonhuman entities and needs [9].

While a socio-relational perspective of human and nonhuman coexistence has gained attention in the field of human-computer interaction (HCI), mainly in research concerned with animals and plants [10-13], it has yet to make an impact when it comes to the design of human-robot interactions. This paper responds to this gap with a speculative investigation into the idea of robot citizenship. The paper first reviews the current debate on the topic of robot citizenship as it is underlined by three different rhetorical strategies: using human analogies, using nonhuman analogies, and pointing to socio-relationality. The paper then explores the implications of robot citizenship as an instantiation of the socio-relational perspective, and in particular its potential for rethinking the way we approach the design of robots in the urban context. In doing so, the paper attempts to move away from addressing citizenship normatively as a codified set of rights and responsibilities by proposing an alternative, complementary design perspective [14] meant to challenge and inspire practitioners to shift from a logic of functionality to one of relationality.

2. Robot Citizenship

Investigations of the social implications of robots through legal categories such as rights, personhood, and citizenship, have become increasingly frequent within academe [15-21]. In the following sections, we draw upon, and extend, existing work on the topic to describe three main rhetorical strategies through which the concept of robot citizenship can be approached: human analogy, nonhuman analogy, and socio-relationality.

2.1 Human Analogy

The first perspective is grounded in the idea that in the future, robots, especially when powered by AI, will become so sophisticated that they will be practically indistinguishable from humans in terms of cognitive abilities, sentience, and self-awareness. In such Blade Runner-like scenarios robots may be eligible for rights and even citizenship. An extensive argument from this perspective is provided by Marx and Tiefensee [18]. Although they remain skeptical about robots becoming fully sentient, they envision functionally equivalent states that would enable robots to perceive and preserve their "wellbeing", making them worthy of protection as "moral patients", as Gunkel [21] puts it. Similarly, due to their growing complexity and sophistication, robots may also be able to detect moral demands from other agents and, accordingly, behave responsibly. Because of such ability to hold both rights and responsibilities, Mark and Tiefensee [18] argue that robots may also become citizens.

Argumentation grounded in possible future abilities of robots, however, is often contested [21-23] because it relies on overvaluations of the actual capabilities of even the most advanced robots. In this sense, such argumentation reads more like science fiction than plausible foresight [23].

2.2 Nonhuman Analogy

An alternative perspective on citizenship that better accounts for current robots' abilities is based on attributing citizenship to "useful" nonhumans. Kymlicka and Donaldson [24], for instance, discuss animal citizenship by focusing on the concept of domestication as a qualifying relationship. Domesticated animals, they note, can be seen as citizens because of their ability to regulate their behavior according to norms of civility (thus respecting the rights of other members), and because of their ability to perform their duties (thus providing a meaningful service for the community). Although criticized when it comes to animals [18], this argumentation can be applied to robots who fulfil the same criteria. There are precedents: rights were recently granted to nonhumans by virtue of their membership, contribution and relationship with the human community. The Whanganui river in New Zealand, for instance, was granted the same legal rights as humans after a local Māori tribe fought for its recognition as an ancestor and a contributing member to the welfare and wellbeing of the tribe [25]. As Forlano [25] explains, "by granting the river legal rights, crimes against the river can now be treated as crimes against the tribe". Similar initiatives include the attribution of rights to the Ganges and Yamuna rivers in India [26] and Lake Erie in the United States [27].

However, attributing human legal rights to nonhumans may lead to open conflicts between the interests of the two, as in is the case of Lake Erie. The attribution of rights to the lake, in fact, generated a protest from local farmers who claimed that their rights (endangered by the impossibility of fertilizing their crops because of the protection of the lake) should be anteposed to the ones of the lake [27]. Despite the merit of accounting for the expanded nature of communities and of stressing the importance of contribution to a shared good, then, this perspective remains controversial.

2.3 Socio-Relationality

While both previous perspectives provide convincing, even if controversial answers to whether and how we could consider robots as citizens, we argue that addressing robots through a logic of rights and responsibilities only provides partial answers. As Coeckelbergh [22] argues in his discussion on robots and morality, by focusing on a robot's individual features, the rights approach does not account for how relations among entities and the social context itself contribute to changes in moral considerations. Instead, we could approach moral considerations from a socio-relational perspective [21-22] in which morality should not be seen as inherent to any single entity but rather as an extrinsic quality. What this means is that a robot should not be addressed as a moral agent or "patient" [28] per se, but as an object of moral consideration by virtue of its relations within a social context.

Accordingly, the socio-relational perspective goes beyond individual abilities, and accounts for the relations between the individual and the whole. In other words, attributing citizenship to robots should not be based on the question of whether robots are "like us", or "help us", but are "part of us" – a point also made by Marx and Tiefensee [18] in their account for citizenship based on robot sophistication, and by Kymlicka and Donaldson [24] in their discussion of citizenship for domesticated animals. Going beyond rights and responsibilities, a citizen, to be qualified as such, should be engaged with other entities in interdependent relations aimed at a collective welfare.

By firmly shifting the emphasis from a logic of rights and responsibilities to one of relations, then, this perspective reveals the need for a richer vocabulary (that would, for instance, help differentiate hard from soft rights [22]), or a completely new one that would enable us to account for the different forms of moral considerations that arise from new human-robot shared performances.

3. A Design Perspective on Robot Citizenship

The preceding discussion hints at how the concept of robot citizenship may help the HRI field to extend its interest from technical concerns to social ones, shifting its focus from pragmatic and technical challenges to topics like relationality and ethics. Given that current debates on robot citizenship tend to focus on normative questions and seek resolution in policy and regulation, a process that tends to react to technological developments instead of anticipating them, we suggest there is value in considering robots as citizens as a matter of philosophical and designerly speculation. In other words, we are not interested in offering legalistic solutions for the more-than-human city or a critical speculation on the near future, but in opening up a provocative *design space*.

By introducing the notion of robot citizenship in this way (in terms of relationality and not legality), we invite designers to look at emerging human-robot interactions not as a matter of individual robotic capabilities but as a matter of the relations among robotic and non-robotic entities. Discussing robot citizenship, therefore, invites designers to approach the design of HRI from considerations of the community, its values and shared goals, instead of from the individual robot's functional capabilities. Through this conceptual shift, considering robot citizenship may not only contribute to the ongoing discussion about meaningful future partnerships between humans and computational artefacts [29-33], but also contribute to a more holistic view of HRI. The question remains, *how can this conceptual shift be translated into actionable design strategies?*

As described above, approaching design from the perspective of robot citizenship asks us to rethink the performance of robots interdependently, and thus investigate the appropriateness of the relationships between robots and other entities instead of robots on their own. As summarized in Figure 1, the design space that opens up in response to thinking about robots as citizens requires that we understand how a robot

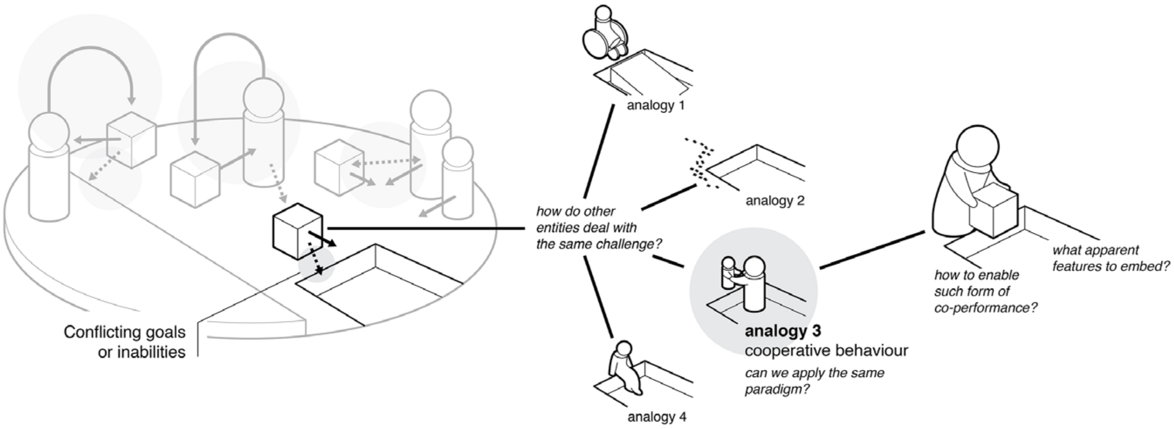

Fig. 1. Overview of the main principles involved when approaching robot design from the socio-relational perspective suggested by the concept of citizenship.

may enter into relation with both other entities and the environment. From this initial framing, then, it is possible to identify opportunities for meaningful and appropriate partnerships by reflecting on the possible roles that both human and nonhuman entities may be asked to perform together, on the basis of what Kuijer and Giaccardi [33] refer to as capabilities that are "uniquely human" and "uniquely artificial".

To this suggestion we add a specific perspective: instead of looking only at what individual entities are 'good at', we suggest considering what they are not good at. As Marenko and van Allen [31] argue, most current approaches to interaction design tend to be task-oriented and efficiency-driven, and therefore tend to produce specific narratives about devices as consistently behaving entities towards which people often build inappropriate expectations. By recognizing limits and coming to terms with unpredictability, and by suggesting narratives of "dumb-smart" [34] entities, designers can free themselves from the idea of designing for perfection and redirect their actions towards "ecologies of things that are mutually responsive and interdependent" [31].

Once they identify such inabilities, designers can explore how the same performance is successfully instantiated by other entities, as a way to envision possible design alternatives. Among these, we suggest focusing on strategies that communicate interdependency and may foster values that can be considered appropriate for human-robot interactions. This perspective helps us not only to pivot towards relationality and interdependence, but also to shift our focus to the extrinsic (rather than intrinsic) qualities of a robot that can enable appropriate forms of interaction. To do so, we need to understand what Coeckelbergh [22] calls "apparent features", according to which the features of a robot are not appropriate or morally significant on their own, but only by virtue of their interplay with other entities (much in the same way that "affordances" differ from technical features). Consequently, by addressing this socially constructed idea of appropriateness, designers are invited to *craft robot features that account for how these features would be experienced and judged by humans.*

In what follows, we illustrate the design space that opens up by considering socio-relationality as a key framing for HRI. We start with a brief discussion of urban robot challenges, and then present three robot concepts that illustrate how addressing robot citizenship can translate into tangible design strategies.

4. Urban Robots in Question

By approaching the design of robots from the perspective of robot citizenship, we developed three concepts for urban robots. These address real world challenges faced by designers of urban HRI, that were identified through interviews with five robotics researchers with expertise in autonomous navigation for unmanned ground vehicles (UGV) (a type of robot used in urban applications, e.g., delivery of goods). We started the interviews with a short introduction about the project and its objectives, stressing our interest in identifying what are the most pressing challenges in urban robotics. We then investigated further the emerging challenges through a focused review of related HRI literature. Then, for each of these challenges, we suggested an alternative approach to the problem by identifying potential cooperative strategies and envisioning apparent features that may facilitate them. We exemplify the concepts with illustrations that show a robot in a specific situation, communicating an implicit message, and provoking a desired response from humans.

4.1 Robot Challenges and Relational Alternatives

Our interviews with the roboticists helped us identify a small series of current urban robot challenges (see figure 2). These challenges include problems related to (1) the robot's need for *adapting to non-dedicated infrastructures* and related social norms, e.g. navigating sidewalks and adapting to pedestrians' speed and norms; (2) inefficiencies resulting from the need for *keeping safe distances*, as a way to appropriately navigate crowded areas and deal with the unpredictable behaviors of other entities; (3) issues emerging from the robot's difficulty of *being understood*, which may lead people to misjudgment and adverse feelings; and (4) inability of *being respected*, which makes the robot a potential victim of human malicious actions, e.g. hacking and bullying.

By reflecting on some of these issues and envisioning possible alternative approaches, we developed three concepts: the *Transparent Robot*, which responds to the issue of being (mis)understood; the *Handleable Robot*, which responds to the difficulty of dealing with non-dedicated infrastructures; and the *Shapeshifting Robot*, which addresses the challenge of keeping safe distances from others.

The Transparent Robot. This concept (Fig. 3A) illustrates situations in which a malfunctioning robot may be perceived as something mysterious and potentially dangerous, thus generating adverse feelings and attitudes in human bystanders. In fact, "if a robot is just standing somewhere looking as a generic box, without doing anything, people may think it's a bomb" stressed one of the interviewees. Common HRI strategies address this issue by preventing and detecting malfunctions with regular interval checks (e.g. [35]). However, this challenge may be reframed by considering the social environment the robot is part of, and relying on the human perception of the situation. Recalling existing practices (e.g., calling for assistance if an elevator breaks; calling the owner of a lost dog to bring it home, etc.), we suggest malfunctioning robots may be addressed not as a matter of manufacturer responsibility, but rather as a case of a community member in need of care.

From this perspective, designers may shift their focus from increasing efficiency to evoking empathy. One feature that may help facilitate this shift is the robot's

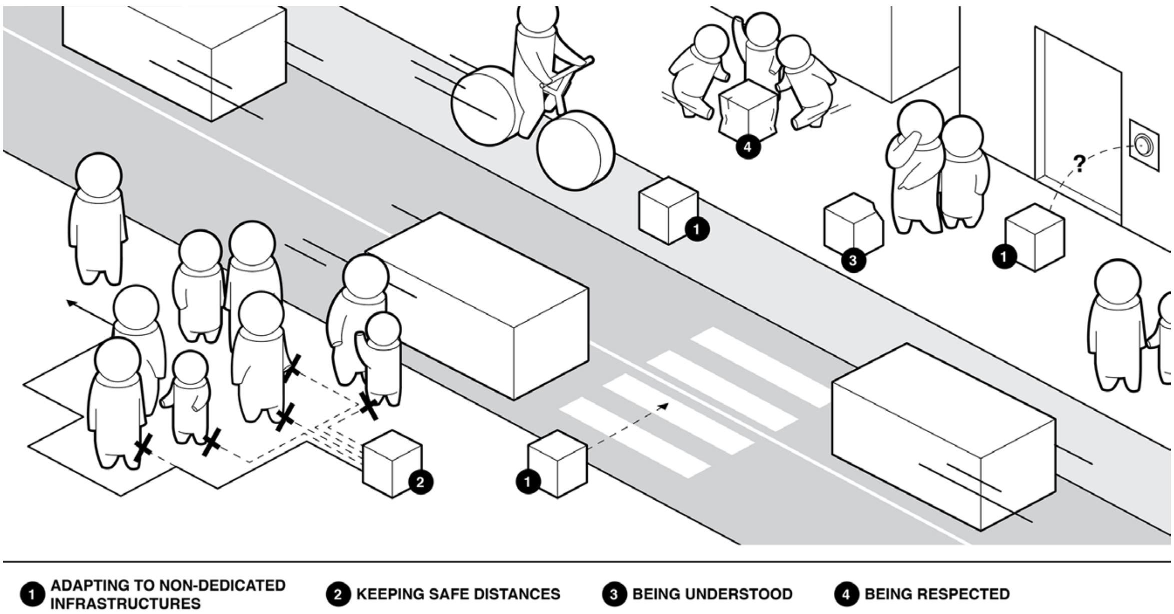

Fig. 2. Overview of urban robot challenges identified through the interviews with roboticists.

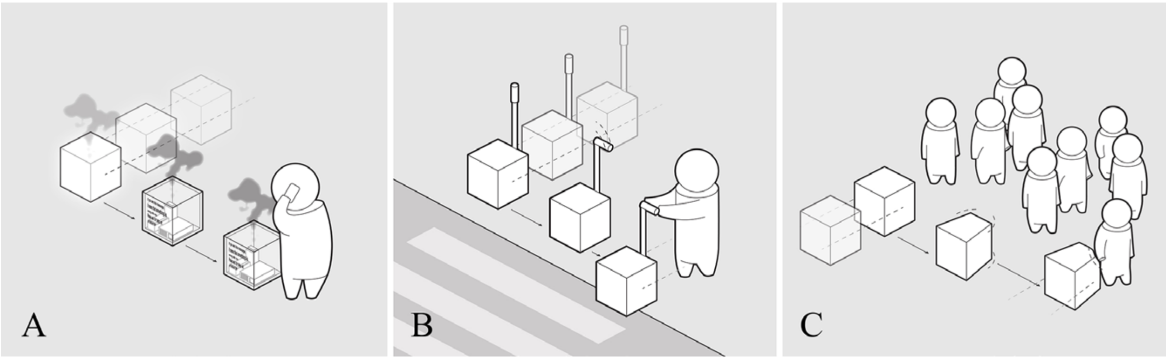

Fig. 3. Rethinking design challenges through relational strategies yielded three concepts (from left to right): the Transparent Robot (A), the Handleable Robot (B), and the Shapeshifting Robot (C).

appearance: changing its appearance from opaque to transparent (with or without additional symbolic elements), the robot can communicate its situation: *"Look what happened to me! I need your help!"* In this way, the challenge of human (mis)interpretation of the situation may become an opportunity to generate empathy and care.

The Handleable Robot. This concept (Fig. 3B) relates to the challenges faced by a robot when attempting to fit its behavior to non-dedicated urban infrastructure. In such cases, the robot's autonomy is strongly dependent on its ability to combine various skills like detection, prediction and planning. Take, for instance, the case of a robot trying to cross a street or a busy intersection on its own – a particularly complex challenge [36]. Within current HRI strategies, this challenge is addressed by improving the robot's autonomy and self-sufficiency – creating better environmental modeling and detection, and designing more sophisticated predictive algorithms. However, if we look at social encounters in similar situations, we notice that the same problem is often dealt with interdependencies generated by affinity and shared membership in the community. Recalling these existing social phenomena, then, we may consider the possibility of a robot's lack of autonomy as an opportunity to instantiate interdependent relationships. Much like children, elderly, or the disabled, robots may cross a street safely by joining a shared performance and relying on the abilities (and kindness!) of others.

When arriving at a crosswalk or needing to cross a busy street, the robot may communicate its need for help by producing a gesture that mimics the way humans reach for help by extending their hand to others. This might be achieved by rethinking the shape and purpose of the flagpoles that sometimes protrude from the robot's back. The pole, in this mode, can be used not only to signal the presence of the robot, but also to function as a steering device that indicates that the robot is flexible enough to be helped. Shifting the position of the pole, the robot implicitly says to humans: *"You can help me by handling me".*

The Shapeshifting Robot. This concept (Fig. 3C) responds to the challenge of navigating a crowded environment, where the robot's difficulty to predict the behavior of a large number of moving agents (especially people) represents a very complex problem. Currently, designers try to solve the problem by developing algorithms based on a "preventive approach" in which the environment and other entities are detected, their behaviors are predicted, and the movements are planned for avoiding collision. Nonetheless, the complexity of the challenge and the insufficiency of current modelling efforts often lead to errors in navigation, harm to humans, or robots stopping in their tracks in order to prevent harm. As stated by one of our interviewees, "most of navigation algorithms are designed to be passive […] there is too much focus on prevention". This highlights how current design strategies do not relate to the social nature of the challenge they address. When we look at crowd behavior, however, we notice that it is often regulated by a series of tacit norms that go far beyond the desire to avoid bumping into others. From body gestures that enable a mutual understanding of intentions, to gentle physical contact, humans, as well as animals, adapt to each other. What we suggest, then, is to look at the robot as a constitutive part of the crowd and, as such, an entity that can enable such mutual understanding and gentle physical contact.

Providing a robot with a flexible soft shell, for instance, may mimic how humans acknowledge and interact in a crowd, sleekly squeezing and slipping through the crowd respectfully instead of parting it aggressively. Through these nonverbal behaviors, the robot communicates to its human surrounding: *"You can touch me as I go by, I'm safe and friendly".*

5. Discussion and Conclusions

The examples discussed above hint at practical implications of approaching robots not as tools but rather as members of a co-performing community. Subsequently, designers may be able to solve some of the challenges inherent to complex urban environments by designing robots that would be perceived, recognized, and tolerated as valuable members of the community. In this mode, the three concepts we describe above *replace self-sufficiency with interdependency; autonomy with mutuality; and a tool perspective with a civic sensibility.*

By considering the community instead of the individual robot's functional capabilities (or lack of), designers can gain a more holistic view of HRI, understanding a robot according to its embeddedness in the urban environment, its social relations and practices. In this perspective, what usually represents a limit and challenge for a robot, may become an opportunity for instantiating meaningful shared performances with humans, in which the abilities of one may become a strategy to deal with the limits of another [33]. Furthermore, by reframing HRI challenges as sociotechnical and not merely technical, the concept of citizenship helps to unfold a design space that is much less reliant on the legal system's catching up to the everyday presence of robots. Thus, while effort is being put to regulate robots from a legal perspective, designers may already move forward by thinking of urban robots as social actors and therefore anticipating regulatory and behavioral responses. The design of HRI, it follows, can become anticipatory instead of reactive.

With that said, despite its potential, this new design space is not free from complications. First, our proposal assumes that citizen robots, or, more accurately, robots that behave as citizens, will elicit certain responses from humans. But, what if nobody wants to take the extended hand of the Handleable robot and help it cross the street? What if nobody cares if the Transparent robot needs help? What if the softness of the Shapeshifting robot is only perceived aesthetically? What if people, despite those apparent features, still perceive robots as an obstruction, a burden, or even as competition?

This last question introduces a second complication. We suggested here that robots may be considered members contributing to the community's common good, but who gets to decide what that means in practice, and how? Should HRI designers be responsible for deciding what robot uses and roles are desirable? Should they hold public referendums on each and every proposal for an urban robot? And even then, what if conflicting proposals emerge from within the community?

These critical questions highlight how despite its practical implications, our approach does not provide solutions, but only opens up a larger space for discussion. This very ability to raise questions and foster further reflections, however, is what we believe represents the very meaningful nature of citizenship as a concept that can be used in the design and investigation of urban robots. In fact, "in certain circumstances asking questions is as important as solving a problem" [37]. Design can play a crucial role in this. What we suggest, then, is to look at *citizenship as a design perspective* that can be used to challenge existing norms and attitudes, provoke discussion and question established practices [38] – a way to question the drive for technical efficiency that characterizes current robot design. Through the concept of citizenship, designers are invited to question beliefs about the role of robots in society, and to rethink their approach to urban robotics from the logic of autonomy and efficiency towards relationality and interdependency.

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Towards Transparency Between the Autonomous Vehicle and the Pedestrian

Abstract

This paper addresses the new problem of transparency in relation to pedestrians' interaction with driverless vehicles, arising from their lack of visual cues to replace those currently provided by the visible behaviours of the driver. It reports two observational investigations of the *affordances* of the street, one looking at the street as static environment, the other at pedestrian behaviours in relation to driven vehicles. The findings of the research were used to identify the decision-making process, timings and exhibited behaviours of pedestrians and drivers in the street environment.

Keywords

Transparency, Interaction Design, Behaviour, Street Environment

1. Introduction

The field of autonomous vehicles (AV) has recently received considerable attention with the rapid development in the industry both by traditional automakers such as Jaguar Land Rover, Nissan and Volkswagen, and leading innovators from other fields such as Google, Lyft and Uber. In spite of the increasing capabilities of autonomous vehicles, such as environmental sensing, object detection and compliance with rules, their ability to react to unexpected situations is still questionable [1]. On a more general level, Zimmerman[2] explains the competent use of a given rule. He mentions that the usage of rules is dependent to the state of normality as the unpredictable occurrence of situations threats the production of desired outcomes. From this point of view, the deployment of autonomous vehicles in the urban environment is still a concern on safety grounds. There is evidence that some types of pedestrians have low levels of confidence in interacting with driverless cars [3].

Companies in the automobile industry were said to have invested in safety-related technology around $80bn dollars by the end of 2018 [4]. Much of the research is concerned with low-level interactions, disregarding the complexity of the urban environment. Autonomous navigation in a busy urban street environment is currently a challenge for driverless car innovators due to the unpredictability of the bidirectional interaction between humans – particularly pedestrians – and autonomous vehicles. The research reported here contributes toward this longer-term goal through research into pedestrians and driver behaviours in the existing street context. This is a prerequisite for understanding how to design more transparent autonomous vehicles whose behaviour is more easily predicted.

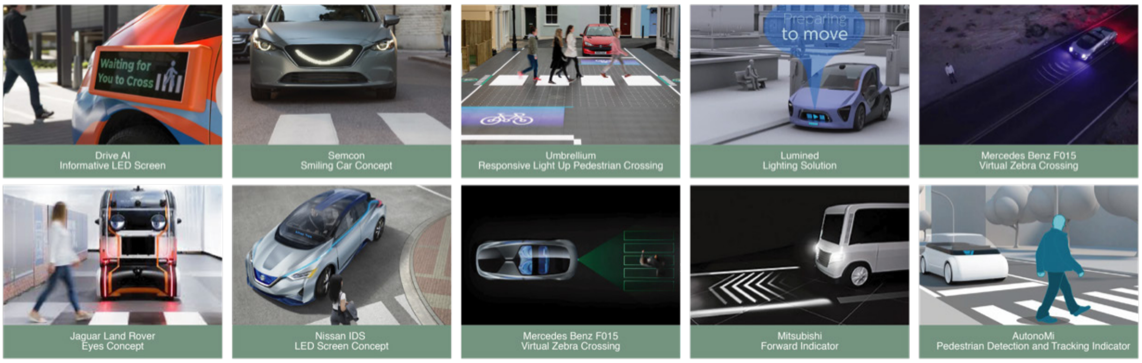

Fig. 1. Designs for autonomous vehicles or streets to improve the pedestrian crossing situation. The products in the pictures are designed, respectively, by: Drive AI, Semcom, Umbrellium, Lumiled, Mercedes Benz, Jaguar Land Rover, Nissan, Mercedes Benz, Mitsubishi, AutonoMi.

2. Key Concept: Transparency

We first introduce *transparency* in our context, then overview relevant interaction design centred on autonomous vehicles. Research in intelligent systems and human interaction shows a clear demand for transparency [5]. Much of the debate is around making machine intelligence accountable [6][7][8] with emphasis on their being transparent *after the fact*, though the need for *intention* to be perceptible is also acknowledged as important, which may include designing intelligent machines so that their general appearance allows their genre of action to be predicted [9]. Our interest is in transparency immediately prior to and during the interaction. Kirsch [10] describes the interaction between two parties as transparent when the user, in our case the pedestrian, with a certain amount of information may understand clearly what actions an object affords. Each party gains understanding through sharing information clearly and intentionally with the other [11]. An important consideration is the optimum amount of information-sharing to reach a satisfactory level of communication [12]. Overloading individuals with information is not desirable in many contexts, but especially when rapid and effective decision-making may make the difference between life and death or serious injury.

2.1 Designs to Increase Transparency of Autonomous Vehicles

When a pedestrian observes a traditional driven vehicle, much of that vehicle's imminent action is predictable because the pedestrian sees not only the vehicle but also the driver. The pedestrian reads the posture, gaze, gestures and expressions of the driver. The vehicle-driver system taken as a whole is productively transparent. If the vehicle is wholly autonomous, however, these key indicators are missing. The vehicle has become *opaque* and its imminent actions are no longer predictable. In the image above, we can see several recent attempts to overcome this problem. In the projects of Drive AI, Lumiled and Nissan, messages inform pedestrians textually of the vehicle's intention, while the smiling-car concept expresses itself through a human-like gesture of smiling to communicate with pedestrians. Another anthropomorphic imitation by Jaguar Land Rover applies moving eyes to the vehicle. The Autonomi concept detects and tracks pedestrians and re-communicates this data through its LED lights. Mitsubishi, Mercedes Benz and Umbrellium concepts instead focus on signals from street signage design.

2.2 Conceptualizing the Problem

Theoretical insights relevant to the problem include those of phenomenology and ethnomethodology. Merleau-Ponty's analogy of the player's navigation and exploitation of the football field [13:168] is particularly relevant to the dynamic, emergent, often antagonistic negotiation by pedestrians, drivers, and others, of the streetscape. It echoes Gibson's [14] concept of affordances and his emphasis on embodied cognition within dynamic contexts. Garfinkel's ethnomethodology is useful for its emphasis on the emergent production of acceptable and effective behaviours, for example

Fig. 2. Panoramic Photo of Exhibition Road

Fig. 3. Panoramic Photo of Piccadilly Circus

his characterisation of understandings "progressively realized and realizable through the further course of the conversation" [15:41] and the emergence of a "common scheme of interpretation and expression"[15:40].
As developed by Zimmerman [2], these ideas of the dynamic, co-production of behaviours include ad-hoc rule-breaking and rule re-interpretation in the service of pragmatic goals. Liberman [16] argued that pedestrians and vehicles concert their movements to form a local orderliness that better solved the problem than enforcing traffic rules.

3. Methods: Reading the Street, and Observing Pedestrian-Driver Interaction

In our first study, we mapped the affordances of two environments in London: Exhibition Road (Fig. 2) and Piccadilly Circus (Fig. 3). These streets were selected because they both attract mainly tourists even though the designs of the streets are different: in particular, the first is a “shared space” [17] with deliberately ill-defined zones for pedestrians and vehicles, while the second has traditional limits.

We looked at the streets in two ways: first our own analysis of the affordances of the environment, then observation of how pedestrians seemed to “read” these affordances. In the second study, we explored how pedestrians understand the intention of drivers and what kind of non-driving tasks are performed by drivers to communicate their intent. The aim was to identify the components of natural interactions between pedestrians and drivers in the chosen street environment, in order to specify the inputs which, in particular, leads pedestrians to make decisions about crossing or not crossing the street.

3.1 First Method: Reading Affordances in the Environment

Gibson used the term *affordance* [18] to capture how the physical state of an object or environment permits and encourages particular sets of interactions. A key feature of his thinking was the shift away from a nominative approach to perception - one based on naming and classifying - to a verbal one, based on action and the potential for action. Gibson’s emphasis was on affordances that already exist, whereas Norman’s later work shifted the emphasis to the deliberate design of visual affordances [19]. By identifying existing affordances it is possible to understand how, through design, we may be able to invite behaviours and to a certain extent predict possible interactions around a certain object. Knappett [20] describes the key elements of affordances as sociality, relationality and transparency.

To explore our two environments and users’ perceptions of them, we created concept maps divided into two parts: direct perception and indirect perception. The first refers is our own observation of the properties of the environment [18]. The second captures aspects of the process of others’ meaning-making in the space, by evaluating it within live social situations [20]. The framework of the map was inspired by Ferrarello at al.’s map where physical artefacts are connected by wires to labels for affordances derived from objective and subjective assessments [21]. This framework captured the differences and similarities in these two environments, showing how people use the street and interact with it. Our findings are discussed below at 4.1.

3.2 Second Method: Using Behavior Coding to Capture Interactions

We conducted live observations of street users in context for brief periods of time on multiple occasions, and coded their behaviours, using standard coding techniques [22], focusing on analyzing interaction [23]. During the observations, we periodically summarized the physical and non-verbal behaviours of the individuals in the specific categories defined in figure 4. Each code is used to mark the occurrence of a specific behaviour or set of behaviours. The result is a sequential record of the behaviours of one or more individuals.

Fig. 4. Behaviour Coding Data Sheet

Weather:	How long they looked each other (sec.)?
Day & Time:	Who made the first move? 1.Driver 2.Pedestrian 3.Cyclist 4.Other (mention on the notes)
Place:	What non driving tasks driver did during the interection period?
Age 1.(0-12) 2.(13-16) 3.(16-24) 4.(25-34) 5.(35-54) 6.(55-69) 7.(70+)	Crossing Diagonally
Gender (M / F)	Crossing at the midblock
Type of User (if definable) 1.Tourist 2.Resident 3.Office Worker 4.Student 5.Taxi Driver 6.Uber Driver 7.Working in Delivery 8.Uniformed Worker	Crossing when there is no oncoming traffic
(number) of People	Crossing when s/he sees other people cross
Group Description: 1.School Trip 2.Friends 3.Family 4.Couple 5.Colleagues	Crossing when his or her company encourages him or her
Commuting Types: 1.Driving 2.Cycling 3.Pedestrian 4.Motorcyclist	Encouraging his or her company to cross
Who does s/he interact with? 1.Pedestrian 2.Driver 3.Cyclist Age-Gender of them	Crossing mid block because shop or touristic attraction is on the other side
What kind of behaviour has been observed? 1.Active Behaviour 2.Passive Behaviour 3.Aggressive Behaviour	Crossing between vehicles when they stopped on the traffic
Where the interaction happened? 1.Road 2.Sidewalk 3.Square 4.Crosswalk 5.Bus Stop 6.Traffic Light	Crossing without paying attention to the traffic
Speed Change 1.Slowed Down 2.Faster 3.Same	Crossing while talking on the phone or listening music
Did they see each other? 1.P yes D no 2. D yes P no 3.Both of them Yes 4. None of them	Crossing even there are obstacles which reduces visibility (parked vehicles, trees, buildings)
	Crossing even though there are oncoming cars
	Driver signals through gaze (1), hand gesture (2) honking (3) light (4)
	Notes

The approach provides information about the frequencies of specific behaviours engaged in interactions by a certain individual. It is reasonably objective, though open to nuances of interpretation: our resources only allowed a single researcher to undertake the coding. It allows us to examine relations between behaviours, either within individuals or among pairs (pedestrian-pedestrian or pedestrian-driver). The observations help us answer questions related to social interactional processes in the street environment during the negotiations.

3.3 Group of Participants

The behaviour coding was applied to a total of 102 pedestrians (43 female, 59 male). There were 2 between age 12-16, 16 between age 16-24, 36 between age 25-34, 38 between age 35-54, 8 between age 55-70, 2 over age 70 (all ages estimated). The observations were undertaken between May and July 2018, on typical weekend days and weekdays. We coded the interactions of pedestrians during direct observation in the street according to the table in Figure 4 and took photos as needed. The data in our mappings are based on observations in the field over three days at different periods of the day at Piccadilly Circus and Exhibition Road. The most significant selection criterion was if they were involved in an interaction with another road user such as a pedestrian or driver. All the selected individuals were trying to cross the road without the aid of any form of signal or control point.

4. Findings

4.1 Findings from Affordances Mapping

Location 1, Exhibition Road, showed that people have an unusual experience of the space. As commonly with *shared space*, users have difficulty "reading" the design decisions represented by the environment. For example, not having a curb or difference of pavement height clearly leads some pedestrians to think the road is for pedestrian only, while drivers fail to identify the subtle indicators of lines and if they are going in the right lane or not. Such ambiguity has been posited as a weakness, and also as a strength of shared space on the grounds that it may cause all involved to exercise greater attention through their attempts to understand the situation [24].

When we look into Piccadilly Circus, there are some very different physical properties compared to Exhibition Road. The design of the junction more closely resembles the rest of London in terms of heights and materials. The organisation of the junction is carefully planned because it is a very crowded and busy environment. The majority of the users' age group is constituted by teenagers and young tourists,

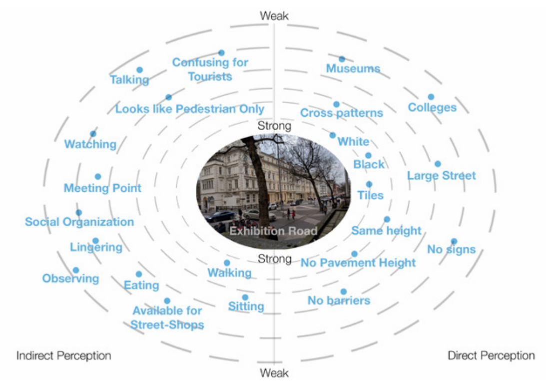

Fig. 5. Affordances Map for Exhibition Road

Fig. 6. Affordances Map for Piccadilly Circus

whilst Exhibition Road mainly attracts older tourists or children. The Piccadilly Circus junction is very busy because of the traffic flow at almost any time of the day, but especially at peak hours, there is a significant accumulation of car users, public transport users, cyclists and pedestrians. Illuminated high screens and neon lights for advertising create a visual distraction, potentially taking attention from the busy street environment. In addition, the number of signals to aid pedestrians is relatively low considering the complexity of the environment.

4.2 Findings from Behavior Coding:

Overall, pedestrians' actions noted were either observing other pedestrians or making eye-contact with a driver. Pedestrians' behaviours were goal-oriented, adaptive and far from automatic responses, however sometimes during the interactions with the drivers, their behaviours were built on elements which are automatized. Figure 6 summarises the key behaviour coding results for both locations for a total of 102 pedestrians (51 Exhibition Road, 51 Piccadilly Circus).

The Willingness to Interact. 85% of individuals were observed looking for signals of the drivers' intention to stop or not. They were trying to ensure that their commitment to action – to cross the road – is appropriate. Clearly, most of the people observed wanted to have feedback or respond before they acted. Throughout the interaction process, 92% of the people were able to make use of sound information; the other 7% were either listening to music or talking on their phone. 1 person out of 102 clearly had poor vision; he managed to cross the road using sound and the help of his companion.

Trust in Collective Behaviour. 42% of pedestrians who were observed planned their crossing of the road by looking at the behaviour of other pedestrians. They seem to put their trust in other pedestrians rather than relying on their own individual judgements of drivers or of the street system. This behaviour occurred mainly in Piccadilly Circus, with 34 individuals. This socially constructed engagement with traffic is a relatively neglected aspect in the literature.

Fig. 7. Results of Behaviour Coding

	Collective Behaviour	*Speed Change*	*Time Course of Interaction*
Exhibition Road	***43 out of 51*** *crossing behaviour occurred* ***individually.*** *Majority of pedestrians crossed where there are no close vehicles to themselves.*	***40 out of 51 pedestrians*** *used* ***speed*** *either as a data coming from a vehicle or as a communication tool with a driver.*	***16 out of 51 pedestrians*** *interacted with another individual for* ***maximum 5 sec.*** *and decided to cross or not to cross the road.* ***21 out of 51 pedestrians*** *interacted with another individual through eye contact for* ***5 to 10 sec*** *to make a decision.* ***14 out of 51 pedestrians*** *interacted with another individual through eye contact for* ***more than 10 sec.***
Piccadilly Circus	***34 out of 51*** *crossing behaviour occurred* ***collectively.*** *Majority of pedestrians crossed through the moving traffic.*	***33 out of 51 pedestrians*** *used* ***speed*** *either as a data coming from a vehicle or as a communication tool with a driver.*	***28 out of 51 pedestrians*** *interacted with another individual for* ***maximum 5 sec.*** *and decided to cross or not to cross the road.* ***13 out of 51 pedestrians*** *interacted with another individual for* ***5 to 10 sec.*** *and decided to cross or not to cross the road.* ***10 out of 51 pedestrians*** *interacted with another individual through eye contact for* ***more than 10 sec.***

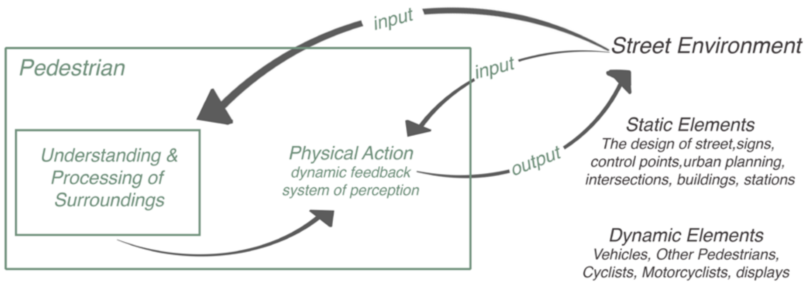

Fig. 8. Perceptual Map of Pedestrians

Negotiation through Speed Change. A majority of pedestrians used the speed of the vehicle as inputs to judge when to cross; they also negotiated with drivers through adjusting their own speed. The increase or decrease in vehicle or pedestrian speeds had a decisive effect on the negotiations between them. It was used as a means to show an intention to the other party. For 72% of individuals, this behaviour had an enacting effect on the opposite individual. For example, the driver reduces speed to allow a pedestrian to safely cross the road or the pedestrian takes a step back while trying to cross to allow the driver to pass instead. An important detail of this interaction is timing and making sure that the opposite party can read one's intention.

Time Course of Interaction. Some individuals carried out a series of actions related to the consequences of prior actions. For example, 20% of the individuals who were evidently in a hurry performed more active behaviours during the interaction period while only 18 of them performed an aggressive behaviour through sounding the horn at the pedestrian several times and making certain hand gestures. On the other hand, the results they received were fast

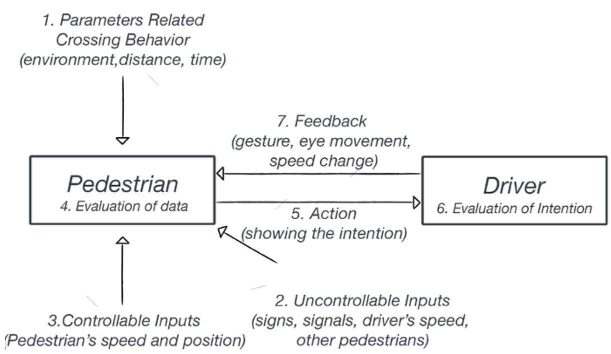

Fig. 9. The Interaction Process of Crossing Behavior

reactions. These interactions were grouped as less than 5-second interaction in Figure 6. Groups comprising families or couples showed more passive behaviour. They prioritised safety and tried to cross when there were as few vehicles as possible. Their waiting time and attention to the vehicles were noticeably higher than the rest. Drivers were more cautious towards these groups of pedestrians. The duration of interaction takes more than 10 seconds compare with individual pedestrians.

5. Discussion: Decoding The Information Flow Between the Driver and Pedestrian

The data gathered through the behaviour coding consisted of the reactions of pedestrians and drivers in two different places and their negotiation in the existing system of a street. The relationship between driver and pedestrian behaviours was observed. A conflict of interest is clearly indicated where each wishes to make progress at the expense of the other. In Figure 7 we have summarised the elements of a pedestrian's perception which affect interactions between pedestrian and driver.

The diagram captures the range of affordances that pedestrians use to interact in the street and the elements that affect their experience. Even without language or digital technology, the affordances of the environment inform pedestrians what actions are doable and preferable. This information can reframe the interaction design between autonomous vehicle and pedestrian.

In figure 8, we created a framework to informs the process of the pedestrian's interaction with the driver, and how it can be affected by the environment. This helps us to gain understanding about the pedestrian's expectation in the interaction.

We have identified how interactions occur in the traditional street environment (Figure 9) and how these might occur with autonomous vehicles (Figure 10). The diagrams show how conceiving the design task as one of constructing affordances, informing possibilities for action rather than only explicitly directing the pedestrian. This can inspire a new way to design transparent interaction between autonomous vehicle and pedestrian.

6. Limitations and Further Research

This study was part of a larger research project focused on designing a transparent framework for interaction between autonomous vehicles and pedestrians. The framework was evaluated by participants of an exhibition using a virtual reality simulation. A future step would be to test variations of the framework through experimental tasks with a range of timings and speeds.

The study described in this paper focused on just two streets. Though different from each other as explained, they do not represent the full range of street types. It would be also helpful to use technology more extensively such as recording the selected streets for periods of time and analysing the timings, speeds and movements precisely. For instance, ethnomethodological video analysis can be considered as one of the methods as well. However, even though there are gaps that can be filled through more observation, we did acquire sufficient information to develop a new approach to designing transparency for future interactions between autonomous vehicles and pedestrians.

7. Conclusion

This study is preliminary research towards designing transparency for interactions in an urban street environment. It contributes to identifying a step-by-step approach to the decision-making process for designed transparency in interaction. In particular, it highlights the importance of feedback, the iterative perceive-act cycle, and the need for driver-vehicle system to act as a source of actionable affordances for safe action.

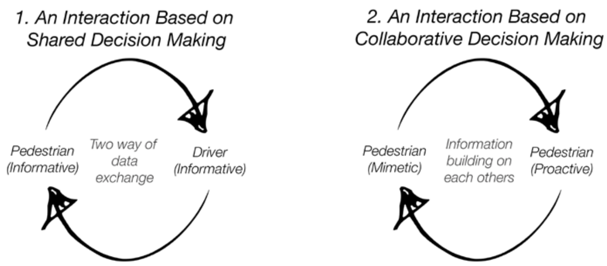

Fig. 10. Types of Interactions Occurred During The Behavior Coding

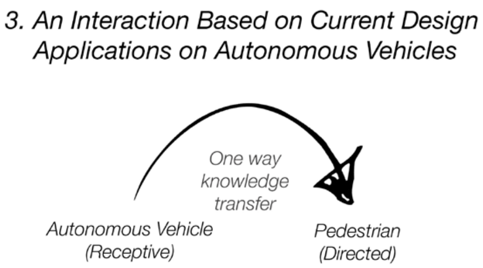

Fig. 11. The Type of Interaction Available in Current Autonomous Vehicles

As a first step, we defined what streets enable right now and what are their interactive elements. Then we looked into the interactions between actors in the same environment. These helped us to understand what is the level of transparency in the interactions happening in the street environment, what people are looking for when they need to communicate with other individuals or interact with other objects.

This qualitative research builds a case for designing interactions with autonomous vehicles by considering the street environment itself and the existing knowledge of pedestrians while taking decisions. The key findings are that the influences on pedestrians' decision-making process are: collective behaviours, subtle timings of sequenced interactions, and the use of speed as a means of communicating intention.

This research points at the opportunity of utilizing the interpersonal trust between pedestrians to help create a transparent interaction with autonomous vehicles. This can be done by triggering this kind of collective behaviour through the physical environment or the inputs of an autonomous vehicle, as well as creating a perception of collectivity in the action of an autonomous vehicle. Also, speed change and interaction time frame can be used as an input for designing interaction with autonomous vehicles. This research is presented as an invitation for future work to extend the models given.

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The Coerced User and the Era of Smart City Dissonance

Abstract

This paper discusses the societal impact of increased connectivity and innovation on the smart city's inhabitants and its effect on the definition of usability. We start by discussing the smart city's connectivity revolution and the way it affects the perception of usability. In so doing, we eliminate the concept of Non-Users and employ instead *Coerced Users*, who do not wish to use the innovation, but are coerced into participating—providing it with physical space and data—and therefore enjoying the services returned in the form of city optimization. We then discuss the need for new design approaches addressing these users that may be translated into innovation *acceptance*. We present a human-centered design study on the Coerced Users of shareable electric scooter services in Tel Aviv. It demonstrates the importance of Coerced User design and its impact on the inhabitants' wellbeing. We found that the Coerced User's rejection of innovation is due mostly to low-value technology implementation in the complex smart city structure, creating a feeling of injustice in public goods distribution and an ambiguous feeling of *"Smart City Dissonance"* that affects the inhabitants' relationship with the public sphere.

Keywords

Smart City, Coerced User, Innovation Acceptance Life Cycle, Micro Mobility, User Experience

1. Introduction

We, as consumers of the public space, are exposed to a large amount of technology. This is due to the "smart city revolution" which uses connectivity technologies and data-optimization software to make our city safer and more efficient [1], thereby increasing our wellbeing [2-4]. As the smart city is based on data and connectivity [2-5], it requires a societal change in order to provide the public with its promised value. The city's inhabitants (residents, workers and visitors) must be digitally connected—a change that impacts their way of life. In return, they enjoy the city's optimization and benefits. With the exponential pace of technological advancement [6], this informed transaction will likely become a core assumption of participating in a city's ecosystem—a new rule that connects personal connectivity with being a part of the city.

We are interested in the impact of such innovation entering the public sphere on the relationship between technological advancement, public space, and inhabitants' behavior and wellbeing. The main problem we examine occurs when technology is adopted [7] without the public's consent—in many cases imposed on inhabitants as a kind of new, unwritten set of smart city rules. The public Wi-Fi pole, CCTV cameras, drones, and shareable electric scooters are redesigning the public space; all of these solutions are designed according to the needs of their *Active Users*—users who employ these solutions. But being placed in the public space, they have an impact on all the city inhabitants—users and non-users alike. As consumers of public space, inhabitants cannot avoid these technologies; and, like passive smokers, they cannot avoid their impact. Gradually, the public loses its option to opt out and "not use."

The connected inhabitants of the smart city are not just losing their ability to stop using, but actually provide the city's ecosystem with data and physical public space exploited for the very services impeding their desired consumption of the city space. These inhabitants are coerced into participating in the process, becoming what we will call *Coerced Users* of this innovation; they are not willful adopters of the technology but are compelled to accept its existence as part of the city ecosystem and are forced to provide it with resources even while suffering from its existence. This could lead either to acceptance or to protective behavior [13-14], as we describe at the *Innovation Acceptance Life Cycle*. They are still considered "users," however, because some of the data collected by negatively impacting services might in turn be used—by such services as these same Coerced Users employ as *Active, Passive* [8-12], or *Incidental* [12] users—and therefore indirect value is created that may have a positive impact on their wellbeing overall.

This conundrum generates many challenges, but it also elicits a better, more inclusive design for the future city. Empathizing with Coerced Users' needs and designing products accordingly will become an important part of design for the connected world, generating inclusive innovation and technology that will reduce, rather than increase, inhabitant anxiety and stress, and will elevate Coerced Users' wellbeing.

In elaborating on the Coerced User, we will review the current literature's definitions of users, expounding upon the adoption, acceptance and rejection of innovation and technology. We will then proceed to a contextual design investigation, using shareable electric scooter services as a case study. This human-centered work includes field observations; an electronic poll (68 participants); eight in-depth interviews with experts in innovation adoption, public space design and Users Experiences; and twelve in-depth interviews with Coerced Users. The paper concludes with insights and directions for follow-up research.

1.1 The Smart City and the Always-Connected Inhabitants

The "smart city" is a city ecosystem that uses Information and Communication Technologies (ICT), Internet of Things (IoT) sensors, and optimization software to make itself cleaner, safer, and more efficient and connected [1-5], thereby providing value-added features for city services and generating elevated wellbeing for its inhabitants; i.e., its residents, workers and visitors. Today, in order to enjoy and benefit from many innovative services, inhabitants must be digitally connected; and, knowingly or not, share ever more information about themselves with the city's services, revealing their locations, habits, and needs.

As we move toward a realization of the smart city vision, it becomes ever more difficult to enjoy the city's benefits without being connected; and, eventually, the unconnected may find it impossible to live in the smart city at all. This increased connectivity and the obligation to share information—the new, unwritten rule of the smart city—raise concerns regarding privacy, data security, safety, and ethics. Prior work suggests that these problems can be addressed via holistic co-design approaches for city services, involving all city stakeholders [3]. Our research raises a different question, however: As a precursor to the design process, in this era of always-connected and self-optimizing cities, we must first understand the identity and characteristics of the "smart city users."

1.2 Usability Definitions

Current designations of users relate to the "activeness" dimension in user-technology interaction. Four kinds of users have been defined: (1) *Active*; (2) *Passive*; (3) *Incidental*; and (4) *Non-User* [8-12]. Users are divided into "active" and "passive" process operators [8]. An active process operator's work differs from that of a passive operator by the predominance of monitoring [9]. The user's "activeness" is a result of task allocation between herself and the technology [10]. *Active Users* have different kinds of interactions with the technology, from operation to maintenance, while *Passive Users* merely monitor the technology and lack control over it. The *Incidental User* has an interest in the information output of the technology but has no control over it [11-12]; her communication with the technology is mediated by an Active User. Finally, the *Non-User* simply does not use the technology—she either does not want to, does not know about it, or uses a competitor instead. For example, during an Ultrasound the doctor operating the machine is an Active User. The senior doctor monitoring the operator is a Passive User. The watching parents are Incidental Users. Parents who distrust the modern medical system and do not use these tests are Non-Users.

1.3 The Extinction of Non-Users

Today, when individuals choose to opt out and not use a technology, they can easily become Non-Users. This situation is changing, however, as city services become fully and perpetually connected, disenabling individual non-use. In the not-too-distant, fully-realized smart city, all inhabitants will be connected and share data with the system, enjoying the optimization of services enabled by the city's connectivity regarding traffic, bureaucracy, and more. They supply data to all services, even the ones they do not use; and enjoy the optimization derived from that data which is the source of the same un-used services. They can no longer not-use; they are part of the optimization ecosystem, and even if they do not want to use a technology, they are coerced into using it as part of the city system. This situation brings about the extinction of Non-Users who, consequently, become what we have termed *Coerced Users*.

1.4 The Coerced User and the Unwitting User

The Coerced User is a connected inhabitant of the smart city and—willingly or not—provides it with data while enjoying its optimizations. Even if she decides not to use some of the city's innovative services, she cannot avoid being part of its ecosystem. First, because these services are in the public sphere, and she cannot escape their indirect influence - much like a passive smoker. Second, because she cannot stop providing the city ecosystem with information that might benefit these unwanted services, and third, because she cannot choose not to benefit from the optimization generated by the data these services provide, which might be translated into optimization of the services she does consume.

For example, a Coerced User cannot simply opt out and not use shareable electric scooter services—to both her disadvantage and advantage. On one hand, the scooters still occupy her space, and she needs to dodge them in the street. On the other, she also benefits from the data they provide the city about the most populated routes—data that might influence the city's public transportation schedule or infrastructure maintenance timeline, and thus have a positive impact on her life. Unlike Coerced Users, who are aware of the technology they try to avoid, some users may not be aware, but still provide data and enjoy the general optimization results. These we have termed *Unwitting Users*—those who, for example, unknowingly utilize a public Wi-Fi signal, absorbing its radiation while providing it with information, such as their location.

1.5 Designing for Coerced and Unwitting Users

As the inhabitants become more connected and public space more occupied by antennas, security cameras, drones, scooters, and more, it becomes ever more crucial to understand Coerced Users and to design the city experience accordingly—using a human-centered perspective. Today, city technologies are designed according to a design methodology "correct" for Active Users, based on principles of *Desirability* (attracting users), *Feasibility* (being capable of production by the manufacturer), and *Viability* (being economically viable and generating value for both users and suppliers) [16]. But since these technologies are deployed in the public space, they need to address Coerced Users as well, answering their needs and considering their wellbeing.

1.6 Coerced Innovation Acceptance

In Coerced User design it is important to understand that—unlike for Active Users—service value does not translate into *Adoption*. For Coerced Users, rather, it translates into *Acceptance*. Presently, in order to create a successful product, designers need to account for the different kinds of Active User—Innovators, Early Adopters, Early Majority, Late Majority, and Laggards—identified in Rogers' *Innovation Adoption Life Cycle* [7]. Each of these Active Users must be addressed accordingly.

The same is true for Coerced Users; the designer must be empathetic to all the kinds of Coerced User when she designs. Coerced Users do not actively use a product: they either reject it, if they find it disturbing, or they accept it as possibly beneficial for others, while consciously choosing not to use it themselves. Here we may define the *Innovation Acceptance Life Cycle* that analyzes Coerced Users according to the following spectrum of acceptance: (1) *The Supporter*, who supports the innovation but does not use it; (2) *The Indifferent*, who accepts it without supporting it; (3) the *Soft Rejecter*, who rejects the innovation but not actively; and (4) the *Hard Rejecter*, who actively rejects the innovation. Each of these must be approached differently. The designer should aim for these Coerced Users to *accept* her product, and design the product accordingly. Bad design will cause a Coerced User to incline toward rejecting the innovation and thus the value it might entail for the city ecosystem. For better Coerced User design, it is therefore important to understand factors that lead to innovation rejection or acceptance.

1.7 Innovation Rejection and the Social Amplification of Risk

The social, psychological, cultural, and economic background of a person, as well as media coverage and gut feelings, have an impact on her perception of technology as a risk, or as something of value [17-21] and these lead to acceptance or rejection. Instead of occurrent probability and causal intensity, the individual analyzes risk according to her psychological and cultural filters, using only a fraction of the information she receives. To these filters she adds possible consequences of the risk and designs a mechanism to cope with it. This private and irrational action can then become a public approach leading to public actions [13]. The *Social Amplification of Risk* theory suggests that an individual's risk perception might have an amplified impact. In a ripple effect, she influences her community's perceptions of risk [14]. The "risk signals" are passed from "mouth to ear," adding to other personal perceptions that reframe the risk. This amplification can impact social, political and economic structures. In only a short time, innovation is framed as risky or otherwise; after this, the window of opportunity for acceptance closes. It is important to take this into account when designing for the Coerced User; for once the public shapes its perception, it is difficult to change it.

2 Contextual Field Research Methodology

2.1 Contextual Case Study: Shareable Electric Scooters in Tel Aviv

After establishing *Coerced User* and *Innovation Acceptance Life Cycle* theories, we will now turn to a contextual field study in order to validate our theories. This contextual field study was designed to understand Coerced Users in a transitional, semi-smart city environment, using a defined case study representing connected technology in the public space. We chose shareable electric scooters in Tel Aviv: last-mile transportation vehicles spread throughout the city, aiming to provide clean and cost-effective urban public transportation. This Micro Mobility solution is not a disruptive technology, but a unique business model of "use and discard:" the user finds a nearby scooter, unlocks it using an app, rides to her destination, relocks it, and pays according to the time used. The scooters do not require an anchoring station; they can be left anywhere. Thus, this service represents the main characteristics of connected technology in the public sphere: it is (1) an innovative intervention in a public domain, which (2) forces the user to be connected, since it cannot be used without a smartphone and credit card, and (3) is now in the interim period that will define its future. These scooters represent an interesting case study for Coerced Users, as there is a growing, worldwide debate about them. They are implemented without any change to the city's infrastructure and impact the way pedestrians need to act. As the Active Users of the scooters can leave them wherever they want, they sometimes create obstacles on the sidewalks. These issues generate rejections leading to protest and, in some cases, vandalism of the equipment. These tools entered Tel Aviv in 2018 and their numbers are growing monthly: from ~300 in late 2018 to ~2,000 in Feb 2019.

2.2 Contextual Field Study Structure

Our study consists of interviews, observations, and a digital poll. **In-depth interviews** were held with eight professionals from the fields of innovation adoption, public space design, and UX. We discussed design and innovation in the public space, and the phenomenon of Micro Mobility. **Observations** in Tel Aviv included participatory scooter usage and shadowing Active Users. We also conducted a Coerced

Users observation, learning how they handle / avoid scooters. **A digital poll** was conducted on the way 68 early adopters, aged 27-50, perceive Micro Mobility. This also formed the basis for selecting interviewees. **In-depth interviews** were held with twelve Coerced Users about their perception of smart city, public space innovation and scooters services.

3. Findings

The Coerced Users supported the vision of Micro Mobility. This is partly due to a general consideration of Israelis as early adopters, positive feedback from the media, and the scooter services' promises to be easy to use, affordable and "green." Nonetheless, these "supporters" of the vision reject its implementation, which is imposed on them, invades their public space, and negatively impacts their way of life. Our research is reflected in the six main themes which follow.

3.1 Theme 1: "One Fits All" Solution

To date, the municipality does not require the scooters' providers to modify their product with regard to speed, quantity, and location. Accordingly, the providers deploy scooters in a "one fits all" approach; some have not even translated the safety instructions into Hebrew. This situation creates an overload on the city's crowded infrastructure: 91% of the interviewees feel that the municipality and providers do not care about the inhabitants. The providers "invade" city space without talking to the inhabitants or modifying the product according to their needs. This creates the impression of an unsuitable and dangerous solution.

3.2 Theme 2: Exclusion of Significant Inhabitant Populations

83% perceive these services as inaccessible to some inhabitant populations based on age, weight, connectivity, and address (i.e., living where services are blocked). This lack of equality in public goods distribution inherently creates Coerced Users. Such populations cannot use the service but have to pay a *Public-Space Tax*—providing services via sacrificing pedestrian public space, getting nothing in return.

3.3 Theme 3: Lack of Enforcement

As these services are owned by private, profit-driven companies, 83% feel that providers desire only that as many people as possible use their services, no matter the risk. There is minimal safety enforcement by the providers with regard to inhabitants that misuse their platform, and they do not prevent underage inhabitants from using it. The safety restrictions presented by the providers are perceived as mere prevention of formal liability. 75% feel that the providers' method of operation is: "if it is not forbidden, it is allowed." Moreover, there is little municipal enforcement, leading Coerced Users to suspect a secret deal benefiting the municipality and providers at the expense of the inhabitants.

3.4 Theme 4: Feelings of Alienation

75% of Coerced Users say the scooters arouse feelings of alienation. This finding expresses feelings of anxiety and a lack of connection between human and space. In the words of our interviewees: (1) "It creates a feeling of alienation. What is it? Who owns it? It's just everywhere." (2) "People just leave it in the street, not caring what it does to the relationship between human and space." (3) "Wherever we go, when my daughter sees a scooter, she turns and says 'Dad, here is your scooter. And here, and there.' This inability to connect to a tool depresses me."

3.5 Theme 5: A Modern "Tragedy of the Commons"

81% feel that the sharing model encourages Active Users to behave in an irresponsible manner that harms Coerced Users' welfare; they ride on the pedestrian side and park in the middle of the sidewalk. The interviewees believe this behavior stems from the lack of connection between the Active User and the scooter, his desire to maximize the service, and the lack of enforcement. These lead to misuse of the service by Active Users to the point of harming both the scooters and the Coerced Users. The "tragedy of the commons" describes a self-interest behavior, contrary to the common good, that spoils a public resource. We may describe the above as a *modern* "tragedy of the commons."

3.6 Theme 6: Mental Workload

75% describe a feeling of stress when talking about Micro Mobility. The service which is meant to engender productivity and reduced anxiety for the Active User, creates a mental workload for Coerced Users. Pedestrians that once wandered the sidewalk with ease must now be on constant alert not to be hit by scooters. Drivers must also worry about scooters popping up, endangering them and getting them into trouble with the law.

4. Discussion

From the above research and described contextual study themes we have extracted three main insights regarding Coerced User design.

4.1 Insight 1

Coerced Users' problems are due to a lack of communication and synchronization among members of the triangle of city stakeholders—municipalities, service providers, and inhabitants—leading to poor implementation. (1) The disconnect between municipality and service providers, together with lack of regulation, creates a burden on the city infrastructure, which is already crowded without scooters. The service provider's data is not shared with the municipality and thus allows neither optimization of public transportation where scooters do not operate nor investment in infrastructure where usage is greatest. (2) The disconnect between municipality and inhabitants makes the Coerced User feel that the city is incompetent in dealing with the service providers, due to weakness or corruption. Coerced Users feel that they are excluded from the public space, and that the city—with minimal municipal enforcement—cannot help them. It creates a sense that "what is not forbidden is permitted" and that these "permitted" solutions come at the expense of the inhabitants, transforming the city from a place that is intended to increase the inhabitants' welfare, to one that is exclusionary, and dangerous. (3) The disconnect between service provider and inhabitants allows misuse by the Active Users and makes it difficult for Coerced Users to complain or understand where potential solutions might originate. Service providers do not have a screening process for users, so there is no connection with them when they start using; moreover, there is no enforcement of responsible usage, so there is also no relation with violators of the law.

4.2 Insight 2

Rejection of the innovation is driven primarily by a sense of injustice regarding public goods distribution; this is reflected in the exclusion of some inhabitants who cannot use these services, but nevertheless pay a *Public-Space and Head-Space Tax*. The exclusion of inhabitants from these services due to age, connectivity, or residency seems unfair and raises questions regarding the motives of the service provider and the municipality, as well as the ownership of public space. These inhabitants cannot use the service, but must give up their public space, wandering the streets alertly and anxiously while getting nothing in return.

4.3 Insight 3

The smart city era is accompanied by a *Smart City Dissonance*: an ambiguous feeling with regard to belonging, and a double-edged sword with regard to efficiency and stress reduction. These affect Coerced Users' "head-space." The first, *Belonging Dissonance*, is that feeling of uncertainty with regard to the belonging of public space and shared tools which—together with a "use and discard" business model—encourages irresponsible behavior, leading to a modern "tragedy of the commons." The second, *Efficiency Dissonance*, is the negative correlation between service effects which are (1) supposed to make Active Users more effective (and therefore reduce their tension), but (2) by their very existence increase the anxiety and stress of Coerced Users.

5. Conclusion and Future Work

Coerced Users and the impact of smart city connectivity on their lives were at the core of this paper. We found that increased connectivity and innovative intervention in the public sphere obligates us, as designers, to change the ways we view and define *Usability* and *Users* in the smart city, and the experiences that will position *Coerced Users* on the accepting side of the *Innovation Acceptance Life Cycle*—providing them with direct and indirect value and increasing their wellbeing.

Our results taught us that technology is not the barrier for acceptance, but rather its implementation in the complex, smart city structure that harms and reduces the Coerced Users' wellbeing. Most of the frictions experienced by Coerced Users stem from disconnections between the stakeholders of the "city triangle:" the municipality, service providers, and the inhabitants. The primary point of discomfort is the feeling of injustice in public goods distribution, realized in the exclusion of many populations from these services. They cannot use these services but nevertheless pay a *Public-Space* and *Head-Space Tax*—giving up their space and feeling anxious in the public sphere without getting anything in return. This paper also indicates that the smart city era comes with a *Smart City Dissonance*, an ambiguous situation that affects our feelings when going out into the open. First is *Belonging Dissonance*, leading to a modern "tragedy of the commons;" second is *Efficiency Dissonance*, whereby a service intended to reduce Active Users' stress has the opposite effect for Coerced Users.

These findings regarding new, smart city users, together with the insights of field research, emphasize the importance of a holistic and inclusive structure of design for the complex smart city ecosystem, and the need for a Coerced User design approach and ethic; these will increase direct value for Active Users, and the indirect value for the Coerced Users, resulting in increased wellbeing. This design challenge is an opportunity to fulfill the promises of a harmonious smart city ecosystem providing benefits, value, and wellbeing to all its inhabitants. It is hoped this paper may form the basis for future work in this field.

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Topic 4.

New Interfaces for Complex Ecosystems

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Drawing Interfaces: When Interaction Becomes Situated and Variable

Abstract

The widespread and pervasive presence of devices equipped with small-size, small-cost sensors and increasing computational capacity affected our interactions, making them growingly ubiquitous and dynamic; an interaction that shifted from being indirect to becoming more physical and direct, as using gestural or vocal commands to control smart systems. In this context, we developed interfaces that draw themselves accordingly to the user need. Drawing User Interfaces receive information from the physical world (users and environment) via sensors, and react modifying their aesthetics and function.

Keywords

User Experience, User Interface, Physical Interaction, Embedded Technology, Smart Objects

1. Interfaces, Embodiment and Materiality

We are in a historical moment of change, where our way of interacting with objects is culturally evolving, due to the unceasing advances of technology. The progressive technological pervasiveness made a growing number of devices more intelligent, interactive and capable of dialoguing among themselves, with the surrounding context and with us. The result is innovative and advanced interactions that produce models and patterns of use that reinterpret the relationship between humans and technology [1–3]. In a context where people and computers are no more considered as separate but as a whole [4], our interest concerns integrated ecosystems where the physical and digital worlds dialogue because of embedded sensors, microcontrollers, and actuators that make machines "sensitive" to external stimuli [5, 6]. Benefitting of a progressive increase in computational capacity (ubiquitous computing), such ecosystems can adapt automatically to circumstances and decrease users' *cognitive load* [7], namely the information they must process to perform a task. Overcoming Graphical User Interfaces (GUI), it expanded the range of possible interactions: from typing and visualizing (as PCs) to manipulation (as *Beosound Edge* that activates a touch-sensitive control interface when the user approaches), dialogue (as *Amazon Alexa* and *Google Home* that can be controlled starting a conversation through voice interaction), and gestures (as *Xbox Kinect* that responds to motion sensing inputs, making the user's body become the controller). This brought to a dual technological advance: the research on Natural User Interfaces (NUIs) [8, 9] and on Tangible User Interfaces (TUIs) [10]. In the former case, the logic revolves around the absence of a visible interface

[11], namely user interfaces that are invisible to its users, or become so through subsequent interactions. The latter case regards embedding the interface into the object using manipulation logics typical of the analogical dimension [5, 12]. Although we recognize that NUIs' immediate and non-mediated interactions are interesting and promising, TUIs pop up as even more fascinating since they imply analog-like manipulations on objects that hide a digital dimension and echo the concept of *memory of use* [13]. However, dealing with physical and computational elements that empower materials, making them reactive and able to inform [14], opens up inevitable reasoning on *materiality* [15], *embodiment* [16, 17] and *affordances* [1, 18]. TUIs make the object on which are mounted both a representation of information and a controller [10]. Achieving such a total unity between interface and interaction has implications as the graspability of the interactions and actions supported [19]. Moreover, as stated by Ishii himself when criticizing tangible bits in favour of his more contemporary concept of *radical atoms* [14], TUIs have limitations in representing change.

Then, recalling that objects are nowadays more than ever *shapers of behavior* [20], we cannot neglect that blending the physical and digital dimensions reconfigures the users' behaviour towards the product, impacting on the kind of learning such objects demand to be properly used [21]. The interfaces we propose advance from this very argument.

1.1 Interfaces that Draw Themselves

We consider that especially the material perspective brings interesting opportunities for the interaction design and HCI fields. Looking for potentially meaningful aesthetic interactions, our specific interest goes on the role that materials, environments and the user's physical body as a combination assume in interactions involving embodied technologies [16, 22]. From this notion, we developed what we define *Drawing User Interfaces* (DUIs henceforth), namely interfaces that draw themselves. Such interfaces receive information from the physical world (users, the environment, and potentially other objects) through sensors, and act accordingly, modifying their aesthetics and function. DUIs concern interactions with objects where the digital information is translated into a manifestation that allows direct manipulation. However, it differs from Ishii's radical atoms [14] where digital information assumes a physical form. Indeed, whereas the physical interaction is maintained, it goes through a visual interface that rises from the surface. DUIs appear on objects rather than being the object itself or part of it, as in the case of TUIs [10]. As GUIs, they display the information on screens, but not the traditional ones. The interface is integrated into the same material that composes the devices, and the feedback is given by the very *skin* of the object that changes depending on the information they receive or to explain the result of an operation. The interface is embedded in the material, and what changes is either its chemical or physical properties. Designing interfaces that draw themselves implies to alter and modify users' perception of objects. In so doing, these interfaces advance a reasoning that grounds on *hacking* objects' meanings [23].

2. Process and Methods

The research is conducted by Thingk, a spin-off of the Politecnico di Milano that experiments with interactive technologies, designing products that disguise themselves. It digs into apparently simple and minimal artifacts (form) that are technologically enriched (function), following the slogan: "objects of daily use with superpowers" (thingk.design). Thingk takes advantage of the principles of digital transformation [24] while pursuing technological hybridization, blending analogue properties and digital immateriality. This approach results into objects with invisible technology and essential aesthetics, that are augmented with unexpected properties. By redesigning their appearance and functions, hence affordances and interactions, the meaning of the artefacts gets affected. Our study capitalizes on how different skins activate different functions, changing how they are interpreted and approached by user [25, 26].

Experimenting on how to use and innovate with DUIs, we apply an iterative design process (fig. 1) where multiple approaches and methodologies are combined to answer different needs [21]. The overall process consists of two main macro-phases. The first follows a design-driven innovation concept [27] that is applied to the research and design phases, when prosumers are involved in co-design sessions with early prototypes

Fig. 1. Thingk's iterative design process, highlighting the steps and perspectives involved

to provide insights. The latter revolves around user testing and data analysis and regards development and production.

The *Research phase* focused on deepening our knowledge about contexts where several elements are intertwined, interacting among them and with the surrounding environment. We analysed lifestyle and technological trends (state of the art) to point out potentialities and constraints of the context of reference, especially breakthroughs in the contiguous areas of interaction design, electronics, and material research. Acknowledging the existence of interfaces that emerge from the surface as Mui's *Calm Design*, and our own *Slab!*, we are also aware of their limits, as their being static and localized. This suggested the concept of a multilayered interface in which layers are activated according to the function required. We tapped into extending from multiple functions to multiple language and meanings that coexist under the skin of the same object.

We are currently running the *Design* phase, with prototypes of use expected by the end of this year. Informed by the research conducted, we decided to completely hide the interface until the object detects motion, an interaction, or a connection with other objects. At this point, the interface appears. This phase involves lead users to verify their response towards the product/interfaces designed, gathering data from survey and qualitative enquiry (from rapid ethnography and participant observation to interviews), but also focus groups and workshops where sketches, renders and use cases are leveraged to stimulate discussion and validate our design choices. The *Development* and *Production* phases are expected to respectively start in one and two years. From an engineering and design perspective, the challenge is developing objects that reconfigure their own function according to the surface that they show, in a logic of quick adaptability to the context of use. We are currently conducting studies on possible technologies (electrochromic displays) and application (from smart product to smart buildings), as part of *DecoChrom*, a Horizon 2020 Project that will end in 2021. During the project we will verify DUIs flexibility through three different applications on everyday objects. Working prototypes will be tested with the *DecoChrom* partners and a with community of prosumers, conducting user analysis to identify possible improvements.

3. Results

In conceptualizing the meaning of *design*, Krippendorff [25] described it as the attribution of meaning to things. Artifacts should, in fact, communicate their function through their aesthetic, which should introduce users to their correct functioning [28]. As theorized by Tidwell [29] the interface has an operational function that triggers the dialogue with the user. Therefore, redesigning the meaning of objects is a practice of a certain importance, which becomes paramount if we consider that Thingk reframes the form-function relationship of products, pursuing an innovation inspired by design, while recognizing users' needs [26], and the current growing technological opportunities [27]. When objects change their meaning, their language becomes anything but obvious [30]. Examples are those interactive artefacts that rely on integrated technological component (IoT) to become extended systems that dialogue with applications and other objects. Starting from such assumptions, we conceptualized a model of variable and situated interfaces that reacts not just to the interactions triggered by users, but also to the surrounding environment (context of use). Recognising the limitations and constraints of both TUIs [14] and NUIs [8], and being aware of the *invisibility dilemma* [31] that comes along, we conceived a typology of dynamic interface that expresses itself and communicates to the user what its form hides (affordance). In an attempt to integrate smart functionality into everyday objects without falling into the aforementioned dilemma of choosing between minimizing disturbance from the main task and adding value including explicit interaction, there is a tendency to hide object's intelligence.

However, the consequence of keeping/making invisible to the user such an increase of functionality results into a dichotomy between aesthetics and functions. Making functionalities recognisable allows users to identify such augmented artifacts as smart and hence use them appropriately. In parallel, the *control dilemma* [32] exposes a crucial point when dealing with smart object automation. The attention lies in designing objects that act and react autonomously to certain inputs, hiding the ongoing complexity to the user without lessening his/her perception of applying control. On this regard, significant is the study on the use of the remote control *Nest Learning Thermostat*, where the users' interviewed stated they were not able to fully understand the object learning process of their habits, hence they were not able to utterly rely on how the smart home automation device was self-setting certain functionality. The control dilemma requires to pay attention to the user, who wants to know what is going on; this insight is on the ground of DUIs concept.

3.1 Ecosystemic (Situated) User Experiences

Focusing on functionality, we often face the problem of how much information an interface should return in order to perform each task. The advantage lies on using a different set of variable commands that allows to isolate and "situate", or contextualize, a device's main functions according to its actual use case. Employing DUIs allows indeed to define situated user experiences that are variable in time and space since they are closely related to the context in which they are immersed. Moreover, these interfaces can be modified and updated over time, potentially changing the product functionality: the object doesn't change, it updates its functions. In this perspective, an object or device can change the interface depending on, for example, its own positioning, and inclination, or according to the location of the user.

So far, we identified three possible use cases:

- Movement: Response to being relocated within an environment
- Reaction: Response to environmental changes (presence of people, physical variations, and other modification in or of the context)
- Dialogue: Functional variation based on the relationship with other connected objects present in the surrounding space

Below we present existing case studies as pretexts to explain possible use cases of DUIs. Describing their functioning we explain how DUIs could be applied to perform similar functions, making the interaction more direct, complete and immediate. In the first use case, *Movement*, the interface responds to the change of position and orientation, revealing itself and displaying different functions. Microsoft' *Surface Dial* is a controller that interacts with different programs and digital elements, serving specific functions according to how it is activated and manipulated. However, the function of the interface is delegated to an external screen, where the information is displayed, while the product itself does not provide any visual feedback on its surface. In this case study, the potential use of DUIs lies in overlapping object and interface, so that functions are communicated directly on the product. In the second use case, *Reaction*, the interface reacts to proximity or interaction with external elements, which can be as much the user as the environment with its variables. Lapka's *Environment* consists of a series of four environmental sensors embedded into as much small

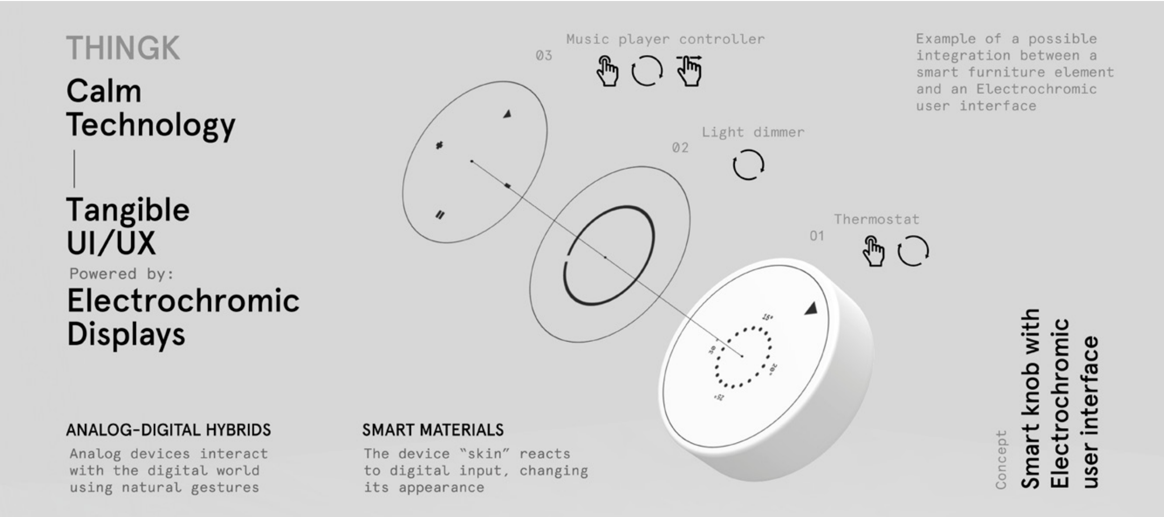

Fig. 2. Drawing User Interfaces: concept of a possible integration of functions

devices, translating complex data into user-friendly visualizations displayed on the smartphone. Once again, the function of showing data is entrusted to an external element: the smartphone display. Mounting DUIs could allow to provide immediate feedback on the product itself. In the last use case, *Dialogue*, the interface relates to the surrounding smart objects. Ikea's *Trådfri* remote control connects to different lamps working by proximity, managing on and off, dim, and color temperature. The remote control recognizes and regulate bulbs within a range of 10m, but does not provide information or feedback. In this case, applying DUIs would allow to show the object to which the remote control is connected, clarifying the functions available. In addition, in the hypothesis of multiple smart objects in the surrounding environment that could be managed by a single controller, DUIs could change the controller interface depending on the object ruled and the function that can be performed. Changing its *communicative skin*, the object performs tailored functions depending on the interpretation of the surrounding variables. The research phase brought to think to functional layers that overlap, populating a single object with multiple capabilities. The main result of our study is designing the transition among various commands and as many functions that coexist in the same object. The output of our investigation is a surface capable of smoothly changing and reacting during the user experience.

To provide a sharp idea of how they work, fig. 2 presents a use case of DUIs applied on a smart object acting as a controller. The object can be exemplified as a cylinder embedding smart sensors that can perform the regulation of values as temperature, volume, and so on, and that is provided with a silent interface. Such object contains multiple layers, each with its own function that gets activated according to the previously described use cases. The object becomes a repository of information that is going be communicated once used. For example, one layer could show how to regulate the temperature through rotation and selection; another one could display a linear scale to operate on the intensity of light, using rotation to dimmer; then, the third layer could allow to play/manage music or movies through interactions as selection, rotation and swipe. This design scenario is an example of possible use cases, as employing DUIs to increase the variables at play, introducing an *auto-nomatic dimension* [33] that enhances the qualities of the elements involved. Attributing a performing ability to the interface, its visual elements gain the ability to instantly act and react to manipulation [34]. These feature and dynamicity require to design considering the relation between the object and the environment both in the form of positional/static identities and as variable elements that are fluid and responsive in their composition.

4. Discussion. A Discourse on Possibilities and Constraints

The use cases described can be developed harnessing various technology. The ongoing tendency to dematerialise objects' physical interfaces frequently led to delegate the operational functions of an object to digital screens. Indeed, most of the contemporary smart products uses embedded displays or transfer data to other devices with screens (mobile and tablet). Such displays, acting as communication gateway, are in charge of returning information. That said, the current technological state of the art witnesses the appearance of smart materials able to reconfigure their shape, becoming potential drivers of information. However, we are still far from the concrete possibility of a material so ductile to display a continuous and updated flow of digital data, through a modification of its intrinsic physical properties. At this state of technology, DUIs are affected by this restriction, and they present a further limitation: since they allow an object to embed multiple functionalities, they do not make any function manifest by default. The absence of the interface, when none of the layers is active, as well as the presence of a variable interface concealed until the moment of use, affects the way in which the object communicates and is interpreted by the user.

In addition, their being entirely based on visual elements makes them unsuitable for being used by people with visual disabilities. By contrast, the information behind these visual components could be translated or implemented by combining them with additional sensory stimuli. For example, dealing with TUIs, Ishii recommends the use of more "malleable" forms of feedback, such as audio and video, that complement, support and complete interfaces. Our reasoning on DUIs possible implementations goes in a direction similar to what Ishii [10] identified as *Double Interaction Loop*, namely a cycle that starts with a first and immediate level of interaction and haptic feedback provided in consequence of touching, grasping and manipulating a physical object, followed by intangible feedback (as audio) and possible physical modification of the object, reflecting a change of the digital data.
A possible field of application of DUIs is between analog (aesthetics and materials) and digital (functions and transitions). Several technologies can be used to build such interfaces. Particularly, we investigate those materials that change the state of their chemical (electrochromic) or physical (e-ink) properties. Both technologies can be integrated into surfaces made of natural materials—as wood, marble, metal—without contaminating their appearance and tactile properties. On the one hand, aiming at the e-ink, as in the case of the *Yotaphone*, ensures excellent graphic resolution but has a color range limited to black and white.
On the other hand, electrochromic screens have the advantage of being the result of a monochrome screen printing technique on transparent surfaces, allowing them to be positioned above the material of the object itself. However, since electrochromic is the technology subject of the research of the European project *DecoChrom*, it is currently the basis on which we are conducting the experimentation. An advantage of choosing this not-new technology is that the electrochromic absorbs energy only when transitioning from a state of transparency to that of opacity; once a state is reached, there is no consumption related to its maintenance.

Designing interfaces we follow a model of experimentation closely connected to the field of IoT where the relationship between objects, technology and context is at the heart of the project. We privilege a design-driven innovation method that takes into account the needs of the user. Hence, the innovation is oriented to the relationship between function and aesthetics, and it relates to the context of use. One of the results achieved is to preserve the aesthetics of products that historically did not mount interfaces, inserting an interactive layer capable of manifesting itself and disappearing when needed. The implications of integrating physical elements with computational processes expand the design possibilities in terms of choosing materials that *become* reactive, dynamic and able to shape, transform and inform [13]. We consider this reasoning significant to various disciplines, from design to HCI, as it explores how interfaces can exploit smart technologies to modify themselves while mixing digital and physical.

As said, DUIs are currently in the prototyping phase, as user research will take place in 2020. The main issue that will be the subject of our upcoming enquire concerns how users will react in front of interfaces that design themselves when necessary, namely changing according to their being placed in space, the dialogue with other smart objects of the digital ecosystem, or the interaction with the user. In doing so, it is central to understand the role of aesthetics in dynamic digital-physical ecosystems. Addressing the design of interfaces for distributed, hyperconnected, and complex smart ecosystem requires to tap into the implications of having multiple meanings coexisting into the same object; meanings that are not persistently displayed, but emerge from the surface when needed. In consequence, it is crucial to enquire the way in which the users will interpret and interact with objects that contain interfaces that are simultaneously:

- Hidden, since they are not always displayed
- Variable, since they reconfigure themselves according to the environment
- Updatable, since they are designed to last more time than the lifespan of the object itself.

To conclude, DUIs take advantage of how micro-processors and sensors can provide an ecosystem of smart objects with awareness of their surrounding, exploiting their ability to dialogue with users, other objects and the environment. These interfaces can disappear, hence they can be used on objects and products that maintain their overall aesthetics while being augmented. The interface is no more influencing or contaminating the look-and-feel of a product. That said, future developments concern the enquiry on users to understand how such interfaces have implications in terms of experience; in parallel, possible advances of electrochromic technology, as well as the application of other technologies, could positively impact on the project.

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Individual Mid-Air Gesture Sets Informed by Conceptual Metaphors: A Case Study on How Users Generate Mid-Air Gesture Sets to Control Video Streaming

Abstract

Recent research on mid-air gesture interaction for TV control aimed to standardize them. To this end, researchers developed a design approach that relies on the agreement rates among the elicited end-user gestures. Contrasting with the agreement based approach; a recent study have shown that the most common mid-air gestures might not be the most favored ones. In addition to this, researchers claimed that the agreement studies ignore users' cultural and conceptual bias. Thus, it can be postulated that the mid-air gesture interaction research can benefit from a qualitative analysis of the users' mid-gesture set design processes. Towards this end, this study investigated users' task conceptualizations and mental models. For this purpose, a mid-air gesture-based video streaming experiment was simulated with 10 participants, 4 females and 6 males. Through the lens of Conceptual Metaphor Theory, the study investigated the similarities between the participants' conceptual representations. The study findings demonstrated that the participants' conceptualizations had clear references to their bodies and prior physical experiences with the objects, which reflected as linguistic representations of orientational and ontological metaphors in participants' explanations. Further findings of the study addressed intersections between participants' mental models.

Keywords

Mid-air gesture interaction, conceptual metaphors, The Wizard of Oz method, video streaming experience

1. Introduction

TV and streaming technologies have advanced significantly in the last 10 years. With the rise of interconnectivity, streaming platforms have revolutionized the TV experience. The number of streaming platform use per household has surpassed that of cable TV use in some countries [1]. The evolution in content accessibility has reinforced the idea of redesigning our interaction with TV [2]. Research on novel TV control systems projects a future interaction experience that surpasses the limits of graphical interfaces. Research in the Human-Computer Interaction field has highlighted that mid-air gesture interaction may deliver the desired "natural" interaction experience. However, researchers have found that the standardization of the mid-air gesture interaction was problematic. In pursuit of a standardized mid-air gesture vocabulary, several elicitation studies were conducted. These studies aimed to find the most recurring mid-air gestures to design the gesture sets. In this way, the produced mid-air gestures could become the archetypes of their category. However, in a recent study, researchers postulated that the agreement-based approach ignores the users' conceptual, cultural and physical bias [3]. Thus, presented agreement calculations were inflated. Moreover, another group of researchers found that the mid-air gesture sets can vary across cultures and that the most common gestures might not provide the best design solutions [4]. Thus, it can be speculated that the most suitable design approach for mid-air gesture set has not yet been formulated. The underlying reason for this problem may be the prevailing gesture consensus approach in such studies because the approach neglected the importance of visual references and assumed that the human interpretation of the outputs and verbal commands could be standardized. Moreover, the method also postulated that the users could always design coherent, engaging mid-air gesture sets in a limited time period. Alternatively, in a recent research, a turn towards a human-centered design approach has been suggested [4]. The study evaluated users' appreciation for all of the mid-air gestures regardless of the agreement rates and found that the most agreed gestures may not be the most appreciated ones. In line with this imperative debate on the design approach, this study aimed to get a better understanding of the users' mid-air gesture set design processes. With this aim, a computer-operated streaming control experience was conducted with 10 participants. Throughout the experiment, the participants controlled a streaming activity with their mid-air gestures, and after demonstrating each gesture, the participants explained their thought processes. Later in the study, with the guidance of Conceptual Metaphor Theory (CMT), the users' conceptual representations for the given tasks, semantic similarities between these conceptual representations, the users' task grouping behaviors, and intersecting mental models were investigated. By doing so, the study evaluated the possibility of employing a mental-model-based design approach. The contributions of this study to the design field are (1) presentation of the collected mid-air gesture sets for streaming control, (2) examination of the conceptual representations of the tasks, (3) presentation of shared conceptual representations of the tasks and participants' intersecting mental models and (4) suggestions for the design of mid-air-gesture-based streaming experience.

2. Background Work

2.1 Conceptual Metaphor Theory (CMT)

Metaphors are commonly used to explain one thing in terms of another. In 1980, Lakoff and Johnson proposed through their CMT that humans' conceptual thought processes are comprised of metaphors [5]. Metaphors reflect the diversity of our cultural, physical and cognitive experiences. Based on how they are formed, Lakoff and Johnson categorized conceptual metaphors as structural, ontological and orientational.

A structural metaphor enables us to define one concept in terms of another concept. For instance, "Argument is War" metaphor uses "Argument" and "War" as concepts. To understand which aspect of the "War" is assigned to the "Argument" concept, we employ the most defined qualities of the "War" concept. Ontological metaphors differ from the structural metaphors in the nature of their source domains. The source domains of ontological metaphors are concrete objects, tangibles, and entities. For instance, "The mind is a machine" metaphor uses the "machine" as its source domain and assigns its qualities to the "mind" concept. In this way, the mind can be explained with the qualities attributed to a machine.

Structural and ontological metaphors show similarities in the way they are formed. Both of them explain unfamiliar concepts in terms of other familiar domains. However, in some cases, we explain the concepts in terms of relationships. Orientational metaphors are formed by relying on these relationships. They define a whole system of concepts in terms of spatial relationships, such as up-down, deep-shallow, or on-off. For instance, "having control *over* a situation" is based on the conception that "force is up".

In summary, CMT advocates that direct, embodied physical experiences can shape our conceptual thinking [6]. As mid-air gesture interaction relies on bodily communication, herein it is postulated that CMT can guide us to decipher the source of conceptualizations represented by mid-air gestures. Although Conceptual Metaphor Theory stands on linguistic evidence, research on cognitive science demonstrated that both linguistic and bodily expressions are resourceful in explaining our conceptualization [7]. Hence, in this study, the analysis of users' self-reported statements and gestural expressions were employed to unfold the conceptual representations in the participants' mid-air gestures. The analysis of the collected materials benefited from CMT in classifying the participants' recurring conceptual representations and gesture grouping behaviors. Classified conceptual representations depicted the type of sources that users consulted while forming their mid-air gestures.

2.2 Gesture Taxonomy and Agreement Based Approach

Previous research on mid-air gesture interaction for TV control systems has focused on eliciting end-users' gestures and proposing methods to design intuitive gesture sets. In the last 5 years, 74.5 % of studies have employed Wobbrock et al.'s "guessability method" to design the most intuitive gesture sets [8]. The remaining studies have used "choice-based elicitation", "Nielsen's intuitive and ergonomic model", "a combination of Wobbrock's and Nielsen's models" and other methods [8]. Due to the prevalence of Wobbrock et al.'s classification model and guessability method, this section explains them in detail.

According to Wobbrock et al., gestures can be classified based on four dimensions: their form, nature, flow, and their binding elements. These dimensions are used in defining a gesture's movement such as static, dynamic and one point; a gesture's relationship with the object and space around it, such as object dependent, world dependent, world independent and mixed dependencies; the continuity of the gesture to be recognized, such as continuous or discrete; and the semantics of the gestures, such as symbolic, physical, metaphoric and abstract [9]. Symbolic gestures refer to the symbolic representations, for e.g., the well-known "OK" and "STOP" poses. Physical gestures are demonstrations of the actual physical interaction with the objects on screen/in the air [9]. Metaphorical gestures rely on semantic associations between the gestures and delivered functions. Abstract gestures are the remaining gestures that do not convey any association with the referred function [8]. Often, based on this taxonomy, researchers employed end-user elicitation studies and guessability method to standardize mid-air gesture sets. In a typical elicitation study, participants are directed to produce mid-air gestures for certain referents and depending on the employed study method, the most recurring or correctly guessed mid-air gestures become the representative of the commands (referent). However, recent research has demonstrated that agreement rates across individuals' mid-air gestures could be quite low in studied samples; moreover, mid-air gesture sets could vary across cultures [4]. In addition to that, the most common mid-air gestures might not indicate that it would be the most appreciated one [4]. Therefore, it is not clear how mid-air gesture sets should be designed. In this sense, users' conceptualization processes can help formulate a better design approach. Towards this end, the present study aimed to understand the type of conceptual representations users deployed to form their mid-air gestures.

2.3 Mid-Air Gesture Interaction for Interactive TV Control

First introduced by Freiman and Weisman, dynamic hand gestures are now being proposed as a novel way of interaction with TV [10]. Since the emergence of dynamic hand gestures, several studies investigated the possibility of redesigning interactive TV experience with mid-air gesture interaction. For instance, studies by Zaiti et al. and Wu et al. investigated users' mid-air gesture preferences for TV functions, and Vavatu et al. compared user agreement rates between hands-free interaction and augmented remote control interaction [2], [11], [12]. Further research on mid-air gesture-based TV control examined the possibilities of hands-free text entry for Interactive TVs and preferences for mid-air gesture control among older adults' [13], [14]. Research on mid-air gesture interaction for TV frequently progressed through end-user gesture elicitation and choice-based elicitation studies. Research in this field constantly aimed to standardize mid-air gesture-based TV interaction often relying on the consensus of the collected mid-air gestures.

3. Experiment

3.1 Participants

Ten participants (F: 4, M: 6, Median: 31), of ages ranging from 29 to 33 years, volunteered for the present study. Their professions varied: three aerospace engineers,

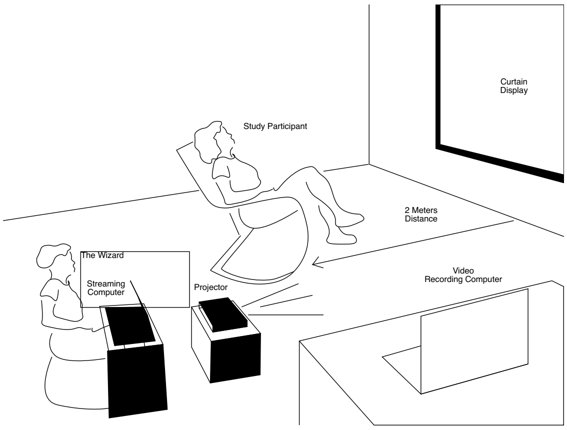


Fig. 1. An Illustration of the Experiment Setup

three mechanical engineers, one system engineer, one mathematics teacher, and two psychologists. The main criteria for the selection of this participant group were that (i) the participants reported prior on-screen gesture experience ranging between six to eight years; (ii) frequent use of online video streaming services; (iii) they had no prior experience with mid-air gesture control systems; and (iv) they were motivated to perform the necessary tasks.

3.2 Procedure

Prior to the study, the participants were briefed about the mid-air gesture interaction. The study took place in a home environment, which the participants visited 1 to 3 times per week. The participants' familiarity with the household could assure that the experiment was close to a real experience. On their arrival, the participants were informed once more that they could use either a single hand or both hands to perform the mid-air gestures. The test apparatuses were a digital projector, a projection screen (2.6 × 2 meters), a speaker and a laptop, the use of which the participants were already familiar with. The study was performed using the Wizard of Oz method, wherein the participants were instructed to interact with hypothetically autonomous subjects [15]. Throughout the experiment, the wizard sat behind the participants so that she would not influence the participants' gesture design process, as shown in Fig.1. Participants performed the announced tasks using mid-air gestures, and after the announcements of the tasks, the wizard simulated the effects. After each gesture, the participants explained what inspired their gestures. The wizard operated the "YouTube" video streaming platform in full-screen mode in this case. The choice of the video platform was based on the participants' familiarity with it. In this context, the participants generated mid-air gestures for the announced tasks in the following order: "turn on the laptop", "turn on the speaker", "connect/pair the devices", "play", "pause", "adjust the volume", "adjust the speed", "adjust the video quality", "subtitles on", "subtitles off" and "watch later". With the consent of the participants, the wizard recorded the whole process using a MacBook Pro in-built camera.

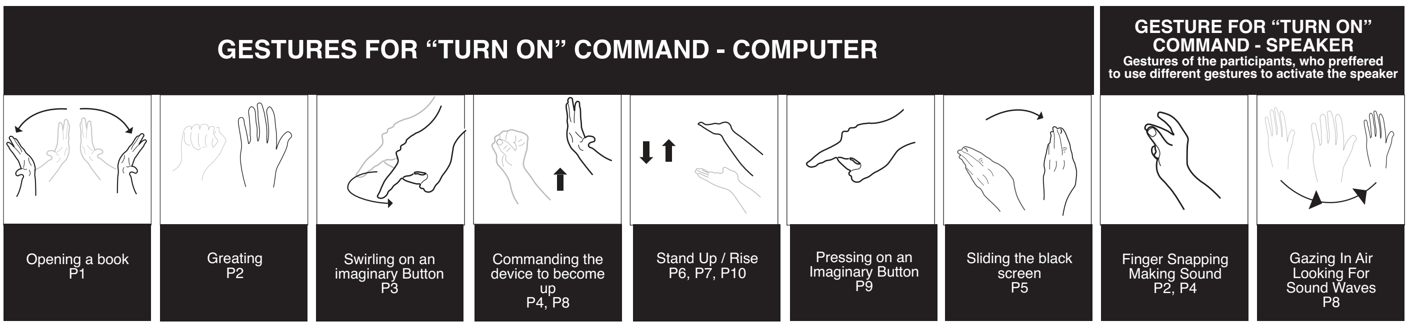
4. Study Findings

4.1 Conceptual Representations of the Commands

This section presents the analysis of the conceptual representations of the commands (referents) reflected in the participants' mid-air gestures.

"Turn On". Firstly, the participants performed mid-air gestures to give the "Turn on" command to the laptop computer. To "Turn on" the laptop, Participant 2 (P2) demonstrated a "greeting" gesture. P4 and P8 used the transition of their palms from a closed state to open state, and the gesture was supported by the rise of their arm along a diagonal axis. P4 and P8 reported that they used "visible, up and ready palm" to represent "being on". P6, P7, and P10 also demonstrated the "rise

Fig. 2. Gestures of the study participants for the "Turn On" Command and the metaphorical references in gestures



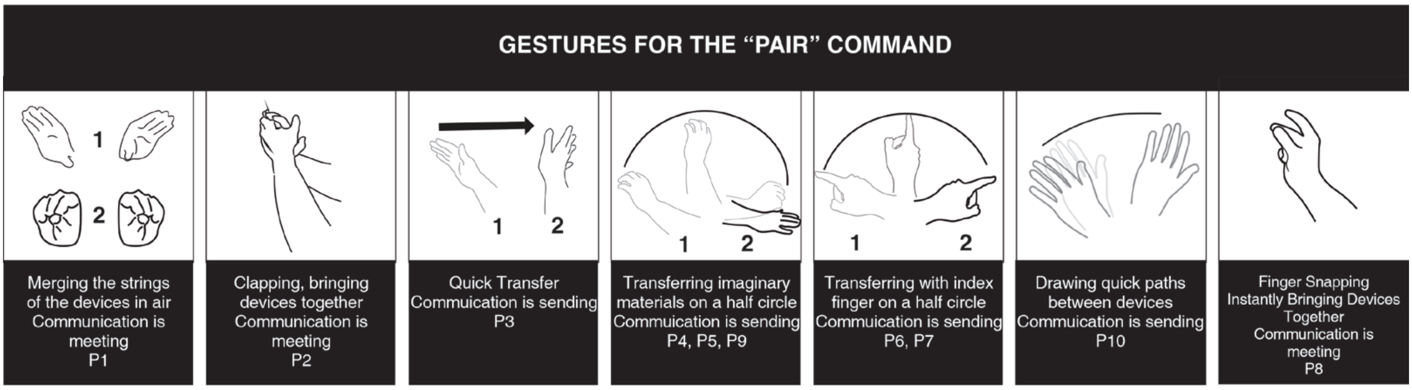


Fig. 3. Gestures of the study participants for the "Pair" Command and the metaphorical references in gestures

& stand up" movements in air with their palms facing upwards, rising along the vertical axis. Conceptual representations of the tasks in 6 participants' mid-air gestures correlated with the orientational metaphors defined by Lakoff as "conscious is up" and "force is up" [5]. Of the remaining four participants, P3 and P9 delivered the command by interacting with imaginary buttons. P1 demonstrated two open facing palms extending along the horizontal axis and reported that the movement depicted "opening a book". P5 swiped her right palm starting from her left to the right along the horizontal axis. The gestures are summarized in fig.2. Later, the participants were also asked to turn on the Bluetooth speaker with mid-air gestures. P2, P4, and P8 mentioned that the speaker would require different mid-air gestures since its predominant purpose was playing music, while the remaining participants maintained the same mid-air gestures for both devices. P2 and P4 snapped their thumb and middle fingers, given that since ancient times, snapping fingers had represented tracing the rhythm [16]. Thus, it can be speculated that the participants referred to the speaker as a company, "who" is capable of responding to them. P8 depicted an open palm slowly moving along the peripheral axis from left to right in front of her upper torso and explained that the movement represented "gathering sound waves".

"Pair". As the third task, the participants were asked to use mid-air gestures to "pair" the laptop and Bluetooth speaker. The participants were informed that the devices' Bluetooth function was on in its default mode. As shown in Fig.3, to connect/pair the devices, P6 & P7 traced a half circle between the objects using their index fingers and P4 & P9 traced a half circle between the objects with their palms. P3 and P5 swiped a single open palm along the horizontal axis and P10 used a single palm facing downwards to wave between two imaginary points. These participants' self-reported explanations indicated that the gestures represented a hypothetical entity is sent through a half-circle or a horizontal path between the devices. Conceptual representations of the task correlated with "communication is sending" metaphor. The remaining participants executed clapping, finger snapping and gradually approaching palm gestures. These participants mentioned that the movement signified "the union of the devices".

"Play". To play the video, of the ten, six participants directly pointed to a random spot on the screen, and of them, only P1 avoided using the index finger on its own for the pointing gesture. Instead, he used his index and middle fingers firmly held together and pointed at the play button as if he was firing a gun. P7 used a finger-snapping gesture, P5 and P8 used the rising opening palm gesture, P2 moved his finger up and P10 swiped his hand to the right. In general, the participants used pointing gestures and performed the gesture in a quick discrete movement. However, P2, P5 and P8's gestures correlated with Lakoff's "active is up" metaphor.

"Pause". Of the ten participants, five used the pointing gesture to give the "Pause" command. One participant closed her palm to a shrunk position and one participant used the finger snapping gesture. Two participants used the static open palm pose and one participant moved down his finger. In general, the participants either repeated the same gestures they used to give the "Play" command or demonstrated the reverse motion. Additionally, two participants used the static "Pause" pose.

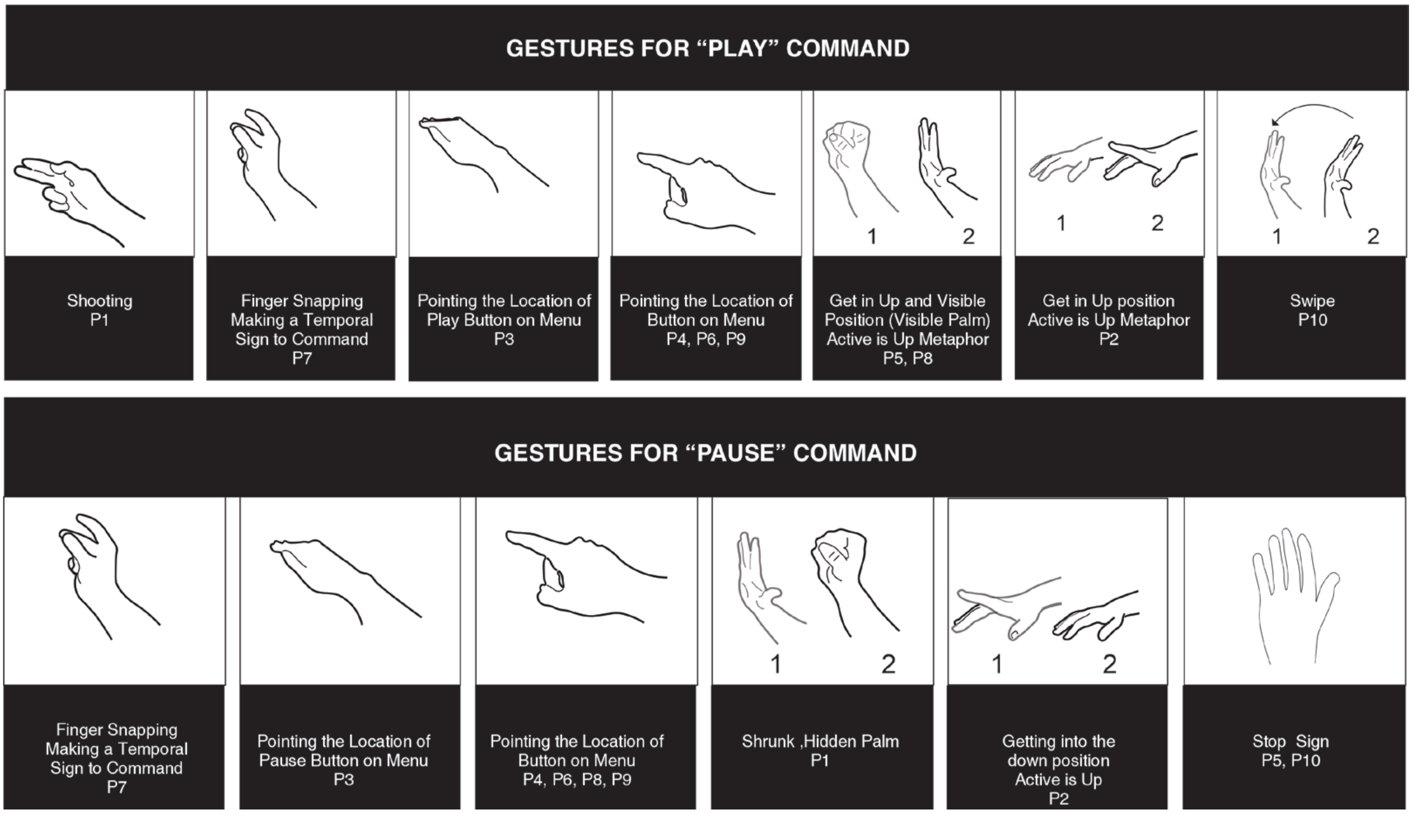


Fig. 4. Gestures of the study participants for the “Play” & “Pause” commands and the metaphorical references in gestures

Volume Adjustment Control. All of the participants demonstrated their gestures along the vertical axis. They either moved an index finger or a single palm along this axis. Only P1 moved his finger around his ear to adjust the volume; however, even he used the vertical axis for adjustment. The participants reasoned that spatial highness represents more. Previously, in embodied music cognition, it is reasoned that vertical representation of the sound amplitude aligns with “greater is higher” metaphor [17]. The findings of this study correlated with this claim, as all of the participants used the vertical axis for volume adjustment.

Speed Adjustment Control. The experiment continued with speed adjustment command. P3 relied on his prior on-screen gesture experience, and consequently, used the double-tap gesture. P9 directly pointed his fingers to the screen. P7 used finger snapping, P2 tapped on his face and P4 used the swiping gesture. P5 tapped and bounced her hand periodically on the horizontal axis while P1, P6, P8, and P10 illustrated a periodic cyclic motion. All except P3 and P9 adjusted the speed of their hand motions to demonstrate the speed required. Except for the pointing gestures, the participants' mid-air gestures were diverse, yet coherent. All of the gestures demonstrated a “periodic” motion either along a linear or cyclic path. The participants associated the command with the motions of “bouncing”, “swirling”, “swiping” and “rolling”. Some of the participants who demonstrated a cyclic motion reported that cassette tapes inspired their mid-air gestures. To give the reverse commands, the participants just reversed the directions.

Video Quality Adjustment. Five participants pointed to the screen to adjust the video quality. P6 moved her right open palm along the vertical axis as she previously used her left hand for the sound adjustment. The remaining participants demonstrated varying mid-air gestures. P2 moved his thumb in “OK” position along the vertical axis. P5 demonstrated a gesture that resembled drawing a "V" shape in the air and she reported that the gesture is inspired by the “sunrise” metaphor. P7 tapped on his eye to adjust the video quality and P8 rubbed her palms on a hypothetical surface in air. P7 reported that he used pointing the eye as an indicator of better vision and P8 reported that rubbing surface refers to clearer vision. These mid-air gestures were semantically associated with vision. Vision is often associated with brightness and clearance,

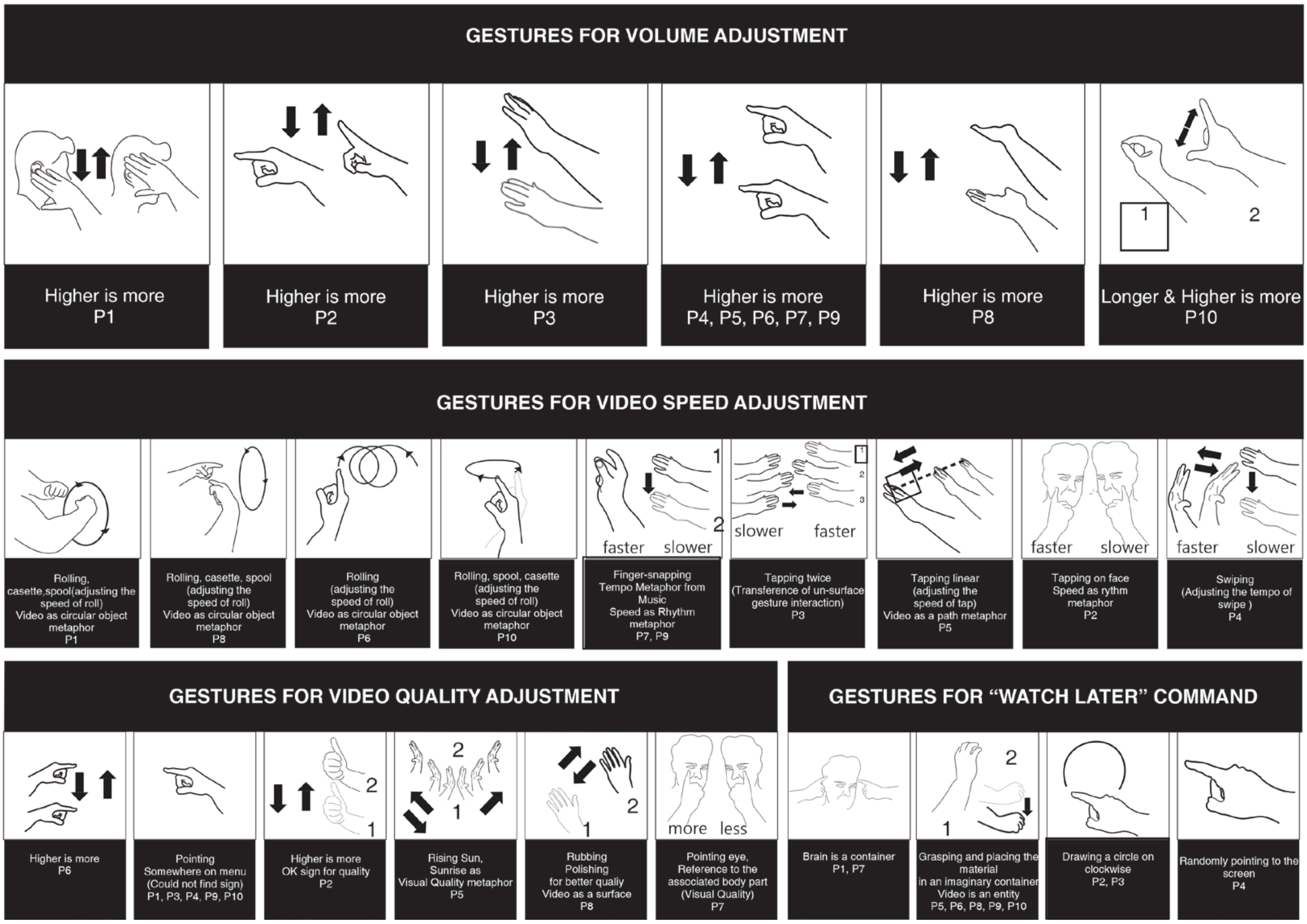


Fig. 5. Gestures of the study participants for the "Volume Adjustment" "Sound Adjustment", "Quality Adjustment" and "Watch Later" commands and the metaphorical references in gestures

and the references were coherent with the commands [18]. Interestingly, the study participants had difficulty in finding gestures to adjust the video quality. All of them asked for extra time to find a mid-air gesture.

"Watch Later". To provide the "watch later" command, two participants directly pointed to the graphical interface and swirled their index fingers in the clockwise direction. Two participants pointed to their skulls with their index fingers. These participants reasoned that pointing to the skull meant storing the information in the brain. Four participants grasped the content with a single hand and placed it in an imaginary container. One participant reported that she perceived the content as a shopping item. Conceptual representations of the command indicated that the content is often perceived as a physical entity that can be grasped and stored in a container.

"Turn On & Off the Subtitles". To turn on the subtitles, P1 and P4 used pointing gestures. P3, P7, P8, P9, and P10 swiped their right hand or fingers along the horizontal axis. The position of their hands emphasized the location where the subtitles were often placed on video players. Three participants demonstrated gestures that did not have any reference to the graphical interface. P2 revolved his right palm from downward to upward direction and rationalized that "facing up" means "being on". P6 used typing gesture with both hands moving along the vertical axis to turn on & off the subtitles. P5 grasped an imaginary entity with her hand. Subtitle control gestures were often physical. However, the representation of "active is up" metaphor was visible in P2 and P6's gestures. Additionally, P5's gesture represented "understanding is grasping" metaphor.

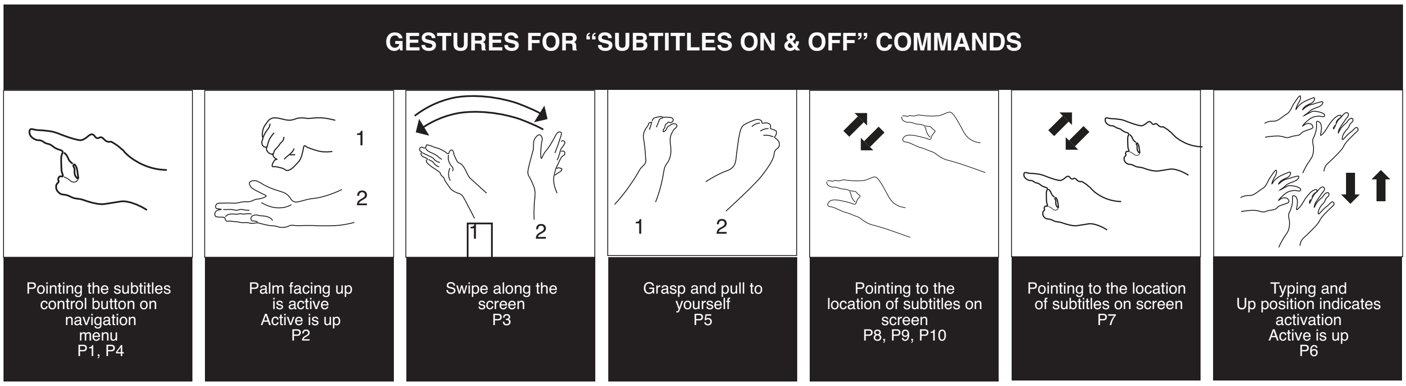


Fig. 6. Gestures of the study participants for the "Subtitles On" & "Subtitles Off" commands and the metaphorical references in gestures

4.2 Shared Conceptual Representations of the Commands

The participants' shared conceptualizations of the tasks are summarized as follows:

Turn on the Laptop. "Force is up" metaphor.
Turn on the Speaker. The personification of the speaker. The participants referred to the speaker as "a person/entity that can respond to sound".
Pair the Devices. "Communication is sending" and "communication is meeting" metaphors.
Play & Pause. "Active is up" metaphor.
Adjust Volume. "Higher is greater" metaphor.
Adjust Video Speed. Representation of the video as "a rolling circular entity" and "speed as rhythm".
Adjust Video Quality. The shared conceptualization correlated with "higher is greater" metaphor, however, the participants also employed interesting metaphors such as "video as a surface", "visual quality as sunrise" and "the eye as a button". P6 used "Greater is higher" metaphor to link the task with the volume adjustment task.
Turn on the Subtitles. The participants agreed on pointing towards the typical location of subtitles on graphical interfaces.
Watch Later. "Video as a graspable entity" and "brain as a container" metaphors.

4.3 Intersecting Mental Models

Pointing Gestures for Relatively Complex Commands. According to the study results, the participants used pointing gestures when they had difficulty in finding suitable physical demonstrations. A study by Mauney et al. found similar results [19]. However, the "Play" command can be an exception to this generalization since the participants used pointing gesture in a distinguishable way.

Reverse Gestures for the Dichotomous Referents. Previous studies have shown that the users often preferred reversible gestures for the dichotomous referents and the findings of this study supported this inference [2], [9]. This behavior often surfaced in the demonstrations of physical experiences.

Same Gestures for the Dichotomous Referents. Study findings have shown that some of the participants employed the use of same gestures for dichotomous referents, such as for "Play / Pause" and "Subtitles on/off" commands. The participants who employed this model associated these commands with clicking the buttons. Our findings support the findings of a previous study by Kühnel, C. et al. [20].

Redefining the Same Gesture with the "Stop" Pose for Dichotomous Referents. Even though the participants were encouraged to use a single gesture, three participants used the static "stop" pose and "OK" pose at the end of certain gestures.

Limited Hand/Finger Movements. Two participants tried to limit their hand/finger use. P9 used her right index finger for most of the commands and P2 placed his fingers on the armrest, which restricted his motions.

Transferring On-Screen Gestures to Mid-Air Gesture Interaction. Our findings have shown that a few participants used on-screen gestures as their mid-air gestures.

5. Discussion

This study aimed to understand how users generated their mid-air gestures through the analysis of their conceptual representations. The motive of the study was to take a step back from agreement calculations and understand the recurring patterns in users' mid-air gesture set design processes. Study findings showed on a conceptual level there were explicit similarities among the participants' mid-air gestures. Study findings indicated that the participants frequently represented orientational and ontological metaphors with their mid-air gestures. As aforementioned, orientational metaphors rely on spatial relations between the concepts. Ontological metaphors enable us to explain concepts in terms of tangibles. When controlling the streaming activity, the participants often described their conceptual representations as ontological and orientational metaphors. Thus, it can be speculated that the physical experiences with the objects and the embodied experiences played a central role in the design processes. However, when the commands did not referphysical experiences, e.g. video quality adjustment, the participants' conceptual representations often relied on structural metaphors. Based on these findings, some of the suggestions to the designers can be summarized as follows:

Participants' Physical Experiences with Objects Inspires Mid-Air Gestures. The participants enjoyed depicting imaginary versions of physical experiences, such as commanding the computer to stand up, rolling the content as if they were rolling a physical wheel, grasping the content as if they were grasping an object and elevating the volume as if they were piling up things. Sometimes, they directly referred to their bodies. Thus, further explorations in mid-air gesture interaction should address physical interactions with different objects and how we refer to our bodies.

Gesture Sets should be Recognizable when Performed in Different Volumes. Some of the participants purposefully used minimal mid-air gestures. However, older adults may not have the same physical abilities as young people do to perform exaggerated mid-air gestures. Thus, mid-air gesture sets should provide a ranging volume use.

On-screen Gestures may not Produce the Desired Engagement. Despite that the volume adjustment uses a horizontal bar on the mobile graphical interface, participants preferred vertical movement for volume adjustment. Thus, a simple transfer of on-screen gestures to in-air ones may not produce equal engagement in users.

Conceptualizations are Grouped in Terms of Spatial, Temporal and Semantic Aspects. To evaluate the wholeness of the designed mid-air gesture sets, gestalt principles can be resourceful. The participants employed spatial, temporal and semantic references to group their mid-air gestures. For instance, some participants relied on "greater is higher" metaphor to group "adjust volume" and "adjust video quality" tasks. Both tasks had different semantic references, however, were grouped in terms of their adjustability along the vertical axis. In such cases, the proximity of the semantic relationships between the conceptual representations should be studied further. The proximity built instantaneously by the participants may be misleading in the design process.

Enable Customization. The designed gesture sets should enable users to add mid-air gestures to the provided sets. In this way, the system becomes adaptable and users can feel in control of their gesture sets.

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A Pedagogy for Noticing – Soma Literacy and the Designer

Abstract

The design fields strive for rich interactions fostered by ever deeper technologies yet continue to work without an overt conversation regarding the experiencing vessel, the sentient body. This body is evermore present in technological interactions, yet poorly understood when assumed only as one artifact among many. Before a true understanding of rich interactions can be realized, a turning of attention to the visceral variables of experience must first be achieved. The experiencing body, the body-in-motion, can be understood as the fundamental constant in all experience. It is through this bodily turn that an expanded palette of variables may be revealed to the design fields. Analyses and interventions through such a tactile and personal lens refocuses the conversation concerning interaction and experience. This paper describes a new course of study in Soma Literacy piloted at Carnegie Mellon School of Design and provides an introduction to Soma Literacy, a new framing and set of priorities applicable to designing for engagement of the felt-sense, providing both a timely provocation, and a much-needed practical aid to designers and educators.

Keywords

Soma Literacy, Interaction Design, Gesture, Motion, Experience

1. Affinity to the Human Body

How can a human body feel the digital? The recent tide of new technologies (in artificial intelligence, machine learning, nano tech, etc.) promises a world where the unimaginable becomes possible and problems previously unsurmountable are now within reach, yet how is the human to participate in such a world? As these technologies evolve, creating new cultural and social landscapes, it is prudent to take a moment to consider how it is that one might, in actuality, inhabit such a landscape. The technological world is certainly smarter, more interactive, and more connected, but what of the aesthetics of human interaction? What is the human experience of AI or machine learning? Is it possible to experience these things at all?

I have investigated these ideas in a series of studies at the Carnegie Mellon School of Design, focusing on the human body as the center of all experience. It is only through a pushing–pulling, breathing–beating, shifting–leaning body where interactions become aesthetic and it is with this bias that I have framed the evolving research.

"The knowable world...is the human body's world, and only those elements that have some kind of affinity to the human body can enter it." [1]

Samuel Todes, writing in Body and World, lays out a deep case for the body as the one constant requirement for the creation of a knowable world. The integrated, moving body is the observer, translator, and actuator of the life-lived. It is the only lens with which we are able to know our concrete and abstract, real, and virtual world [1]. Here, I ask the reader to consider the wording, "affinity to the human body," as "…only those elements that have some kind of affinity to the human body can [become known]. [1]" In order to build an experience for an actor, the designer must begin with a goal of something that can actually be experienced by the human actor. We have no affinity for cell division, or nuclear fission, or the digital change from a 1 to a 0. That is to say, we have no way to feel these things, so if the goal is to make them known, to make them aesthetic, the designer has to first recognize this threshold and then offer a bodied interaction [2] to foster the knowing.

Hyper focus on expanding rapidly evolving technologies without an overt attention to the human participation in these new landscapes runs the risk of debasing the very bodies that the technologies were invented to aid [3]. If we are to understand the semantics of technologies, then it must be through an understanding of human body-able form and movement, a Soma Literacy, as this is the only category of technologies that afford an experience [4].

2.1 Fundamentals of Experience

In service of the above-mentioned attentions, the Carnegie Mellon School of Design required a new 8-week unit of study titled *Fundamentals of Experience* to all undergraduate Junior design students (Communication Design, Product Design, and Environments foci) in spring 2017 and 2018. The course introduced the design students to base concepts of felt interactions [4] recognized at the soma-tier of experience [5]. The methods were entirely interactive with no whiteboards, post-its, PowerPoints, or lectures utilized. The primary methodological disposition was to literally engage the students in the experiential concepts. The expectation was that as the designers developed a deeper soma literacy, they would be able to use this enhanced perspective to recognize, analyze, and manipulate (design with) the given soma-tier variables.

In preparation for the course, we researched fundamental concepts of sentient experience such as tempo, cadence, beat, meter, range, crusis, phrase, rhythm, agogics, tension and release, rhythm, flow and interruption, ease and efficiency. We then looked for ways to engage the students with the concepts as participatory, extra-linguistic, kinesthetic and enkinesthetic [6] (social) experiences.

The exercises were all based on the methods of Émile Jaques-Dalcroze [7], an early 20th century music pedagogue who used bodies in motion to build awareness to the felt experience of music. Throughout the eight sessions we utilized Dalcrozian methods to drive the student's attention to the felt experience of unfolding interactions. The strategies all involve the full group of students in simple, shared motions: walking, clapping, swaying, leaning, etc. The motions are regularly entrained to some outside force: a beat, a neighbor, the instructor, improvised music from a piano, prose, etc. Once some amount of synchronicity between the body of the participant and the outside indicator is achieved, the instructor then provokes the experience by manipulating any of the concepts being studied. By adjusting variables such as tempo, cadence, beat, meter, range, crusis, phrase, rhythm, agogics, etc., the participant is forced to either adjust their attention to maintain the entrainment or suffer the breakdown of the interaction. These methods fostered a redirection of the student's attention to the soma tier of their own experience as distinct from the aural, visual, or logical realities.

2.2 An Introductory Lesson

The first day of *Fundamentals of Experience*, the class was directed to simply walk about the room. Once we got over the micro-awkwardness of what seemed to many as an odd request, the instructor adjusted the exercise by building on the simple instruction and slowly morphing it into a deeper experience.

The simple *"walk about the room" was incrementally adjusted to include: "Walk with direction (Stake out your own path, do not walk in a circle)" . . . "Look where you are going (not at the floor)" . . . "See the peers that you pass" . . . "Greet a peer with a smile, a high-5, or a handshake as you pass" . . . "Adjust your tempo to match the tempo of the* *music from the piano (teacher improvises music from the piano)"*

Over a period of about four minutes, we were able to progress from a directionless walking around the room to an enkinaesthetic series of interactions that required a specific kind of attention. With each small instruction, the students were nudged toward a more entrained, more embodied interaction and persuaded away from common biases of sight/sound/thought. The enactive techniques [8] fostered an attention to the bodied, the participatory, moving, shared experience with others.

2.3 An Attention to the Interstitial

On a separate occasion, the students were asked to listen to music from the piano...then to tap the beat… then to walk that beat…then to tap while walking the same beat…then to find a partner, face the partner and "patty-cake" the beat…then to press their hands on their partner's hands and push and pull, back and forth, in a sawing-type motion.

The beginning instructions of "tap the beat" etc., revealed a common bias to the snapshot version of experience. When asking the class to demonstrate what they were paying attention to, the students first defined the beat by the moment of the hit, the moment when their hands came together, the *crusis*, the touchpoint. Through the expanding of the lesson to include the sawing motion shared with partners, we succeeded in revealing the felt space between these touchpoints and as a result, offered the students some insight into a ubiquitous phenomenon common to all felt interactions. We carried these insights (among many others[1]) into the analysis of experience design tools.

2.4 Experience Analysis Tools

Throughout the course we critiqued analytical tools commonly used in design to describe or plan experiences (i.e. journey maps and service blueprints [9 - 10] As the class acquired soma literacy skills, some

Fig. 1. Leading design students in the sawing motion, ***Fundamentals of Experience*** 2018.

of the shortcomings of these tools became apparent. While such tools are perfectly useful for charting out the successions of moments, they fall short if needed to demonstrate an attention to the interstitials that are the hallmarks of the act of experiencing.

Rather than focusing on snapshot touchpoint to touchpoint accounts of interactions, Soma Literacy values the felt, lived space between these touchpoints and as a result affords a view that speaks to the truly tangible, visceral, participatory elements of interactions

The course concluded with the students proposing various revisions to such tools, attempting to include the interstitial trajectories revealed through their enhanced soma literacy. We then tested their revisions by proposing redesigns to common interactions (i.e. interactions such as riding the bus, progressing through a queue, following a recipe), then debating the role of the felt interstitial trajectories in significant experience.

2.5 Lessons Learned

With inspiration from the somaesthetics of Shusterman [11], performance as practice of Schwiebert [12], pedagogy of Jaques-Dalcroze [13], pragmatic philosophy of Wittgenstein [14], James [11], and Dewey [15], we presented an investigation of the body (soma) as the experiential core of perception and action [16].

The exercises permitted a depth of understanding that was not possible without engaging the student's actual sentient vessel, their own bodies in the knowing. Whereas traditional sketching permits the designer to explore two-dimensional space, and prototyping permits a sketching (or testing, playing, manipulating) in three-dimensional space, here we were interested in the analogous *sketching* in the fourth-dimensional space,

[1] For more examples of the exercises and projects completed please see pages 211-236, https://www.academia.edu/39225809/SOMA_LITERATE_DESIGN_Recentering_the_Interstitiality_of_Experience

Fig. 2. Carnegie Mellon Junior design students participating in the *Fundamentals of Experience course*

time. And in these examples, where the attention was on significant experience, it is not merely time, but time as it implicates participating bodies.

This study explored Soma Literacy as a tool of analysis, to notice how experiences, by default, design bodies. Seeing experience through this lens offers a different kind of body-ing from the majority of body-implicated design methods that use the body as a tool for ideation. While there are a number of design practices that use awareness of the body either as inspiration for designed interventions [17] (i.e. bodystorming [18], Wizard of Oz prototyping [19 - 20]) or as a model for other types of ideation (i.e. biomimicry [21]) the attentions that will permit the actor/designer an authentic experience in technology must be primarily concerned with the actual, in the moment body-in-motion.

The initial runs of the *Fundamentals of Experience* course demonstrated that (1) there is an extra-linguistic tier of experience that students can recognize, (2) this tier of experience is full of distinct variables that can be isolated, analyzed, and manipulated, and (3) with even a basic understanding, the designer can offer interventions, nudging an actor(s) toward preferred states.

Rather than only focusing on a logical dialectic knowing, these strategies supported kinaesthetic knowing by:

- Presenting all of the content through group settings which not only encourage joint participation, but more-so a deep empathetic entraining of self-to-other,
- Pairing students with multiple partners and small groups every class,
- Using a spirit of play to push everyone to improvise, create, perform, share, and reflect in speed-round succession.

3. Transdisciplinary in Design

The human body-able technologies of form and movement, which include concepts such as flow, cadence, crusis, and agogics are central to any sort of participatory happening whether it be in manufacturing, web interfaces, theatrical performance, or ditch digging. AI and the surrounding technologies have no promise of aesthetic except to achieve these types of engagements [4].

"…designers should have knowledge of how to shape aesthetic interactions in a more visible, explicit, and designerly way. This is a kind of knowledge we are currently missing in [the interactive design fields] [22]."

How do we adjust to an ever-evolving landscape of design attention?

A first attention must be to the **temporal.** The deliverables of third and fourth order design are all expressed as happenings, experiences, and cycles [23]. Rather than things merely seen or touched, Design for Service [24], Social Innovation [24], and Transition Design [25] all require solutions experienced as unfoldings and proceed with a tempo, a gait, a cadence, and a trajectory. This reality, requiring a valuing and attention to experience as unfolding time, opens a complex space and a need for a wholly different set of variables from the design rhetoric of the past.

A second attention must be to more interest in, and technology for, the **feeling body**, as this body is not only implicated in, but central to the concept of interactions, experiences, and engagement. While the body in design is ever-more prevalent (as in motion sensing tech, AR/VR, or the "Soma-Based Theory" collective at CHI), it will only be through an explicit recognition of the body as a sensuous body, a body that experiences only through motion, where the connections will achieve aesthetic significance. If the practices are to discuss and design with efficiency, impact, and authenticity, an understanding, "sensory and cerebral, […] characterized by an inward responsiveness to an outward stimulation [26]," becomes critical lest they separate the sentient actor even farther from their world.

Here, at the crossroads of these two concepts: experience as unfolding time + sentient body, is where the Soma Literacy agenda becomes specifically relevant to design. Without an attention to and understanding of such concepts, the HCI and design communities will continue to working under an incomplete understanding of the role of aesthetics, and will be unable to efficiently discuss, analyze, and design with the soma tier of experience, inherent in every interaction and the proving ground for all significant participatory experience.

4. A Soma Literacy for Designers

"Thinking more broadly about this issue […] it seems that we collectively have a very limited capacity to talk about and communicate haptic sensations clearly [27]."

"We believe improved somatic empathy (through heightened body consciousness) could improve our ideation not only in movement-based interaction but in any interaction that deeply engages our body [28]."

The usage of the term soma comes from Richard Shusterman's sentient perceiving body-mind [29], a unified whole that is the active participant in an unfolding reality. Soma Literacy starts with acknowledging the body as the soma, noticing the feeling, dynamic, living body.

Soma Literacy also notes that we come to know our worlds through a variety of registers of attention or tiers of experience (attentions to the visual, aural, logical, and somatic). Rather than a Cartesian mind/body split, Soma Literacy recognizes the embodiment of the actor, where one's thoughts, actions, and attentions are all implicated, one affecting the other, and even determining the other. The challenge of such attentions is in juggling one beside the other. Ontologically, we are embodied beings. Practically however, we develop habits and coping mechanisms that often skew and limit the noticing of the experiencing body. Common biases toward seeing, hearing, or thinking can run so rampant as to override the root discerner of experience, the resounding feeling in the sentient body.

Lim, Stolterman, Jung, & Donaldson, wrote a short paper in 2007 titled, *Interaction gestalt and the design of aesthetic interactions.* In this paper they lay out a basic case for Soma Literacy in Design.

"…the challenge here is to create a language that helps a designer understand which attributes are to be considered in order to create a certain gestalt that in turn will result in desired user experiences. […] This language includes: (1) a good sense of what it is that is designed […] in our case the interaction itself which we call interaction gestalt, (2) a good sense of what is possible for a designer to manipulate when designing the design target—in our case, the attributes of the interaction gestalt, and (3) a good sense of how to manipulate these attributes in order to shape a specific design [22]."

Soma Literacy is just this, the understanding of the bodied implications of an interaction. Currently the fields of IxD have a very shallow discourse concerning interstitial spaces, performative entrainment, and awareness of the experiencing body. There is no agreed-upon understanding of the terms *experience* or *embodiment* as would be relevant to design, and there is no common listing of terms, concepts, or recognized palette of temporal variables. Literacy reveals what is hidden to the illiterate. Without an overt conversation of Soma Literacy, the design fields (and now I include music, dance, drama, cinema, painting, architecture, HCI and IxD) will struggle to comment on what is felt.

Soma literacy is both (1) a way to analyze personal experience (analyze why a moment was or was not impactful) and (2) a way to create or foster an experience by willfully participating (or not) in the heavy/light that surrounds us or by designing an experience with these soma variables in mind. Soma Literacy gives one a specific lens to see through and participate in the world. It reveals tiers of experience that are hidden to many. This ongoing research attempts to highlight both the validity and the opportunities for the design fields in gaining such an understanding.

5. Conclusion

Deep technologies are now commonplace and raging forward. Separate from the engineering challenges of these initiatives are the challenges such technologies pose to our culture, society, and relations. If we aspire to *experience complexity*, or design for "connected and expressive artificial ecosystems [30],", if we are to design "with a particular focus on the aesthetics and human experience of these new systems [30]," then a reorienting of experiential attentions are necessary, a reorientation to the intimate, sentient living body.

We are analog. All experience-ing is analog. Any implication of a *digital experience* is a misdirection which can only lead to a distancing of the human from their world. It is only through body-ing that one can come to know a technological world, as "…only those elements that have some kind of affinity to the human body can [become known] [1]." Our challenge is first to understand experience as the participatory kinesthetic and enkinesthetic *action* that it is, that is, develop a Soma Literacy, and then recognize the affordances of the burgeoning technologies that permit such an involvement. We must be continually reminded that the body is not capable of static being or of binary on/off positioning. The body is living. The body is analog. The body experiences over unfolding time and cannot jump from instant to instant (touchpoint to touchpoint, 1s to 0s) separate from the interstitial swing-toward and swing-away-from.

How do we adjust to an ever-evolving landscape of design attention? What new palettes do these modern fields obscure, reveal, and require? In our pilot course, *Fundamentals of Experience*, we explored base concepts of experience through personal engagement. The initial participatory lessons in Soma Literacy used methods revealing concepts outside of the traditional design education, yet potentially critical for the modern designer who is working evermore in explicitly temporal and technological realms. Regardless of the technology, if one is to consider the temporally unfolding aesthetics of any interaction, it will be only those artifacts that possess an affinity to the human body that can actually engage the human actor.

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Topic 5.

Smart and Multi-Sensory Systems for Behavior Change

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Designing Phygital Activities In a Smart Multisensorial Room: a Collaborative Cognitive Environment for Children with and without Disabilities

Abstract

Technology integration in education has a great potential to transform learning paths, to overcome barriers and increase meaningful interactions among students, teachers, and the environment. Phygital learning is an emerging approach that balances the innovative technology-driven experience content with the traditional and physical one. In the context of Inclusive Education, this approach is particularly promising for enhancing the learning domains (cognitive, affective, and psychomotor) of children with disabilities. Recognized as integrators in multidisciplinary teams, characterized by a broad vision on users' needs and experience, and familiar with the creative problem-solving process, designers can have an active role in developing new learning activities. This paper describes the development of Magika, an interactive Multisensory Environment, that supports inclusive education via playful *phygital* (physical + digital) activities for children with and without disabilities. 30 specialists, among product and interior designers, electronic, materials and mechanical engineers, primary educators, therapist, and caregivers, were involved in a co-design process to define the educational and therapeutic objectives of phygital activities, according to the Italian primary school education system.

Keywords

Multisensory Environment, Environmental Design, User Experience, Phygital Learning, Design For All

1. Introduction

Inclusive Education is a fundamental point in the Italian education system, even though schools are not well equipped with spaces for learning, play, and socialization specifically designed for children with disabilities. In this context, our research aims at supporting and developing activities for children with physical and intellectual disabilities (ID). We design activities for LUDOMI project, one of the winners of the Politecnico Social Award of 2017 [36], whose goal is to provide multisensory smart rooms for schools. The project strengths are on the one hand the innovative interactions for users and on the other hand the multidisciplinary approach of the project, which allow merging different competences starting from system integration skills to expressive-sensorial properties knowledge of the materials. The output of the cooperative collaboration between therapist, educators, and caregivers is Magika, a smart multisensory room that supports inclusive education via different phygital (physical + digital) activities.

Role of designer. By their nature, designers are connectors and facilitators in transdisciplinary dialogues between different knowledge [1]. The designer profile continues to evolve according with the complexity of the context in which he works, our society [2]: design discipline has become "adult" and its problem-solving process (*design-thinking*) is commonly applied by other professionals to design products, services and experiences, innovation processes, business models and strategies [3]. The evolution that industrial designers have experienced includes a significant change in practice, that is not limited to just design thinking [4]: from a strongly "artistic-intuitive" practice to research and validation-based one [5]. The involvement of designers in the processes of functional materials development [6–8], or in social innovation projects, is predominant also in companies which are examples of this change. Designers have always had a special relationship with materials and artifacts' materiality [9], [10]. Today, industrial designers play an active role in shifting towards a "radical" process of material development [11]: from practical experimentation to materials properties, from reflecting on materials quality to expanding the meaning of materials.

Paper structure. This paper presents the conceptual framework used to design phygital activities that integrate the tactile sensory perception to empower learning through sensory-motor experiences. In this perspective, we want to shed light on the role of the designer in a technological environment for social innovation. Firstly, we describe the integration role of the designer in an interactive environment, then we focus on the main features of Magika, and we delineate the guidelines for designing phygital activities in a such innovative interactive environment.

2. Smart Multisensory Room

Background. Multisensory environment's rationale is grounded on the theories of embodied cognition and sensory integration that emphasizes the formative role of embodiment in the development of cognitive skills such as mental imagery, reasoning and problem-solving [33]. Specific interventions for persons with special needs aim at stimulating basic perceptual mechanisms and promoting perceptual learning [33]. They often take place in a dedicated Multi-Sensory Environment (often referred to as Snoezelen [34]) - a room equipped to provide gentle multisensory stimulations through sounds, lights, projections, soft fabrics, and materials. Prior research indicates that combining the physical and the digital world and offering multisensory stimuli through embodied interaction provides support for persons with disabilities. MEDIATE [35] generates sound and visual stimuli in response to gestures and footsteps on the floor in front of a large display and would stimulate low-functioning non-verbal children with autism. In this framework, in a multisensory room, we designed phygital (physical + digital) activities, which refer to tasks in a physical environment that a user can physically interact with to manipulate digital information. This work sheds light on the potential of phygital approach in a multisensory room. According to Antle [24] and Falcao [25], the possibilities provided by tangible interfaces, such as physical manipulation, physical-digital mappings, exploration, and collaboration, represent promising opportunities for learning. Eisenberg et al. [26] also support the fact that tangible technologies provide richer sensory experiences through the interweaving of computation and physical materials, extending the intellectual and emotional potential of people's artifacts and integrating expressive aspects of traditional educational technologies with educational properties of physical objects.

Materials are at the core of any physical artifact, and not only they contribute to its function, but they also have aesthetic and emotional values that allow designers to shape the character of a product. Among different material features, expressive-sensorial properties [27] are the ones embodied in the 'skin' of a product [28] and can be related to users' experiences with and through materials [29]. These properties are usually, but not always consciously, evaluated by product designers when selecting materials and finishes. The surface features that can be perceived by the human senses as linked to a material's physical properties [30] are named *sensorial properties*. On the other hand, if such features are largely linked to a product's value and identity, or user experience and preference, they are identified as *intangible properties*. Karana et al. [31] focus on materials having a dual meaning, one that emphasizes the role of materials as being technical and the other experiential. One of the pioneers of the material experience both in a sensory and intangible way is Bruno Munari [32],

Fig. 1. The picture captures Magika environment with all its equipment, including material frames, smart objects, and RFID reader (ERA).

a designer and a design educator who gave great contribution to Design in reinforcing creative thinking in design education as experimental investigations.

Introducing Magika. Magika [13] combines and extends the features of existing multisensory digital systems, proposing an inter-connected space where all children are involved in new forms of full-body, playful, multi-sensory, learning experiences. Magika's primary stakeholders are children from 4 to 10 years old, especially those with disabilities. They present physical, psychological, sensory impairments that cause a learning difficulty and a situation of marginalization [23].

Secondary stakeholders are support teachers, teachers, psychologists, therapists, eventually parents, and the community overall. We developed a technology, Magika, that transforms an empty room into a multisensory room (Figure 1) that integrates visual contents projected on the walls and the floor, ambient sound, smart physical objects, connected appliances, smart lights. These elements, controlled using a tablet and automated by a PC, react to children's manipulation and body movements (touchless interaction provided by a Microsoft Kinect) to offer visual, auditory, tactile, and olfactory stimuli in any sequence and combination.

3. Guidelines for Phygital Activities Design

Since Magika is a multisensory room where children explore the environment through different senses, we introduced tactile exploration. Phygital activities have been chosen as the proper channel to explore the physical world interacting with digital inputs and feedback, and, moreover, this environment gives the children the opportunity to learn sensory association connected to the tactile experience. In the next sections, we describe the design process of activities, starting from the objectives up to the definition of a phygital activity framework.

Requirements Elicitation. We decided to test the phygital approach with therapists and teachers to clearly evaluate its potential. We decided to opt for a focus group to commit therapists and teachers directly and promote cooperation. Due to the long-term fruitful collaboration, all participants (3 therapists, 3 teachers, 2 designers, 2 software engineers) felt comfortable and confident in speaking openly and frankly. The focus group started with a description phase, in which the multisensory room was shown. We asked specialists to impersonate into their therapy or educational session with children with and without disabilities, to exploit the potential of the room creating activities with materials freely without any forced interaction flow. Specialists tried to explore activities with available materials for 15 minutes each and took notes when required. We then met them in the focus group, and the moderator asked questions about their experience. The outcomes of this focus group allow us to design phygital activities in the multisensory room properly.

Target. Activities could be played by both neurotypical and children with disabilities, among which not only the ones with physical, visual, or auditory impairments but also with intellectual disabilities (ID). ID is a term used to indicate a set of chronic deficits of cognitive, communicative, and social skills that limit learning, adaptive behavior in everyday life. ID is associated with neurodevelopmental disorders such as autism, Down Syndrome, or learning disorders. It involves 3% of the population in developed countries [18]. As regards children with visual and auditory impairments, they refer on the one hand to blindness, low vision and color-blindness and on the other hand to deafness and hard-of-hearing deficits. Moreover, we include children with inability to use a mouse or slow response time, and limited fine motor control. Our approach is focusing on offering alternative input devices to let the multisensory room accessible to everyone.

Objective Taxonomy. Thanks to the focus group, we were able to understand and collect some basic educational objectives, from which we design phygital activities. We collected them in the following taxonomy:

1. *Primary school cognitive objectives*: A. Basic logical categories; B. Space-time concepts; C. Measurement and size concept; D. Hypothesis and causality; E. Socio-affective capacity
2. *Disciplinary objectives*: A. Chemistry: experiment and understand the properties of materials in a multi-sensorial context; B. Technology: learn to interact with digital and non-digital tools;
3. *Transversal objectives*: A. Live multisensorial experiences; B. Participate in communication exchanges, learning the value of confrontation; C. Develop reflexive skills, adding personal relevance; D. Knowledge in action: learn to recognize sensory inputs and associate them with physical properties of materials.

As a second step, a collaborative environment is required to let all the children with and without disabilities, both cognitive and physical, play together. For this reason, another important objective is to realize design-for-all activities.

Material Selection. The material samples used in Magika were selected according to technical/functional requirements and sensorial properties, based on a previous research project [14], where the relation between sensorial properties of materials and associated descriptors was investigated. First, selected materials shall be resistant enough not to be easily damaged by children when they are called to manipulate and explore them actively. Then, materials must fulfill hygienic standards, being washable and non-toxic. Another important aspect is that children cannot be

Table. 1. Selected materials with their ranked properties

Tag	Colour	Lightness	Texture	Softness	Slipperiness	Deformability	Transparency
A1	Pink	1	2	4	2	2	3
A2	Orange	1	2	1	3	2	3
A3	Light brown	1	2	2	3	3	3
A4	Red	2	2	3	3	3	3
A5	Light green	2	2	2	2	3	3
A6	White	3	2	4	2	5	3
B1	Light pink	2	1	5	1	2	2
B2	Transparency	2	1	5	1	2	2
B3	Blue	3	/	5	4	4	3
B4	Black	3	3	5	4	3	3
B5	Light grey	4	2	5	4	4	3
B6	Light grey	4	1	5	1	4	3
B7	Black	4	2	5	4	4	3
C1	Green	2	/	3	5	3	3
C2	Gold	1	1	5	1	/	3
D1	White	1	3	3	3	2	2
D2	White	1	3	5	2	2	2
D3	Grey	1	2	4	1	1	3
D4	Light grey	4	/	4	4	3	3
D5	Blue	5	/	5	4	4	3
D6	Black	5	/	3	5	3	3
F1	White	1	2	5	3	1	2

exposed to risk environment where they could get hurt, thus material selection is affected by non-breakable and non-sharp properties. At last, keep in mind our target is fundamental: experience for children with physical or visual impairments could be facilitated choosing material not too heavy or too bulky; as regards users with cognitive disabilities we expect some frustrated behaviours, thus material should be soft enough to avoid any risky situation. Following the above steps, 30 material samples were selected, and then they have been classified by 5 material experts rating them according to 6 material properties (Table 1).

The considered material properties are: lightness (Light-Heavy: 1-5 scale); texture (Rough-Smooth: 1-5 scale); softness (Soft-Hard: 1-5 scale); slipperi-ness (Slippery–Unslippery/No fluent: 1-5 scale); transparency (Transparent-Opaque: 1-3 scale); deformability (Stiff – Flexible: 1-5 scale). After ranking materials, they have been tagged to be recognized by the system with RFID tags, according to their material families (A – Polyurethane; B – Rubber; C – Composites; D – Fabric; E – Natural Material; F – Smart Material).

Phygital Activity Framework. Since the main goal is to let children play and collaborate through the game and learning about basic knowledge of materials, we designed a framework for phygital activity: *on-boarding phase*, the first-time children enter the room, they are called to answer simple questions to profile the user; *instructions activities*, which aims at familiarizing with room and materials; *tactile activities*, which goal is to explore and learn materials properties. Three interaction are possible: the one with hands, the other with feet and the activities which include both. To provide a modular and flexible activity with materials, cardboard-frames are produced: bigger frames for feet and smaller ones for hand. For the same reason, two dimensions of material samples, that can be inserted in the frames, are provided (Figure 2).

The flexible approach encourages teachers to build and select their own materials set. To provide an engaging and likable user experience, the activities are explained and presented by an animated cartoon-avatar which looks like the cardboard frame of materials. The on-boarding phase is experienced just once followed by the instruction activities, which could be exploited any times teachers require. As concerns the tactile activities, they could be played every time, but they required that both on-boarding and instruction phases have been experienced, otherwise children would be not able to accomplish the task required. The tactile activities are structured in steps:

-*Explanation phase*: the avatar defines what the activity is focused on (i.e., recognize the correct properties, identify the material association);
-*Exploration phase*: the avatar shows to the child how to explore the material to recognize and identify correctly the associated property;
-*Instruction phase*: the avatar gives the instructions to the child explaining which materials take to play with and which task he shall accomplish;
-*Action phase*: the child fulfills the avatar requirements;
-*Reward phase*: they receive the proper reward if acts correctly.

The materials recognition system is RFID-based: each material is tagged with a label and the system, through a tangible object in the room, could identify if the child took the correct material from the material set [17].

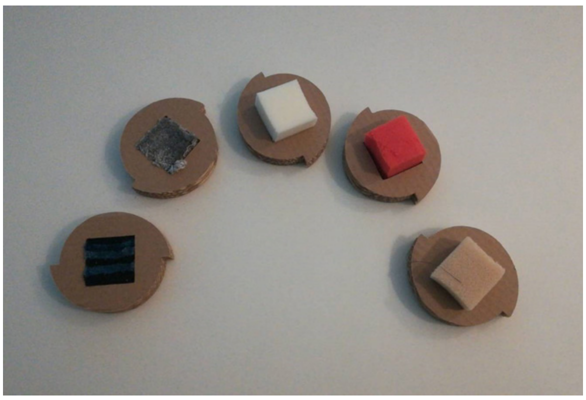

Fig. 2. Material frames: each material is tagged, and it is designed in a modular way. Feet-frames (left – 33 cm x 33 cm), hand-frame (right – 10 cm x 10 cm).

4. Results

Design Phygital Activities. The *on-boarding phase* has been defined accurately for profiling users. Magika gathers data regarding their preferences about materials, not only referring to their likability but also question them about sound-material or image-material associations to adapt each activity to the user preferences, and to avoid any unexpected behaviour from children with disabilities (i.e., aggressive reactions). This information could also be used during *tactile activities*. *Instruction activities* are designed independently from that just to let children get familiar with the room. As a result of the focus group session, the tactile activities are:

-*Memory-tactile game*: children shall identify and couple two items of the same material exploring them with their hands, and as classical memory game required, they shall remind their correct positions.
-*Twin-tactile game*: children are required to match the material they explore by feet and the one they experience through hands.
-*Scaling game*: children explore materials, and they are called to rank them according to the proposed property in crescent or descent order. This game provides a different difficulty level, which is adapted to the user knowledge and expertise.
-*Storytelling game*: children are immersed in a story, where they are required to accomplish a specific task to go through the narration, mainly based on sensorial associations.

Phygital activities have been designed following the objectives guidelines elicited by specialists discussed in the previous section. In Table 2, the activities and their main features are collected.

Design Principles. To define design principles, we specifically asked specialists to express opinions on the usability of phygital activities and personal will to use it in everyday school or center-routine. We asked them to focus on the design and the mandatory features that might be added to activities in the room according to their expertise. All specialists were willing to contribute and pointed out some design guidelines when developing phygital activities in the form of potential requirements. The design principles elicited for the creation of phygital activities are:

Table. 2. Designed activities and their main features

Designed activities		Objectives	Target	Tools	Players	Design Principles
On-boarding		1A, 1C, 1D, 2B, 3A	Children with and without disabilities	Digital projections, Sounds	Individual	Adaptivity, Aesthetics, Design-for-all
Instruction Activities		1A, 1B, 1C, 1D, 2B, 3A, 3B	Children with and without disabilities	Digital projections, Sounds, Hand/Foot-frames	Individual/ Group	Aesthetics, Design-for-all
Tactile Activities	Memory-tactile	1A, 1B, 1C, 1D, 2A, 2B, 3A, 3B	Children with and without disabilities	Digital projections, Sounds, Hand/Foot-frames	Individual/ Group	Adaptivity, Aesthetics, Design-for-all, Controllability, Flexibility
	Twin-tactile	1A, 1B, 1C, 1D, 2A, 2B, 3A, 3B	Children with and without disabilities	Digital projections, Sounds, Hand/Foot-frames	Individual/ Group	Adaptivity, Aesthetics, Design-for-all, Controllability, Flexibility
	Scaling game	1A, 1B, 1C, 1D, 2A, 2B, 3A, 3B, 3C, 3D	Children with and without disabilities	Digital projections, Sounds, Hand/Foot-frames	Individual/ Group	Adaptivity, Aesthetics, Design-for-all, Controllability, Flexibility
	Storytelling	1A, 1B, 1C, 1D, 2A, 2B, 3A, 3B, 3C, 3D	Children with and without disabilities	Digital projections, Sounds, Hand/Foot-frames, Smell	Individual/ Group	Adaptivity, Aesthetics, Design-for-all, Controllability, Flexibility

-*Adaptivity*. Before starting to play in the room, the system needs to know which stimuli users like most and the ones which could create frustration to them: Magika collect this information for adapt the phygital activities according to the user during the *on-boarding* phase.

-*Aesthetics.* In our project, this aspect is linked to the exploration of the expressive-sensorial properties of materials, generally used by designers to emotionally engage the user. Through the activities of stories, we try to create an immersive environment in which to educate to the multisensory experience through stimuli and visual-tactile and olfactory associations. The intelligent environment favors the repetition of associations preferred by the user and tries not to propose those critical to the subject.

-*Controllability.* We have also designed a tool to tackle complexity in this technology-enriched system to let teachers control the multisensory room. The tablet-based app allows teachers to manage the whole experience and it contains three different sections: Create, where teacher can build their custom activities; Play, where teacher can choose which activities to perform during a session in the multisensory room; Live, which is a control panel thank to which teacher can go ahead during an activity even if the system is not working properly (i.e., Kinect is not detecting precisely the child position).

-*Design-for-all*. Activities are designed to provide information to children through different channels, both visual and auditive. Following the principle of *design-for-all*, Magika becomes an inclusive environment where other children adjust their interaction modes according to the ones with impairments (reverse-inclusion). Multisensory environments also allow a wide range of people with different perceptive and cognitive abilities to play actively in the room.

-*Flexibility*. The teacher can introduce new custom materials which could be used during the activities in the room. They are free to enlarge the material kit and create new activity according to their needs using the Create section of Magika tablet-based app.

Designers are required to multidisciplinary and openness towards an evolving system design (in our case activities). In fact, we did not think about activities related only to the materials provided but based on the preferences of the children or those of the teacher, trying to encourage the implementation of new materials. The critical aspect is their use in property classification activities; however, they could be used in stories and/or other games (or relaxation, etc.). Since the two rooms have been installed in two primary schools, we tested our phygital activities in an educational environment. Children performed an explorative session where they played with the designed activities in the room. All design principles played a key role in supporting children activities in the room. A methodical experimental study will be performed for providing evidence on the effectiveness of the design process.

5. Conclusion and Future Work

To achieve its goals, the project must necessarily embrace a multidisciplinary approach. In technological terms, the project requires advanced system integration, Internet of Things, physical systems, interactive olfactory systems, and physical exploration of materials. To design the Magika physical space, the "smart" objects, and their interactive properties, different skills from the design field are needed (UX, UI, interior and product design) [16]. The definition of stimuli and activities for children involves the educational and therapeutic skills of professionals in disability. These multidisciplinary requirements guided the definition of the working group and the partners. The innovation of the project is also in experimentation, unique in its kind for complexity and size. The empirical validations of interactive technology for individuals with disabilities are intrinsically very difficult, and the total of participants in existing empirical studies varies between 3 and 20. The project team has installed two Magika Room solutions in real contexts (two primary schools in suburbs-city) and will conduct an experiment on the field involving over 800 children with disabilities of 10 municipalities in the Milan suburbs, 58 teachers, and 51 classes. In this complex digital-physical ecosystem, a schematic experimental approach will be adopted to collect valuable information regarding user experience.

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Recommendations when Designing to Address Procrastination: A Psychological Perspective

Abstract

Procrastination is a common behaviour that psychologists have found to have many negative consequences for both the individual and society. Standard psychological methods for addressing procrastination require significant time and effort, and consequently suffer a lack of adherence. This paper synthesises relevant psychological research to identify possible approaches designers could take in order to offer immediate aid to procrastinators. We suggest that an understanding of the psychological mechanisms underlying procrastination may inform and guide designers in creating interventions that shift some of the effort associated with undertaking tasks from the individual to the designed environment. In the paper, we draw on different psychological perspectives and strategies, highlighting how this information may be relevant and applicable for designers who aim to address and reduce procrastination behaviour through designed interventions.

Keywords

Procrastination, Design, Psychology, Motivation, Attention

1. Introduction

We all find ourselves putting off things that we would have benefited from doing earlier. For the many, procrastination is occasional –a few tasks without deadlines never get done and some tasks are done last minute – but generally the procrastination does not have a big impact. However for some populations like students, (85-95% of whom report procrastination[1]), and those with high autonomy over their time [2], procrastination is prevalent and can have a large impact; affecting mental health and job performance. For 20 percent of the adult population, procrastination is habitual [3] impacting all aspects of life. The current psychological treatments for reducing procrastination take practice and effort [4], which can be particularly difficult for procrastinators. Almost half of those starting cognitive behavioural therapy, a common treatment, drop out before progress is made [5]. Designers may be able to help people reduce procrastination in a more immediate way by creating environments that counteract underlying causes. In a cross-disciplinary endeavour, this paper presents designers with the relevant psychological theories to consider when designing interactions that navigate the complexity of procrastination.

Putting tasks off does not necessarily constitute procrastination. There are many good reasons to delay a task: sometimes it is beneficial to wait in order to work with the latest information; sometimes another task is more important; sometimes a person needs a break first [6]. As Steel defines it, procrastination as the needless delay of a task to one's future detriment [7].

Procrastination is correlated with many undesirable outcomes. Procrastinators tend to have shorter-term, lower-paying jobs and make up nearly 60 percent of the unemployed [8]. Procrastinators often have poorer general mental health, lower self-esteem, lower self-efficacy, higher levels of neuroticism [7] increased stress [9], more long-term unhappiness [2], higher levels of self-sabotage[7], and higher levels of guilt due to breaking social norms [10]. In spite of this many people argue procrastination helps them: “I work better under pressure”; “it helps focus me”. However, empirical studies present a different story [9], [11], [12]. People make more mistakes, are less creative, and enjoy the overall experience less, both while they are delaying the task and when they are doing it under time pressure[13]. As Pychyl puts it, ‘People don’t work “better” under pressure; it’s just they “only” work under pressure’[6].

Procrastination is also costly to society. In addition to ‘putting work off’, people procrastinate in many contexts of life, including health and wellbeing [14], life transitions such as retiring from work [15] and their personal lives [6]. Putting off health care choices [14], retirement savings [15], and on average procrastinating twenty-five percent of the work day [2], means that employers and taxpayers have to make up the difference. Arguably, if designers can help people address their procrastination, then both the individual and society will benefit.

Procrastination is often viewed as the result of laziness or lack of planning. However, as Steel’s review of procrastination studies shows, procrastination results from failures in the self-regulation of emotion, attention, motivation, or engagement [7]. Psychologists typically address self-regulatory failure through cognitive behavioural therapies, restructuring negative thoughts and behaviour patterns [16], [17] teaching specific goal-directed behaviours [18], [19], implementation intentions [20] and Applied Behavioural Analysis [21]. Psychologists also employ cognitive strategies to increase self-efficacy, reduce negative thought cycles, self-handicapping, and irrational beliefs [19], [22]. These strategies all address the underlying regulatory failure but require significant time and effort to implement. Though 95 percent of procrastinators express a desire to change [9], many are discouraged and unable to adhere to therapeutic practice because the focus is on long-term change rather immediate aid[5]. This paper focuses on psychological approaches that designers may operationalise through the shaping of the physical environment, to offer people more immediate aid, as well as supporting the process of learning non-procrastination. We are particularly concentrating on work-based tasks conducted at a computer. There are other ways of affecting how a task is done through design that are outside the scope of our consideration, for example, through: changing the task itself; changing the context of doing the task; changing the user. We focus here on making change through the design of the built environment and the interactive artefacts within it.

A review of the literature in conjunction with Blunt and Pychyl’s work [23] highlights three types of task that people commonly procrastinate in the process of doing:

- Tasks that cause anxiety: It might be that people are unsure of what is involved in the task, it might be that they are unsure of their ability to do it, or it might be the consequences of failing are high; but all of these cause anxiety that people want to avoid;
- Tasks that are tedious: These tasks may not be hard but require people to focus on something which isn’t engaging or stimulating;
- Tasks that are effortful for low perceived reward: These tasks tend to be frustrating because, in spite of consuming a lot of effort, people get very little in return.

The cognitive view of procrastination as a failure in self-regulation means, in plain terms, that a procrastinator has been unable to make themselves do an undesirable task rather than do a more enjoyable one [7], [19]. The ‘self-regulation failure’ involved in procrastination can be described from a range of cognitive perspectives. The perspectives of willpower [24] and emotion regulation [10], [25] are highlighted in this paper in terms of their potential relevance for designers.

2. Willpower Perspective

Psychologists have found that willpower is a finite resource [24], [26]. As people go through the day, their willpower is slowly used up, regardless of how it is used. To forgo distractions, people use up willpower. When people have many pleasurable distractions surrounding them, their willpower resources can be quickly depleted [26]. Technology design now provides many instant 'fun distractions' (e.g. smartphone game applications or social network sites), making it increasingly hard for procrastinators to attend to the task at hand. Their willpower is constantly being called upon and therefore is readily used up [6], [26], [27]. People also have many work-based distractions, with constant alerts making it easy to switch their attention away to simpler tasks [28], [29]. To address procrastination from the 'willpower perspective', designers need to look at how to reduce the amount of willpower required for each type of task. Willpower is used for both starting and maintaining task engagement.

The following will argue that designers can reduce the willpower requirements by:

- Making the task more desirable;
- Making the distractions less desirable;
- Using pre-decisions ('implementation intentions') to reduce periods of high demand on willpower.

2.1 Making Tasks Seem More Desirable

Feasibly, designers can increase the desirability of work tasks using several strategies. One strategy is to design for Flow conditions that are associated with enjoyable and intrinsically rewarding experiences [30]. Flow is commonly used by interaction designers to increase engagement. One aspect of Flow is knowing how well you are progressing [31]. We suggest that designed environments could provide people with feedback on their progress offering them the opportunity to feel good about it. This could be particularly effective for tasks which have long-term rewards.

Other key aspects of Flow are knowing 'what' and 'how' to do the task at hand and having the skills to accomplish it [31]. Designed interactions could help people break large tasks into more achievable steps helping increase their confidence and use their current skill levels in order to experience Flow. However, if Flow is, fundamentally, about balancing challenge levels and individual skill levels[32], then it is important to acknowledge that sometimes people have to do tasks where this is not the case. Consequently, designers may need to consider another strategy. Rather than designing for Flow, they could increase task desirability by adapting the environment. Creating environments and interactions that users find desirable, may make tasks seem more enjoyable (or less disagreeable). Grading by a fire, with a hot drink steaming beside you seems more appealing than sitting in a hard chair, under fluorescent lights.

Starting a task is the most difficult part, and distractions can cause people to 'start' (re-engage) several times, even within one working session [6], [13]. Once people have started, the distractions and fears that were motivating them to procrastinate are less noticeable and they often find the task more pleasant than expected [13]. By creating pleasurable interactions when initiating work designers may be able to use the salience of starting a task to increase task desirability. Experiments investigating cognitive abilities during dual tasks[33] indicate that interactions on different sensory channels (touch, site etc) to the main task can be processed without interfering with work[34]. We suggest that designers be careful not to create interactions that could present barriers to the work, and to consider how the experience could change over time, to avoid mundanity. We also predict that different solutions may be needed for 'starting a task' versus 'restarting after a distraction'.

Alternatively, designers could increase desirability through adding extrinsic rewards —a core component of gamification. Gamification aims to replicate the principles of gaming in non-gaming contexts and is commonly used by designers to increase engagement [35]. Extrinsic motivation is known to be helpful for changing behaviour [36]–[38] and can be attractive as it seems simple to design a reward system. Still, we advise designers to look carefully at schedules of reinforcement and interval times [39]; just a few milliseconds difference in timing rewards can make the difference between a successful system and a gimmick that loses its appeal. Notably, several studies indicate that extrinsic rewards may reduce intrinsic motivation [38], [40]. These results are not conclusive

[41] but do highlight the complex relationships between different types of motivation. If using extrinsic rewards, we recommend considering social rewards that are concurrent to the tasks. Social rewards are hardwired for neurotypical people and are strong motivators [42]. We suggest offering social rewards during the task rather than the end, which could add to the task pressure consequently increase procrastination [10], [43]. We conjecture that concurrent rewards may mimic intrinsic motivation so people judge the task itself as enjoyable. This is why having a 'study buddy' can be so effective[44].

2.2 Make the Distractions Less Desirable

Removing Distractions. Designers may be able to reduce the required willpower by removing distractions, thus making them less desirable in the moment—studies show that "Out of sight, out of mind" isn't just a saying [6], [27], [45]. Online Procrastination guides [6], [46], [47] suggest using tools like website blockers or devices like Saent [48]. We conjecture that some people find it easier to work in public spaces [44], because the social norms limit some of the distractions. Interestingly, the act of removing the distractions can be as difficult as starting the task [49], particularly if a person's leisure and work share the same space. We propose that making distractions easy to remove and not associated with 'depriving oneself from pleasure' may be a helpful approach.

Drowning Out Distractions. On the whole external distractions can be removed or avoided. However, internal distractors (thoughts) cannot be simply removed. It takes willpower and effort not to follow a daydream or give in to self-doubt [6]. Stress narrows peoples' attentional focus [50–52] which can aid in ignoring internal distractors—an apparent benefit of working last minute. Unfortunately, this narrowed attentional focus can also result in poorer work outcomes and missed opportunities [51], [52]. Designers may be able to recreate the positive aspects of narrow attentional focus by using sensory stimulation to 'drown out distractions'. According to the Perceptual Load Theory of attention processing, overloading perceptual inputs, may reduce vulnerability to distractions as there is no perceptual capacity left to process new information. Murphy, Groeger & Greene [53] give an excellent example: if a person is reading, a buzzing fly is likely to pull their attention away from their book. However, if the text is printed on mostly transparent paper with words on both sides, their sensory attention has to work hard to decipher the letters and the person is not likely to notice the fly. As long as the additional sensory inputs do not require cognitive attention, they generally do not interfere with cognitive performance [34], [54]. We conjecture that designed environments or artefacts could use sensory channels to pleasantly overwhelm a person's perceptual processing. The sensory inputs will need to be subtle enough not to divert attention from the primary task. For example, some people find sounds or music helpful when writing, but find songs with lyrics distracting. Companies like Fuzeinteriors [55] already place high important on the sensory experience of work spaces. And installations like Sensorium by Les M Studio [56] offer excellent examples of engaging touch.

Negative reinforcement. Alternatively, designers could use negative reinforcement as a motivation strategy [57–59]. Principles of negative reinforcement suggest a 'less pleasant environment' when people are 'off task', will make distractions less appealing and motivate people to focus. For example, when a person is 'off task', the chair they are sitting on could react becoming bumpy and less comfortable; and when attention is redirected to the task, the chair could become comfortable again.

When reviewing technologies that have been designed to address procrastination, we found negative reinforcement was a popular strategy. The smartphone application (app) "Yelling Mom" is a prime example; an alarm yells at the user until they do their work [60]. We identify issues with this approach, negative reinforcement becomes ineffective if it can easily be avoided: if the user can turn off the phone more easily than starting an assignment, then it is not likely to add motivation. Again we invite designers to consider carefully how negative reinforcers may become a barrier to the task: interventions where it easier to leave the workspace than to start work may, in fact, reinforce procrastination.

Scaffolding. It is possible, though not necessarily advisable, to use guilt as a negative reinforcer. Anderson suggests 'scaffolding' to force non-procrastination [45], [61]. He suggests creating environments that constantly remind people to do their work [61]. The presence of clocks, reminders and post-it notes makes it difficult to dismiss work or justify delay. Though quite possibly effective, we are wary of this approach, on the presumption that it is not necessarily conducive to a pleasurable work experience. Motivation from guilt, rather than enjoyment, will likely not boost positive emotional associations, which in turn would not increase intrinsic motivation. If designers were to consider using this motivation strategy, we suggest integrating periods of time free from pressure so people can experience positive downtime. Additionally, if the designed interventions 'invite' people to work, rather than 'pressure' them to, then the associated guilt may be reduced; but the reminders would still be there.

2.3 Implementation Intentions (Pre-Decision Making)

Finally, people can reduce willpower by spreading out the decision making. Implementation intentions is a psychological strategy employing pre-decisions to reduce spikes in cognitive load [62]. In the case of procrastination, the procrastinator would make the decision of when and what work to do beforehand. When the time comes to act, the pre-made decision requires less cognition. Implementation intentions are most effective when pre-decisions for distractors have also been made [63]. For example: "Even if I don't feel like starting, I won't open the news, not even for one article"; or "if Facebook is still open from yesterday, I will close it before looking at the timeline". These pre-decisions makes the cognitive process simpler when the event happens [64]. There is an opportunity for Designers to create physical reminders of pre-decisions. For example, a coffee table might automatically transform into a desk at the time the person intends to work. We expect that physical reminders will not only reinforce the pre-decisions but also make it harder for people to ignore them (similar to non-procrastination scaffolding).

3 Emotion Regulation Perspective

From an 'emotion regulation perspective', people tend to procrastinate to avoid the negative emotions they experience when approaching a task [25]. The three types of tasks evoke different emotions so they should be addressed in different ways.

3.1 Effortful with Little Reward

Tasks which are effortful with little reward evoke frustration. Such tasks could be helped by reframing them so their value and rewards are perceived better [50], [65]. How to reframe will vary. Herein, we recommend focusing on latent benefits of the task, or the accomplishment of doing the task. Anecdotally, people find that counting focused hours or progress is useful way of feeling good. We suggest designers could reward users with subtle changes in the environment as they work to highlight the passing of time or progress. (This also links with one of the aspects of Flow mentioned earlier [31]). When highlighting the passing of time, be careful it doesn't cause people to regret the hours they have put into unrewarding tasks.

Simple extrinsic rewards could also be used to make the outcome appear more worthwhile [36]. Though as mentioned earlier, there's a danger of the task becoming even harder when the rewards are no longer present. If designers were to employ gamification we propose carefully developing the rewards that fit the specific task and context: rewards that appear condescending will make the situation worse.

Conversely, a designer could address the frustration rather than the reward. Many people find grumbling and sharing their frustrations to be a release because it allows them to acknowledge their emotions [66], [67]. As long as this doesn't become rumination, wallowing, or a form of procrastinating, then we think a designed interaction for people to express their frustrations may help them move on to the task.

3.2 Tedious Tasks

Simple tasks that are tedious may be addressed by making the process itself more stimulating and enjoyable. The performance of tedious clerical tasks were improved by just adding the smell of peppermint to the environment [68]. Designers could engage a variety of sensory inputs, but should be wary of not slowing the process as this will increase the tedium. We also suspect that if people see the stimulation as gimmicky, they are likely to reclass the task as effortful with little reward.

The theory of optimal stimulation may be particularly useful for understanding people's behaviours during tedious tasks. Optimal stimulation states that people function best at a specific stimulation level [69], [70]. If people's stimulation is below this, they self-stimulate, similar to those with ADHD, seeking out new engaging activities or engaging their senses through movement and sound. If individuals are over stimulated then they withdraw, similar to those with autism, focusing on small details and creating 'white noise' sensations to drown out inputs. We expect that if designers can increase peoples' stimulation during tedious tasks, then their perceived boredom and their desire to redirect their attention will decrease.

3.3 Anxiety

People find tasks that cause anxiety particularly difficult. Generally, the best way to reduce the anxiety is for the person to start the task and discover that they are in fact capable. Interestingly, experience sampling studies have found that people feel happier when they are doing the task they have been putting off [13], [71]. In fact, people often wish they had started earlier so they "had more time to spend on the interesting aspects"[13]. The anxiety associated with task engagement is often not acute anxiety but low-level anxiety caused by uncertainty and the unknown. We identify that designers have two general approaches open to them. Either they can reduce the anxiety directly or can they distract people from it, aiding progress before they give up. We speculate, working last minute can be attractive because people no longer have time to worry.

To address anxiety directly, designers may use physiological approaches to activate the para-sympathetic nervous system – encouraging people to breath more slowly and assume relaxed body postures[72], [73]. Other than exercise, this is one of the most reliable ways to reduce stress without addressing internal thoughts [68]. Many applications already exist to support relaxed breathing[74].

Further, environments could be designed to counteract the anxiety, by evoking associations of comfort and social support. Social support has been shown to be a significant moderator in stress [75]. A designer could create environments that remind people of their support networks during a task or they could provide communication channels to facilitate social support in work environments. There is also potential for design interventions to directly simulate social support. Touch is a vital aspect of human connection [76]. Social touch is as effective at communicating emotion as facial expressions and is stronger than verbal communication [76]. Social touch has been shown to increase compliance in some cases, and decrease anxiety, as well as raise serotonin levels and general health outcomes [76]. Simulating touch may allow people to experience the effects of social touch even without others. Several attempts have been made to simulate touch, particularly in autism research after Temple Grainden's hug machine[76]–[78]. These devices have not been empirically tested, although the techniques are widely used, and products such as weighted blankets are common in the autism community. There is an opportunity for designers to analyse the aspects of a comforting touch and then apply them through non-human mediums. Interactive furniture that subtly hugs the user may be help people feel supported and comforted. Designs like Hugvie®[79] and TapTap [80] are used in the context of remote communication, and when empirically tested indicate drops in cortisol[81].

Distraction from emotions is a common (though not always healthy) way to regulate emotions. Pychyl and Sirois described procrastination as 'maladaptive emotion regulation'[25]. By avoiding the task, the procrastinator avoids negative emotions. We think helping people sidestep anxiety may be the most effective way to offer immediate aid. Over time this will build positive associations and hopefully reduce the anxiety. For procrastination, ignoring emotions can be positive because doing the task addresses one cause of the anxiety.

To distract from emotions, the theories of optimal stimulation [70] and perceptual load [53] suggest that people may be able to direct 'spare' attention towards low-level stimulation rather than their anxious thoughts. If designers were to combine emotion distraction with a social touch they may be able to create a low-level sensory stimulation that shifts attention, as well as giving an emotional boost. We would encourage designing two-way interactions that give both the user and object a prominent role. For example, A desk could react to a user's nervous fidgeting and by squeezing their hand simulating a social touch. Similar to TapTap [80].

5. Developing Research and Conclusion

The previous sections have contributed to design research by outlining the ways that a design space for addressing procrastination can be approached and informed by psychological perspectives. The general strategies proposed herein could be tailored for specific contexts and tasks. Our current research takes these strategies and applies them to the context of tertiary students working at home. We are focusing particularly on students because: firstly, they have the highest levels of procrastination [7]; secondly, because they are still learning to self-regulate and, if we can help develop positive strategies early, they will hopefully carry on in later life [82]: and thirdly, they do not have fixed work spaces which means they often work in spaces that are also for used for leisure. Spaces used for leisure are particularly hard to work in because they present habituated distractions and do not trigger work behaviours through associations [83]. We aim to tailor the design interventions for the different stages of task engagement. Interventions to start a task will differ from those to maintain a task. We also acknowledge that finishing is a crucial part of the process. At the end of a work session, people can feel enjoyment, pleasure and pride, which are key to increasing their positive associations with work. This has design implications, for emphasising the feeling of achievement through designed interactions.

This paper provides designers with a grounding in the some of the psychological theories of procrastination. It offers suggestions for how these insights can inform and guide the design of the physical environment and interactive artefacts within it, in order to address procrastination. Design strategies will differ depending on whether the designer addresses willpower or emotion regulation, and depending on what type of tasks they want to support. We hope that this cross disciplinary synthesis will provide a framework for design interventions that inspire and challenge tangible research outcomes.

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R2S: Designing a Public Augmented Printed Media System to Promote Care Home Residents' Social Interaction

Abstract

Social interaction between care home residents was found to be limited and positive peer relationships were difficult to establish. Our research explores the potential of designing socio-technical interventions through digitally augmenting residents' daily activities in public spaces. In this paper, we present 'R2S', a system aiming to support residents' social interaction by augmenting public print media in care homes. We describe the design motivations, design process and a user trial of R2S. The result indicates a promising design direction to create shared experiences by augmenting individual behaviors in care homes. Implications are also discussed in three levels to inform future design of social technologies in public caring environments

Keywords

Nursing Homes, Social Interaction, Public Displays, Augmented Reality

1. Introduction

Positive peer relationships have been repeatedly identified as an essential element of care home residents' quality of life [1]. However, in the past decades, in spite of improving physical caring environments, boredom, loneliness, and helplessness were still reported as common problems in care homes [2]. Although researchers suggested that residents should go to the public areas more often to engage with others [3], many surveys indicated that most residents still spent a large portion of their time in their private rooms alone and inactive [4], which is a strong predictor of many mental diseases [5]. Hosting various scheduled activities has long been recognized as the main solution to attract residents to go to public spaces, but this kind of intervention has many limitations [6]. Besides, Roberts et al. (2015) found that the social relationships between residents were mainly established through informal and unplanned activities [7]. Claessens (2013) also argued for the importance of providing social opportunities rather than enforced sociability [8]. Therefore, more innovative ways are needed to make the public caring environments more attractive and engaging to support residents' social interaction [2]. In recent years, various public systems have been designed to socially connect people belonging to one community. However, older users have long been playing a minor role in designing novel technologies. Research and implementation of such technological interventions are scant, especially among institutionalized older adults. Our research aims to provide knowledge and implications of designing socio-technical applications in residential care settings. In the following part, we firstly learned lessons from previous work, and propose a design direction to promote residents' shared experience by digitally augmenting their daily routines. Then, we present our exploration of designing a public augmented print media system (R2S). A user trial was conducted to collect initial feedback and further refine the system. The findings could inform future research and practice on designing technological social interventions in caring environments.

2. Motivation from Previous Work

The early explorations of socio-technical interventions in care settings could be traced back to the 1990s when researchers sought to reduce demented nursing home residents' agitated behaviors by adding visual, auditory, and olfactory stimuli to simulate different types of environments inside nursing homes [9]. With the proliferation of modern technologies and the increasing demands for high-quality care facilities, socio-technical interventions have been explored in diverse forms. One branch of this area attempted to develop assistive social robots that function not only as an interface for older people to digital information but also an intermediary agent to connect them by providing companionship [10]. However, many studies identified older adults' reluctance toward robots with a social purpose for being non-authentic in their expressions and interaction with humans [11]. Our research mainly followed another direction where the explorations aimed to influence residents' social behavior or feelings by designing shared displays [14]. For example, Gaver et al. (2011) designed a mobile device called "The Photostroller" to support residential social care by continuously displaying a slideshow of images from social media [12]. Residents can select image categories with a removable control unit. Kang et al. (2018) developed an interactive gallery called "OutLook" that can display real-time views of typical local places [13]. Both of the case studies conducted field trials and found a similar problem that many residents tended to passively watch instead of actively interacting with the displays. They rarely used the interactive features without the facilitation from caregivers, family members or designers. The main reason was concluded that the two systems failed to fully blend in residents' living environments and stable daily routines, which would decrease their time and frequency to interact with technologies and other people. Therefore, we assume that, since it is difficult to change their long-term habits, why don't we enhance their current daily routines instead of introducing more new interfaces or interactions? Can "less is more" be a principle in designing social technologies in care settings? We believe it could be a promising direction to explore.

According to many observational studies, reading is one of the most common behaviors in public caring environments [2, 4]. Various kinds of print media (books, magazines, newspapers, etc.) are usually provided to continuously support residents' daily entertainment in public areas. However, restricted by the conventional form, most print media products are designed for individuals. Reading and communication rarely take place simultaneously. Furthermore, due to the physical and mental degradations, reading is getting increasingly challenging and less attractive for many older people, which has the potential to be augmented by larger displays and dynamic forms of digital information.

Given the opportunities and challenges, we turned to explore the design potential of augmenting print media by technologies to increase the attractiveness of public print media and promote shared experiences. Although the technological solutions to augment print media have been extensively explored in the fields of education, exhibition, commercial promotion and entertainment [16, 17, 18, 19], most of them had certain requirements on users' precision and proficiency, which was very difficult to be accepted and easily used by older users [15]. Moreover, most of these studies lacked further considerations of social contexts, especially in caring environments.

3. Design Process

The design process consists of a preliminary study and participatory design sessions. Both of them were conducted in the open areas of Dutch care homes belonging to a caring organization in Eindhoven. It has set up 22 nursing homes with similar environments and services in this city. Although most participants had physical disabilities or sensory impairments in varying degrees, all of them had normal cognitive functions because the care homes had separate areas for the residents with dementia.

3.1 Preliminary Study

Before designing the system, several questions need to be addressed. For example, among so many kinds of print media provided in nursing homes, which have the potential to be augmented? Which genres of print media products have the potential to trigger residents' social interaction? To answer them, we started with a contextual study to investigate 21 residents' use of print media, preferred genres and their related social demands and barriers [6]. The method used was a combination of card sorting and semi-structured interviews. The results indicated that reading newspapers was one of their most common choices in public spaces. We also found that news was their favorite genre not only personally but also socially. Although newspapers were often used by caregivers as an evocative material in scheduled social activities, they rarely trigger residents' communications in their daily lives due to the difficulties of describing and understanding between each other. Guided by these insights, we started with newspapers as an example to design a prototype system.

3.2 Participatory Design Sessions

The participatory design (PD) sessions were conducted with 8 residents to establish a preliminary concept. In each session, the designers acted as an impartial moderator to collect user requirements through active dialogues with residents. The topics of the dialogues focused on the participants' use of newspapers, their preferred sections, perceived attractiveness and sociability of the combination of digital and print media [20]. We also brought newspapers and common smart devices such as tablets and smartphones to simulate future scenarios. We found the participants' perceived attractiveness and sociability of augmented print media were positive. The priorities of their design requirements were concluded as follows:

1) The interaction with print media should be simple, effortless and interesting.
2) The interaction with digital information should be as simple as possible.
3) The digital interface could be designed with familiar elements to older adults.
4) The system should allow residents to freely decide the content and time to augment.
5) Videos and images are the main forms of digital augmentation.
6) The digital information should be continuously updated.
7) The systems should be used by individuals or shared in small groups rather than the whole public area.
8) Residents' common interests such as local news are the primary contents to augment.

4. Design of R2S

4.1 Concept Design

Although many design criteria derived from the PD sessions were still general and not enough to construct a completed system, we believe it is necessary to

Fig. 1. An overview of the preliminary concept design: R2S

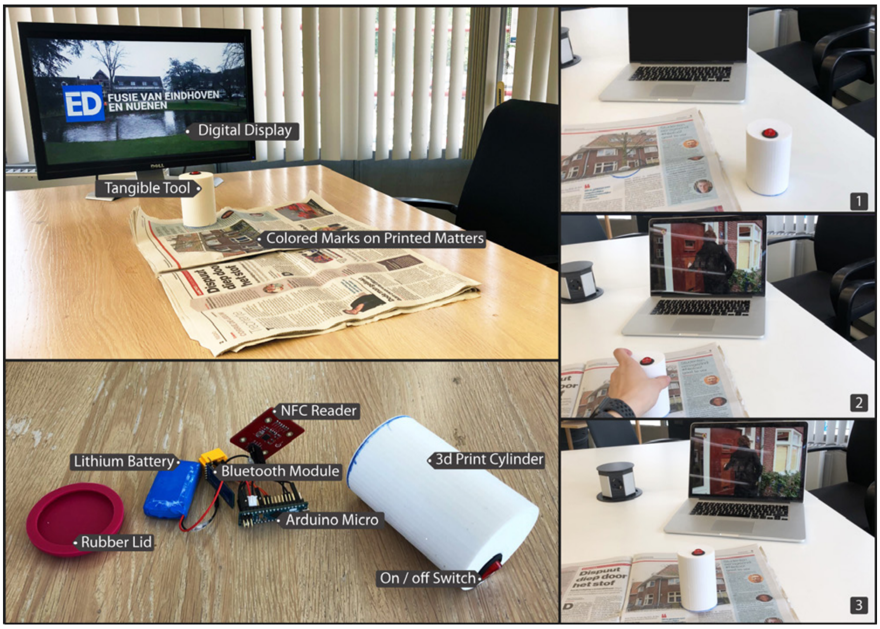

Fig. 2. The prototype implementation of R2S

explore an initial concept to be refined through the following user tests. Figure 1 provides an overview of the preliminary system design called ‘R2S’ (reading to sharing). It is a tabletop system distributed in the primary public area of care homes. Each unit of the system mainly consists of a tangible tool, newspapers enhanced with special marks (colored circles) and a digital display running R2S application. The marks can indicate the interactive areas on the newspapers. These areas are specially enhanced by related technologies for printed matter recognition. The tangible tool is a wireless tabletop device to identify each mark. It has a concise appearance with a white cylindrical body and a red switch at the top. It can stand steadily so that users do not need to keep holding it. Residents can decide when and which content to augment. They just need to place it on a certain mark to get access to corresponding digital content from the screen. The digital media could be directly played online from news websites or social media so that residents can check the updates. The digital interface is also very simple. It directly displays digital videos or images with brief descriptions in digital texts. When no one uses the system, the screens display nothing to avoid disturbing. As shown in Figure 1, residents can not only use R2S individually to compensate their physical barriers of reading newspapers but also share it to their social partners through the public display, which requires very little effort to describe and understand.

4.2 Prototype Implementation

For rapid prototyping, we adopted NFC technology to bridge printed content and digital information. As shown in Figure 2, multiple transparent mini NFC tags are attached to newspapers. They are surrounded by sketched blue circles. The shell of the tangible tool is 3d printed with ABS. An NFC reader (RC522) is installed at the bottom of the shell to recognize nearby NFC tags. The tangible tool can be paired with a computer via Bluetooth, which is realized by a Bluetooth module (HC-05) connected to an Arduino Micro board. The board is powered by a lithium battery (7.4V) and also in charge of the data communication with the NFC reader and computer. The R2S software application is simulated with a live-programming platform VVVV that is characterized by real-time rendering and quick visualization. The identity code of each tag can be read by the tangible tool and sent to the computer via Bluetooth. The simulated application can receive the code, link them to related local or online media files and display.

5. User Trial

To initially collect user feedbacks and further refine R2S, a user test was conducted in the canteen of a care home belonging to the same caring organization mentioned above. According to the caregivers, the canteen was the main public area where most residents would like to stay. Five residents (2 males and 3 females, aged from 65 to 92) agreed to participate individually. They were recruited based on the same principle with the one in the design process.

Each session was started with a brief verbal introduction of the design contexts and purposes. Then, we showed the participants six short videos of some existing solutions of augmenting paper interface to avoid restricting their minds within our design (Figure 3). The solutions were also printed as cards to facilitate recall and comparison. To test R2S, we firstly presented a 1-minute animated storyboard to provide an overview of the future scenarios. After this, we offered them the prototype to freely experience for 10 minutes and provide feedback. According to the residents' preferences reflected from the PD sessions, we enhanced the newspaper through four kinds of content including a piece of entertainment news, a piece of local news, real-time weather information and crossword puzzles. In the final step, we encouraged the participants to refine the prototype system or propose new solutions by quickly sketching on paper or digitally visualizing with the live programming environment (VVVV). We also prepared some related physical design references to facilitate this process (Figure 3).

6. Result

6.1 Concept Feedback

All of the participants showed a positive attitude towards the idea to bridge print and digital media. However, none of them thought the demonstrated existing solutions could be applied in care homes. Even though we explained simultaneously, few of them could eventually understand the demonstrated user interactions that have been taken for granted by young people. P1 said: *"My granddaughter taught me many times, but I still cannot use it (tablet)." "They look too futuristic. People here may get curious, but most of them always keep a distance from the innovations."* P5 remarked. When showing the storyboard of R2S, all the participants could quickly understand the concept because it illustrated their daily lives. Overall, they were optimistic about the future application. P5 said: *"Such thing is important to provide different things for people here to spend their time. Their life is too structured."* He could already envision many social scenarios such as watching sports news and discuss local events together. They all agreed that the canteen was the ideal place to install the system for more social opportunities. P2, P3 and P4 emphasized the importance of distributed displays to entertain smaller social groups. In addition, all of them agreed that the tabletop tangible interface and interaction was much friendlier than the demonstrated modern digital devices and interactions.

6.2 User Experience

Although most participants needed our guidance to find the marks in the beginning, we found that they already learned how to use the system from the storyboard. When they got access to the digital augmentations, they firstly showed surprised and delighted with the experience. All of them could not help talking about

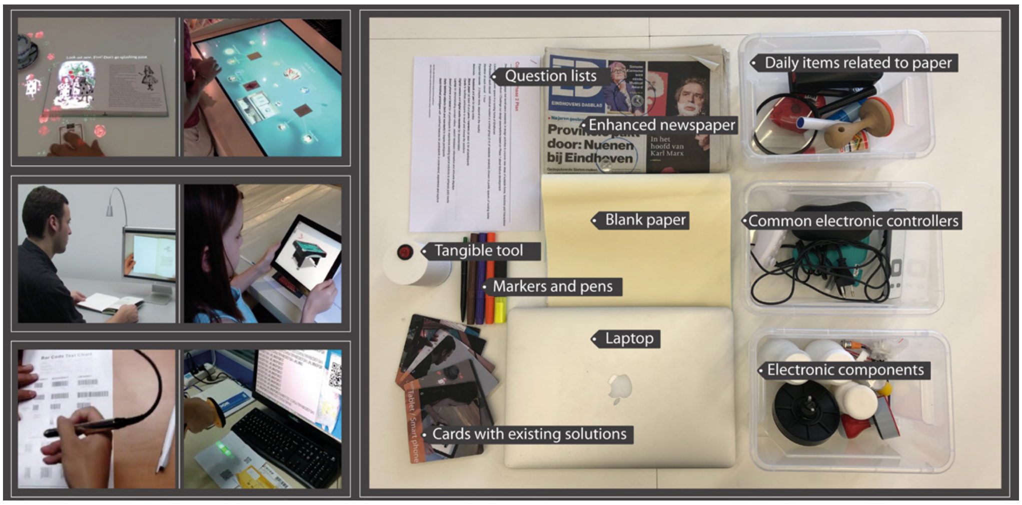

Fig. 3. The demonstrated videos of existing solutions and the materials used in the user study.

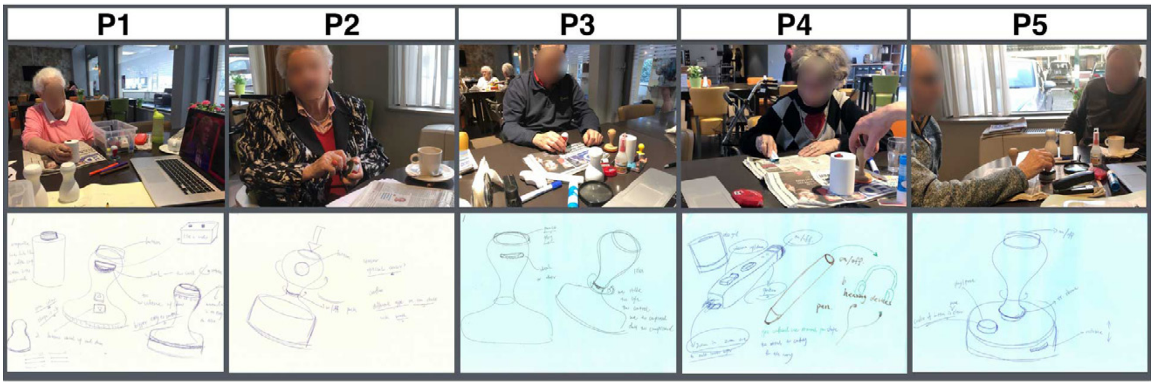

Fig. 4. Five participants experienced the prototype and proposed ideas to refine R2S.

the detailed information on the screen, especially the local news. They praised the simplicity of the system. *"Of course, it is very new, but it is not complicated. People will get familiar with it quickly."* P1 said. Even though we encouraged them, no additional digital interface or interactions were required. *"Select and watch. That's it. The simple the better."* P5 said. Although the tangible tool was very easy to use, some participants hoped it could be more attractive. *"It should stand out among other daily items on the table otherwise people like me could not notice it."* P2 suggested.

6.3 User Refinement

To refine the system, all the participants started with the tangible tool because it was what they directly interact with and they were more familiar with physical objects. They relied on the design references very much for inspiration. As shown in Figure 4, four of them thought the shape of the stamp was a better form because it is more interesting and more convenient to pick up or hold. P4 thought the pen was her favorite form because of better mobility, but she also admitted many residents here could not use pens for neuromuscular diseases. They all pointed out the importance of volume control because the acoustic environment in the public area was very unstable. *"The volume needs to be loud if the group is watching it, but it may disturb others if it is too loud."* P4 said. Besides volume control, they were also encouraged to propose other potential functions, such as pausing, switching images, rewinding and zooming in (Figure 4). However, they repeatedly emphasized that these functions were not necessary if they would make the system complicated. *"You must keep it simple. Just basic functions otherwise people here will not use it."* P2 said. In addition, most participants hoped the screen should be a little larger for the better social experience and the marks on the paper could be highlighted with brighter colors or other materials. Their proposals on digital interfaces were very limited. Only P1 suggested there could be some simple digital instructions to guide new users.

7. Discussion

The participants' positive attitudes towards R2S identified a promising direction to design social technologies by augmenting their daily items or activities. However, their resistance to the demonstrated existing solutions also showed the necessity of certain design principles. R2S was designed following the criteria that we gathered from the PD sessions. Many requirements were further confirmed in this user trial. We believe this study could shed a light on designing socio-technical interventions in residential care settings. We discuss the design implications in the following three levels.

7.1 Design for Accessibility

The sociability of such technologies can hardly be realized if residents keep a distance. That might be the reason why the top three requirements from PD sessions focus on good accessibility. The simplicity and familiarity of the form, function and interaction is the premise for the residents to start to use the technologies. The feelings of technical intrusiveness should be minimized. In this case, tangible interfaces and interactions were preferred by the participants. All the participants refined the system into something they were familiar with such as stamp and pen. Their proposed function and interaction were inspired by their experience of using television and radio. Although various new features were proposed in the refinement, most participants were willing to sacrifice them to keep simplicity.

7.2 Design for Attractiveness

Based the first level, as the requirement No.4 indicated, the participants pursued better attractiveness to keep using the technologies. Besides the sense of control, this user trial identified other requirements related to pragmatic and hedonic qualities. In this level, designers should consider not only ergonomic factors to lower their physical barriers, but also aesthetic, psychological and emotional factors to increase their confidence and interest to use. In this case, the participants proposed various new forms, functions and interactions to meet their different needs. However, designers should not enrich the user experience by sacrificing the accessibility. We suggest the systems could be designed in a hierarchical structure. The basic functions should be embodied in simple forms and interactions for new users and the residents with lower capabilities. Some "hidden features" could also be provided for richer experience and long-term use.

7.3 Design for Sociability

We believe the sociability could be naturally achieved once the accessibility and attractiveness are properly addressed. In order to gather in-depth feedback and given the difficulties to simultaneously involve multiple older people to refine the system, this user trial was conducted with individuals rather than groups. Although the social functions of R2S could not be directly evaluated, from our observation and user feedback, we initially confirmed the requirement No.5, No.7 and No.8. The result indicated that the properties of shared displays (size, number, location, etc.) and the displayed content are two important factors that could contribute to the sociability, which needs to be further evaluated in group tests. We also believe the requirement No.6 is helpful to sustain residents' social interaction, but it also requires future field tests in longer terms.

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Topic 6.

Design and Semantics for Health and Inclusion

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Nova Creatio: A Clinical Perspective on Rehabilitative Everyday Objects for People with Chronic Stroke

Abstract

Stroke affects 15 million people worldwide and is the third most likely cause of death. Unilateral impairments after a stroke affect the ability to carry out daily activities with the affected arm and hand. The preferential use of the less affected side can lead to a so-called learned nonuse. Although a number of assistive everyday objects are available to people with stroke, little is known about how everyday objects could be designed to be useful for a self-directed rehabilitation and how the user experience of stroke patients could be evaluated to design complex digital and/or physical systems. We developed a set of design criteria that other designers can use to create rehabilitative objects. We interviewed 12 stroke health professionals to investigate what the user experience in the rehabilitation process looks like, and which clinical criteria need to be considered in the context of designing rehabilitative objects. Interviews were analysed using thematic analysis. Results indicate that to encourage the use of the affected arm and hand in people who live at home and have reached the chronic stage of the recovery, self-efficacy needs to be in place. Furthermore, people must undergo a behaviour change in order to overcome the learned nonuse.

Keywords

Stroke Rehabilitation, Qualitative, Design Criteria, Learned Nonuse

1. Introduction

A stroke is a form of brain injury caused by lack of blood flow or oxygen delivery that leads to irreversible injuries to parts of the brain and can affect physiological as well as psychological abilities. A stroke affects approximately 15 million people annually worldwide, causing the deaths of one third, while another third survives with persistent disabilities [1]. Physical impairments commonly affect one side of the body in the form of hemiparesis, which is weakened muscles, or hemiplegia, which involves the paralysis of muscles [2]. Recovery from a stroke is a complex process that is likely caused by a learning-dependent process and a factor called spontaneous neurologic recovery [3]. The concept of spontaneous neurological recovery [4] is often referred to when explaining why improvements of motor impairments seem to plateau after the first weeks [5] in the upper limb within the first three months [6]. After this time, stroke survivors are likely to compensate for lost motor function of an arm with an enhanced movement of their less affected side, leading to a self-taught suppression of movement named the ‘learned nonuse’ of the affected arm [7]. Learned nonuse can be overcome by applying a physical restraint on the affected arm to evoke an initiation of use of the affected side while providing repetitive, contextualised training and behaviour change components. The intervention based on this principle is named constraint induced movement therapy (CIMT).

Assistive technology [AT] is used after a stroke to compensate for the loss of functionality of the upper and lower limb and enable a safe discharge into the community. AT can be part of activities involving employment, mobility or communication [8, 9]. Commonly provided products after discharge from hospital are used for bathing, walking, and home adaptations such as modification of stairs [10–12]. Products and technology that fall into the category of assistive products help compensate for the loss of functionality rather than contribute to the rehabilitation process.

While these objects may help stroke survivors carry out everyday activities again, we argue that they facilitate compensatory movement patterns and potentially 'learned nonuse', as they help avoid the use of the affected limb. We believe that everyday objects could be designed to facilitate the use of the stroke patients' affected side, therefore contributing to their recovery. It has further been reported that people suffering from complex regional pain syndrome can express behaviour patterns similar to learned nonuse after a stroke [13]. Designing for initiation of use of the affected limb for stroke rehabilitation is a highly complex human experience and specific design strategies can help designers to design digital or physical systems for it [14]. Our design strategies could potentially be beneficial for other clinical populations as well. Also, at this stage it is unclear what kind of design criteria such objects need to fulfil. We have developed a set of design criteria that other designers can refer to in order to design objects for a society that is becoming unavoidably older and more likely to survive a stroke and be affected by it. We conducted 12 semi-structured interviews with healthcare professionals to gain an understanding of clinical factors influencing the user experience of such novel designs and to develop a set of design criteria that other designers can refer to in the process. This will hopefully help designers in this challenging and complex system that involves non-typical physical abilities, cognitive challenges, and intended behaviour change.

2 Methods

2.1 Semi-Structured Interview Content

We used semi-structured interviews with stroke healthcare professionals to gain a deeper understanding of the rehabilitation process and strategies that can help to overcome learned nonuse. The primary questions in the interview guide were kept broad and open. Prompts that repeated the key concept were used during the interview to gain more in-depth information. The interview script outlined the main topics for the interview and started with questions about the participant's expertise. The flow of the interview influenced the order in which the remaining primary interview questions were asked. If participants did not elaborate on the concept of learned nonuse or had little involvement with chronic stroke survivors, additional follow-up questions were asked to ascertain if they were aware of the concept. Each interview was transcribed in full. For the interviews a set of main questions and follow-up questions were used:

- How is the rehabilitation process structured?
- Is the movement constrained during rehabilitation? If yes, in which form?
- Which kind of emotions are influencing the rehabilitation process?
- What kind of resources can people with stroke access?
- How would the ideal rehabilitation system look?

Follow up questions concerned the following points:
- How is feedback provided during the rehabilitation?
- What are the steps to set up goals for the rehabilitation?
- How are home-based assignments implemented in the process?
- How do you try to evoke an initiation of use of the affected arm and hand?

2.2 Recruitment

We interviewed health professionals who had worked with acute, subacute or chronic stroke patients in clinical practice or research context. The interviews took between 30 and 120 minutes (average 60 minutes). Non-probability snowball sampling [15] was chosen for this study, in which participants recommended further possible interviewees.

2.3 Thematic Analysis

The transcripts were analysed using thematic analysis in a theoretical or deductive form to identify, report, and analyse patterns and themes within the data [16]. Interviews were conducted by the first author. Initial codes and themes were generated by the first author and reviewed by the second and third authors.

3. Results

3.1 Study Sample

Twelve interviews were conducted with stroke therapists and stroke researchers. Eight interview partners were female and four were male. Three were occupational therapists; two worked as physiotherapists; one worked as a neuro physiotherapist; one worked as a professional therapist focusing on assessment post-stroke; one worked in the tertiary sector and had a background in musculoskeletal therapy; two worked as researchers focusing on stroke therapy; one worked as a scientist focusing on the recruitment of acute stroke patients for studies; and one was a supervisor of a clinic. Two therapists worked in Australia and ten worked in New Zealand.

3.2 Design Criteria

Based on analysis of the interviews, we developed a set of design criteria [17] that can be used in the design process to create everyday objects with a rehabilitative purpose.

Restrain	The interaction with the objects needs to restrain movement to evoke an initiation of use and remind the user to use the affected arm
Contextualise	The object needs to be used within an activity of daily living
Repetition	The interaction with the object needs to be repetitive
Feedback	Feedback needs to be positive, immediate and quantitative
Challenge	The interaction with the object needs to become progressively challenging
Self-efficacy	The interaction with the object needs to contribute to developing self-perceived self-efficacy of the user
Usability	The interaction with the object needs to be achievable for a person with motor impairments after a stroke
Behaviour change	A behaviour change component needs to encourage the use of the affected arm and hand in daily activities e.g., behaviour change contract

Table 1. Design criteria

3.3 Themes

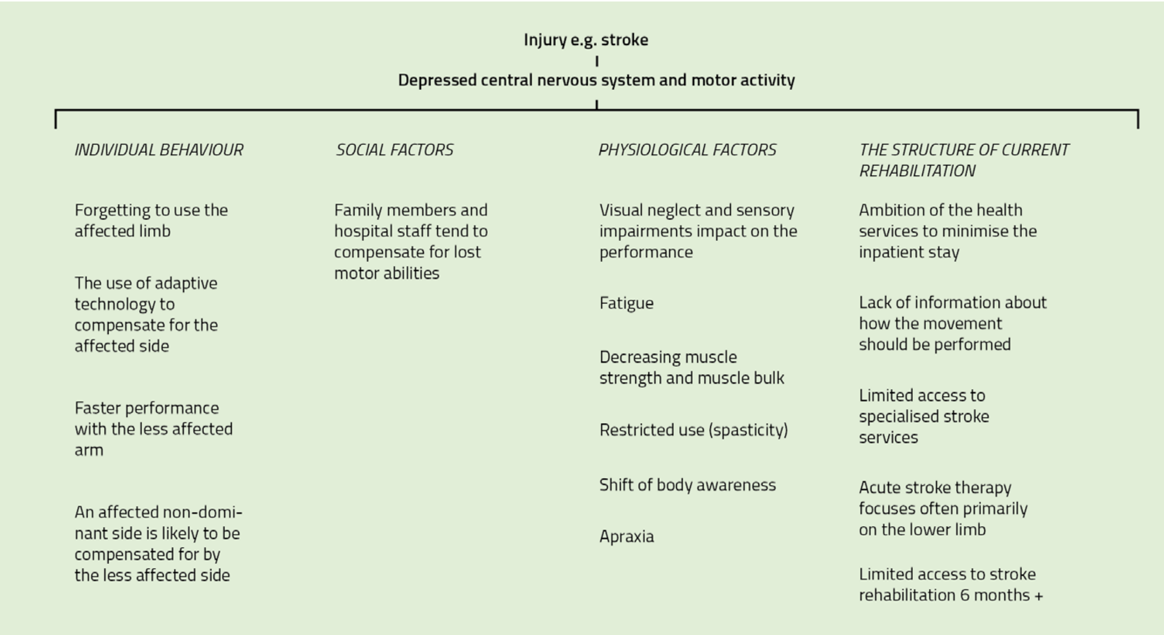
The following section outlines details of the themes that were mentioned during the interviews. The section has been divided into firstly, factors that facilitate compensatory movement patterns after the stroke and consequently a neglect of use of the affected arm and hand and, secondly, the structure of rehabilitation interventions including CIMT that aim to minimise compensatory movement patterns and evoke an initiation of use among people with stroke.

Factors Contributing to 'Learned Nonuse'. The development of compensatory movement patterns and learned nonuse after a stroke is multifactorial and develops over time; see Figure 1. Four different factors were mentioned during the interviews that contribute to its development after stroke: physiological factors, the structure of current rehabilitation, individual behaviour, and social factors.

Physiological factors included factors such as cognitive impairments; apraxia, which causes difficulties in understanding the purpose of the rehabilitation; spasticity; fatigue; visual neglect; a shift of body awareness; and sensory deficits that can cause issues with proprioception and light touch. Once a person starts to compensate with an enhanced use of the less affected side, the muscles on the affected side start to decondition, causing a decline in muscle strength and muscle bulk.

What it tells us is that even a moderate level of impairment will promote nonuse. You have to be really, really good before you routinely use that hand and arm for everyday tasks and that is shocking. So the impairment scale is 66 out of 66 and we have found, and others have found, that before that if your score falls below around 55 you won't use that hand and arm. Your MAL [Motor Activity Log] score will drop below three for both amount and quality of use.
Scientist 01 (Participant 05)

Fig. 2. Factors influencing the development of learned nonuse based on interview results.



A focus in the acute and subacute rehabilitation process seems often to be on the lower limb, due to the stroke patients' wish to be able to walk again. This is also reinforced by the target setting of health services to minimise inpatient stay getting patients ambulatory for discharge. One result is that focus on the upper limb occurs relatively late in the rehabilitation process or not present at all.

It was further mentioned that people with a mild stroke and a rather high level of motor functionality are often confronted with statements telling them that they are not expected to get much better and that the focus is on more severe and acute patients. Historically, the focus on compensating for the loss of functionality occurs once a person has reached the chronic stage. The focus on compensation and use of assistive devices, often provided by occupational therapists, can further contribute to the development of learned nonuse by facilitating the use of the less affected side.

"*They basically tell people when you are on a higher level: 'There is nothing you can do'; 'you are pretty good, so just be glad that you are as good as you are'; 'go home and don't worry about the things that you would like to do'; 'just thank god that you are alive and not too bad'. What is bad, I reckon. I think because I never ever met any stroke patient who told me that they are not too bad.*"
Occupational therapist (Participant 02)

People with stroke tend to neglect the affected side after failed attempts during the acute stage. The self-taught compensatory movement is reinforced through the easier and faster performance of the less affected side and simply forgetting to use the affected arm. It was further mentioned that the effects of 'learned nonuse' seem to be stronger in people with stroke who have reached a late chronic stage, that unsupervised training can reinforce compensatory movement patterns, and that there is an increased risk when the non-dominant hand is affected.

"*People quite often quickly become one-handed especially when it is their non-dominant hand that is affected by the stroke.*" Physiotherapist (Participant 06)

Social factors contribute to the phenomenon as well. Relatives and occasionally hospital staff would try to make the life of the stroke survivors as easy as possible by doing tasks for them.

Initiating the Use of the Affected Arm and Hand. In the following section the initial assessment, goal setting, feedback, emotions and elements of an effective rehabilitation intervention will be outlined. Figure 2 highlights which factors are part of a general rehabilitation right after the stroke. It additionally outlines themes mentioned in the context of learned nonuse.

Essential elements in the rehabilitation process

ASSESSMENT	*GOAL SETTING*	*FEEDBACK*	*EMOTION*	*CRUCIAL REHABILITATION ELEMENTS*
Determine motor deficits *Determine the amount of learned nonuse* Therapist can understand motivations, daily routine and attitude of the person with stroke Baseline for outcome measurements that can be reflected back	*Often have given up trying to use the arm at all* Goals need to be relevant to the person, specific, achievable, purposeful, part of daily activities and potentially competitive Milestones are defined that help during the process to validate improvements Complex movements can be broken down *Demonstrate the correct movement* *Include behaviour change elements such as a behaviour change contract*	Provide positive & instant feedback Person needs to try to perform the movement before feedback is provided Improve movement patterns and be a motivational aid Oral feedback as well as 'hands-on' Visual documentations e.g. video recording offers room for discussion as to how to improve the movement *Increase motivation to use the affected arm* *Increase self-efficacy*	Person has to develop a feeling of responsibility for their recovery process Sadness, fear, depression, grief, anger or frustration about the rehabilitation process and funding Have to accept the loss of their previous role Positive emotions were mainly associated positive rehabilitation outcomes *Confronting situation when they have to work hard during the therapy*	*Further practice and reinforcement of using the affected arm* Repeat the movement Contextualise the movement Include family members in the process Provide information about the structure and purpose of the rehabilitation Incorporate self-directed training elements in a daily routine Take account of the environment such as the person's home

Fig. 3. Elements to initiate the use of the affected arm in clinical practice. Learned nonuse-specific elements are highlighted in blue.

The initial assessment of the impairments helps the therapist determine motor deficits, to understand motivations, daily routine and attitudes of the person with stroke to set appropriate recovery goals. The assessment is further used as a baseline for outcome measurements that can be reflected back to the patient. In the process different assessment scales are often used. If people had reached the chronic stage of the stroke and received rehabilitation interventions such as CIMT, the therapist would determine the amount of learned nonuse by using assessment scales such as the motor activity log (MAL), which is a 30-question interview guide to determine the amount and quality of daily use of the affected arm and hand.

Based on the assessment outcomes, appropriate goals are determined. Goals that are focused on during rehabilitation need to be relevant to the patient, specific, achievable, purposeful, part of daily activities and potentially competitive. The goals should be task-based, rather than abstract ones such as 'I want to use my arm again'. It was further mentioned that they need to be contextualised.

The use of feasible, meaningful and specific goals for the process provides motivation in the often frustrating rehabilitation process. The person has to develop a feeling of responsibility for their process. Once the goals are determined, milestones are defined that help during the process to validate improvements. Complex movements can be broken down into individual components to then be mastered and learned as a sequence. Demonstrating the correct movement helps the patient understand how the movement needs to be performed effectively. Repetition of the correct movement is a core element of the process. Video recording is used to provide visual documentation and offer room for discussion on how to improve the movement.

The role of the therapist was described as a form of personal trainer that helps to reach the rehabilitation goals. They would provide motivational input in the form of feedback during the rehabilitation. Feedback is provided orally as well as in a 'hands-on' form. It should be provided instantly, appropriate for the person and task. Feedback is used to improve movement patterns as well as being a motivational aid.

So you want people to remain as positive and optimistic as possible but you have to be realistic so [...] it just needs to be realistic so saying something like 'Okay… I really see that you want get back to work but you are still in hospital right now'. So what steps do we need to take to get you there?

"You need to do x, y, and z but right now you just need to focus on the first part. To be able to get back to work you might need to be able to walk or you might need to be able to concentrate to complete a task for an hour or so."
Professional therapist (Participant 04)

In order to evoke an initiation of use of the upper limb in people with signs of learned nonuse the therapist has to provide sufficient motivational input and feedback to convince the patient that they should be trying to use the arm and that it is just the learned nonuse that impacts on their functional performance. When people with chronic stroke go back to see a therapist, they are often depressed and have given up trying to use the affected arm at all. When they are asked to work hard during the therapy session it can be experienced as an extremely confronting situation.

"You can't start these guys off trying to do more complicated things because they are doing nothing. So even if you think that they have some capacity [...]. The first couple of days with those people are always focused on trying to get them to just initiate the use of it and that can be anything really."
Occupational therapist (Participant 02)

The emotions that the patient goes through can have a significant impact on the process. Most therapist mentioned mainly negative emotions such as sadness, fear, depression, grief, anger or frustration about the rehabilitation process and funding system. Patients must go through the process of accepting the loss of their previous role such as being the main provider for the family and accepting their new role and limitations post stroke. Rarely would someone see the stroke as a life-changing event that transforms their life positively.

"We even have patients crying in the gym out of frustration because they are disappointed."
Supervisor of a student-run clinic (Participant 09)

Positive emotions were mainly associated with positive rehabilitation outcomes. The feeling of surprise after being able to perform movements was mentioned as evoking the wish to continue trying to use the affected arm in more activities once positive results have set in. It was emphasised that to overcome the signs of learned nonuse the person needs to go through behavioural changes. To secure an effective treatment, carers and family members are informed about and involved in the process. The use of a behaviour contract signed by the therapist and the person with stroke seems to be an effective tool to evoke a feeling of mutual responsibility. There are different techniques such as diaries or home practice sheets that help remind the patient to use the affected arm as often as possible.

The use of a physical constraint as part of CIMT to evoke an initiation of use was mentioned by a small number of our interview participants. The functional purpose is not primarily to restrict the movement, but to remind the patient to use the affected arm and limit the possibility of compensating with an enhanced use of the less affected side. It was emphasised that CIMT, which uses a physical constraint as part of the protocol, is a behaviour change intervention and that the physical constraint is just one element of the intervention.

4. Discussion

Assistive devices such as one-handed chopping boards and stroke cutlery are often provided to people who have experienced a stroke. These devices help to compensate for the lost motor abilities rather than contributing to the rehabilitation process once the person with stroke has returned home. However, devices such as the one-handed chopping board do not restrain movement of the affected arm and hand to contribute to an initiation of use, but enable the user to chop food one-handed. Furthermore, it does not contribute to a behaviour change to make sure that gains made in the process persist in the long-term. These are qualities commonly found in current rehabilitation devices. They demonstrate the lack of guidelines for designers to develop products and systems that properly address and evaluate the needs and complex situations that stroke patients face.
This is not surprising, as designers also experience complexity when designing for stroke patients. Our findings will hopefully assist designers in this process by contributing to the body of knowledge in the discipline through strategies and concrete criteria. We conducted 12 interviews with stroke rehabilitation health professionals to develop an understanding of the user experience of people with stroke from multiple clinical perspectives. We developed a set of design criteria that

can be used to develop objects with a rehabilitative character. Our results indicate that there is little focus on people who have reached the chronic stage of the stroke recovery and, due to financial and other resource limitations, the focus of current rehabilitation is often on the lower limb. It is therefore unclear if people who reach the chronic stage of the stroke have reached their full potential for recovery of use of their upper limb, or have started to express signs of learned nonuse. People with stroke have to face a constant struggle of accepting the new situation or waiting for improvements. Studies indicate that change can be experienced as necessary but associated at the same time with abandoning possible improvements by relying on technical aids, environmental improvements and other people [18].

Our study indicates several factors that contribute to the development of learned nonuse in people with stroke. The descriptions of physiological factors and individual behaviour contributing to learned nonuse correlate with its description in the literature as a self-taught behaviour that develops over time and is reinforced through unsuccessful motor attempts, failure, punishment and pain [19]. Additional personal and physiological factors mentioned in previous studies are: the extensive time to plan, initiate and complete a movement; fatigue; lack of confidence and control over the situation; pain; fear of negative consequences; and fear of becoming dependent on others [18,20].

The findings of this study in terms of social factors correlate with previous findings [21]. Additional factors are social isolation caused by losing contact with friends and colleagues; not belonging to the work community; and attempts to hide the condition in order to appear 'normal' to others [20–22]. Another potential factor is gender. A study by Taub et al. [23] showed that female participants made greater gains on the 'Motor Activity Log' than males, with the possible explanation that the females were faced with a stronger expectation to use the affected arm to perform tasks again that are connected to traditional female roles such as housework and cooking.

Initiating the use of the affected arm and hand. The initiation of use of the affected arm and hand in the chronic stage of the stroke is crucial to overcoming the learned nonuse and decreased functional impairments. In the context of neuroplasticity, learned nonuse has been connected to the principle of 'use it or lose it' [24,25], meaning that once compensatory movement patterns facilitate a neglect of the affected arm and hand potential underlying abilities to use the arm are lost. CIMT offers a detailed intervention protocol to overcome learned nonuse and has been part of our interview protocol. Few participants in the current study were familiar with the protocol. Participants who used CIMT mentioned that the protective safety mitt was preferred over the sling or cast to restrain movement and initiate use of the affected arm and hand. The mitt minimises current criticism regarding the patient's safety by only limiting the ability to use the fingers and hand in activities of daily living, but maintaining the ability to extend the arm in the case of a fall or to compensate for balance problems [26,27]. Therapists who used CIMT emphasised that the intervention aims to evoke a behaviour change rather than being repetitive task training and the constraint is not the main component, despite the name suggesting this [28]. Findings of this study show that the physical restraint reminds the patient of an extrinsic motivator [25] rather than limiting movement.

A number of factors were mentioned that seem to be unique in terms of initiating the use of the affected arm and hand and overcoming learned nonuse in the chronic stage of stroke. These are: assessment of the amount of learned nonuse; strategies to evoke the initiation of use based on assessed motor capabilities and motivational input; and the need to elicit a behaviour change. Feasible goals build the foundation to address learned nonuse successfully. The person with stroke is able to achieve the self-determined goals which improves self-efficacy [25]. Self-efficacy is the perceived competence to attain a specific level of performance in a given environment. It is the subjective cognition to carry out a particular behaviour and does not necessarily relate to the actual competence [29]. It seems to be essential to develop self-efficacy in order to choose to use the affected limb. However, little is known about it in the context of upper limb stroke rehabilitation due to a strong focus on the lower limb in most studies [25].

The mentioned elements of rehabilitation can be mapped to the elements of self-efficacy of mastery experiences, vicarious experiences, and verbal persuasion. However, the fourth source of self-efficacy, the physiological and emotional state [30], was not mentioned. The motivational input and keeping the patient engaged in the process of initiating use of the affected arm and hand was mentioned as a core element. Motivational input aims to convince the stroke survivor that they have the potential to use the arm and that it is just the self-taught behaviour that is stopping them from using it.

To address learned nonuse and evoke initiation of use, the rehabilitative object needs to address and increase self-efficacy beliefs. However, this is a complex process involving multiple factors. Self-efficacy beliefs rely on acquirable skills, increasing the belief of the individual that they can gain these skills, modelling the requisite skills, and defining activities in a way that make them achievable, as well as providing explicit feedback during the process [30]. A behaviour change component can help to secure gains made in the rehabilitation process in the long-term.

5. Limitation

The interview results need to be considered in light of the study sample. Two participants worked in Australia where the health system and stroke guidelines might be slightly different. Furthermore, most of the participants were located close to Wellington and Auckland which are two of New Zealand's largest cities. Access to stroke services might be different in provincial areas of the country and indeed internationally. Since none of the stroke therapists were located in a rural area, there might be a potential bias included in the results. We invited participants working in the private and public health sector. However, the majority of participants worked in private clinics and research contexts where people with stroke might be more encouraged to work on their motor deficits. A closer collaboration with local hospitals and hospital staff might potentially help to recruit participants who work with people with stroke who are less motivated.

It needs to be considered that the strategies focus on objects that can be used in the home environment as part of the rehabilitation process. Home-based stroke interventions were mentioned during the interviews as being a crucial element in the process. Nonetheless, there seems to be no consensus on one specific therapy approach. Furthermore, in New Zealand, access to stroke services for people with chronic stroke and mild impairments seems to be quite limited. One of the therapists mentioned that only highly motivated survivors with sufficient funding would try to improve motor impairments in the chronic stage, which indicates a lack of support for this stroke population.

People with stroke were not involved in this study and they could provide further insight about additional design criteria that influence the use of rehabilitative objects in the chronic stage of the stroke. We have taken account of this and applied for ethics with the Health and Disability Ethics Committees in New Zealand in order to involve people with stroke in the second stage of our research.

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The Semantics of Conspicuity: Design Strategies to Address Conspicuity in Type 1 Diabetes Medical Devices for Adolescents

Abstract

This paper reports on the development of semantic strategies designers can use when designing medical devices for adolescents with type 1 diabetes to match their preferences for conspicuity. Adolescents with type 1 diabetes use medical devices that can cause unwanted attention in public settings and can create perceived social pressures. The semantic strategies address conspicuity by enhancing the traditional medical device to make it more beautiful, disguising the medical device as a non-medical item, concealing the medical device from the public, personalising the medical device for the user, and using technology to advance the medical device. Participatory design methods were used to understand adolescents' experiences of using medical devices in public and how the semantic strategies could be applied to match their preferences for conspicuous or inconspicuous medical devices. Both adolescent participants with type 1 diabetes felt comfortable testing in public; there were occasions where they did not want to answer questions from onlookers. Participants favoured a combination of the semantic strategies. In particular, they were making the device look less "medical" and more beautiful, and utilising technology to make the device more inconspicuous. This research developed semantic strategies to design new medical devices that match adolescent preferences for conspicuity.

Keywords

Type 1 Diabetes, Conspicuity, Semantics, Participatory Design, Adolescents

1. Introduction

Type 1 diabetes is an invisible, chronic autoimmune disease where the pancreas is unable to produce insulin to regulate glucose levels in the body. Adolescents aged 13-18 with type 1 diabetes are required to follow an intensive self-management regimen that includes, frequent monitoring of blood glucose levels, diet, exercise and self-administering insulin [1]. Adolescent development research shows that self-managing in public spaces can be challenging, as it can draw unwanted attention and questions, at a life stage when social acceptance is critical [1]–[3], this is commonly referred to as stigma. The term stigma did not accurately represent adolescent experiences, as it is a word that elicits strong emotions that not all adolescents feel towards their medical devices [2]. Whereas the term conspicuity does, as adolescents do not always want to be the centre of attention and would prefer an inconspicuous device in specific settings.

Previously the priorities when designing for medical conditions and disabilities have been to enable the user while attracting as little attention as possible [4]. This traditional approach has been less about creating a positive image around a medical condition, and more about designing an object which projects no image at all.

Semantics should be considered while designing medical devices [5] for adolescents with type 1 diabetes. Krippendorf and Butter [6] have defined product semantics as: "the study of symbolic qualities of man-made forms in the context of their use and the application of this knowledge to industrial design."

Product semantics requires the designer to understand the context in which the product is used and addresses how the product communicates in its environment [6]. Semantics has been used in past research to describe strategies to elicit surprise through the design of a product [7], similar semantic strategies have been developed in this research; however, the strategies aim to design conspicuous or inconspicuous medical devices.

Adolescents' self-management of type 1 diabetes should be considered in a social context, and the semantics of the medical device should be reflected when designing for adolescents with type 1 diabetes. In this research, we aim to develop strategies that address the semantics of conspicuity to enable designers to create medical devices that provide adolescents with the opportunity to disclose their medical condition when they choose.

2. Methods

2.1 Development of Semantic Strategies

The strategies were developed by analysing literature through thematic analysis [8]. We used the six-phase approach to thematic analysis [8]. The thematic analysis comprised stages of familiarising yourself with the data, generating initial codes, searching for themes, reviewing potential themes, defining and naming themes and producing a report. The literature analysed included five different pieces that discuss strategies to reduce product-based stigma (being the more common terminology than conspicuity). The strategies in the literature were disregarded if they did not address the design of a tangible product. Table 1 describes the final themed strategies.

2.2 Participatory Design

Participants were two adolescents with type 1 diabetes aged 15. One boy and one girl took part in the semi-structured interviews, collage, and sketching. The two participants were involved in the initial development and exploration of the strategies. Participatory design methods were used in the research so that adolescents with type 1 diabetes were able to discuss the semantic strategies and share their opinions and experiences. Participation in design involves open dialogue, communication and trust [9]. Participatory design is a process of investigating, understanding, reflecting, establishing and developing ideas with participants [10].

The participants took part in semi-structured interviews, collaging and sketching activities to discuss their preferences towards conspicuity and to visualise their preferred semantic strategies. A collage is a less formal and more creative way to discuss ideas. It provides adolescents with an opportunity to project personal information onto visual artefacts [11]. The images used for the collage are of products that could be categorised into one of the developed semantic strategies.

Sketching with the adolescents' allowed the participants to sketch their ideal future concepts. The sketch concepts were influenced by the collage and the ideas discussed in the interviews. This is an opportunity for the adolescents to tailor the concepts towards type 1 diabetes medical devices and sketch new more conspicuous or inconspicuous devices based on their preferences. Thematic analysis was also used to analyse the interviews collages, and sketches. Themes from the interviews were identified and compared with the developed semantic strategies.

3. Results

The final results discussed in this section includes the five semantic strategies, the results from the interviews discussing the strategies, or experiences relating to the strategies and the participant sketches of possible medical devices.

3.1 Semantic Strategies that Address the Conspicuity of Medical Devices

The final semantic strategies developed through thematic analysis, range on a scale (fig. 1) from conspicuous to inconspicuous to allow for adolescents' preferences to be met. Strategy 5 and 4 could be both be designed as inconspicuous or conspicuous objects, therefore their points extend across the scale. Each strategy also provides a different level of consumer appeal and medical appeal, which can also be demonstrated in figure 1. The majority of current medical devices (fig. 5) would lie within the medical and conspicuous area of the diagram. The final strategies are outlined below.

Enhance the Aesthetic Appearance of the Traditional Medical Device. The advantages of enhancing the aesthetics of a medical device are that it allows the device to appear less "medical." By enhancing the aesthetics, it can make the device more innovative, stylish and modern. This can be achieved through colour, texture, pattern, material or form. An example of enhancing the aesthetic appearance of the traditional medical device is Epipi designed by Harry Moorman (fig. 2). Epipi still retains some of the traditional elements of an EpiPen; however, it has been improved through choices such as material, colour, and texture.

Personalise the Medical Device for the User. By personalising an object, it provides the user with a sense of ownership over the object. Personalisation

Table. 1. Strategies developed through thematic analysis

Theme	Source	Strategy	Description of strategy
Enhance the traditional a medical device to make it more beautiful	[12]	Fading out and Disguising	Hide and replace unpleasant features, with more pleasant ones, which fit the context.
	[12]	Drawing Positive Attention	Design devices that create positive attention for assistive technologies
	[3]	Reinforce the medical role played by the device	Design the device with materials, colours and textures that make it appear medical.
	[13]	Diversion of attention	Create a diversion of attention away from the medical aspects of the device.
Disguise the medical device as a non-medical item	[13]	Camouflage – disguise	Camouflage or hide the medical aspects.
	[13]	Extra ability	The device provides another ability.
	[13]	Reshaping product meaning through meaningful interaction with other products	The interaction of products can be cooperative, competitive, or independent.
	[3]	Downplay stigma sensitive features by disguising the product as an accepted non-medical item	Make the device less noticeable and allow the user to hide their type 1 diabetes.
Conceal the medical device from the public	[14]	Covering the stigmatising object	Conceal the disabling or stigmatising part of the product
	[3]	Minimise stigma-sensitive aspects of the device by making it invisible or less confronting and minimise its presence.	Make the device less noticeable and less embarrassing in public
	[12]	Hiding and Covering	Hiding to manage both visible and non-visible stigma.
Personalise the medical device for the user	[12]	Personalisation	Products feel more tailored to the user
	[11]	Individual identity	Allow the user to personalise their device, either through mass customisation, or the user incorporates their own identity.
	[3]	Strengthen the individual identity of the device by providing more opportunities for personalisation, so users value it as an extension of their personality.	Provides participants with a sense of control and ownership over their device. It reflects the user's style and allows them to feel proud of their device.
Use technology to advance the medical device	[12]	Designing Stigma Out	Technology can be used for reshaping the user. Assistive products can become more varied, tailored and personalised.
	[11]	Reshaping product meaning through advances in material technology	By integrating new technology into an existing product, it provides the designer with a way to reshape a product

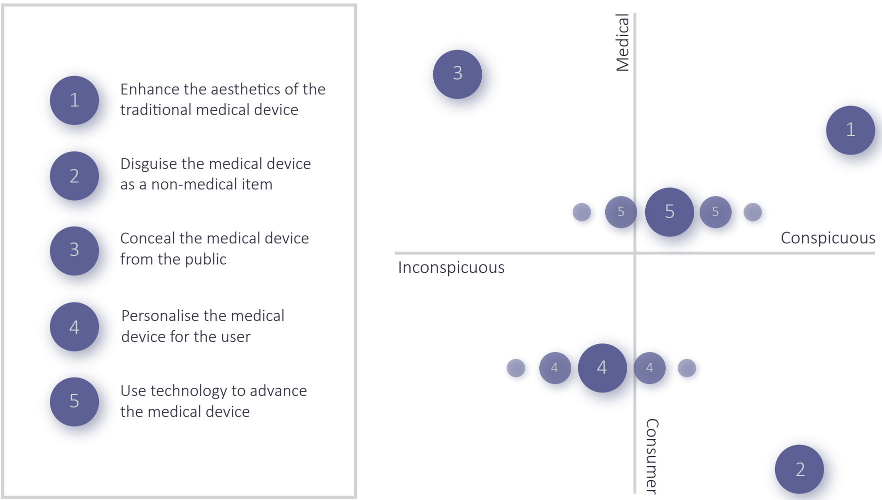


Fig. 1. Diagram showing the conspicuousness and consumer appeal of the strategy

can be achieved through providing the user colour options, patterns and engraving. Jacobsen [12], Vaes [13] and McCarthy [3] all mentioned this strategy in their research as a way of making the user proud of the object and therefore encouraging them to use their devices more regularly.

The Hue inhaler (fig. 3) designed by Tim Zarki is a device that demonstrates the opportunity for personalisation. The Hue inhaler is a device that not only fits into the personalisation strategy but also could be an example of enhancing the aesthetic appearance of the traditional medical device. Personalisation is a strategy that aligns well with several other strategies, as it can be achieved through small changes, and provides the user ownership over their medical devices.

Disguise as an Accepted Non-Medical Device. This strategy aims to remove the 'medical' aspects from the design to create a conspicuous object that can be used openly in public spaces. Disguising the medical device as another object allows adolescents to use the product in public, without the object being recognised as a type 1 diabetes medical device. This strategy is similar to, two of Vaes's [13] strategies that aim to reduce stigma in products. The strategies aimed to camouflage or disguise the products. McCarthy [3] also used this strategy; however, renamed it as "disguise the product as an accepted non-medical item." Examples of this strategy could include disguising medical devices in everyday objects such as a watch, cell phone, or keys.

Conceal the Medical Device from the Public. For adolescents who are more embarrassed by their type 1 diabetes or their medical devices, they might gravitate towards concealing their medical device from the public. This strategy is different from disguising as an accepted non-medical device, as it asks the designer to remove the object from the view of the public altogether. This strategy often works well with technological advancement, as many of the opportunities to design for this strategy are through wearable technologies such as temporary tattoos (fig. 4), contact lenses, and microchips. This strategy is a useful one to consider as it withdraws the device from the view of the public, making it more comfortable for adolescents to test in public discreetly if they choose to.

Technological Advancements. As technology advances, the desire for newer, smaller and slimmer type 1 diabetes medical devices is becoming apparent

Fig. 2. Epipi. Image courtesy of Harry Moorman.

Fig. 3. Hue Inhaler. Image courtesy of Tim Zarki.

Fig. 5. Current traditional type 1 diabetes medical devices available in New Zealand

[15]. Developments in technology have allowed for more experimental blood-glucose meters such as the Freestyle Libre, the tattoo blood glucose sensor, the Google lens blood glucose meter, and blood-glucose ink. As technology develops, it will become increasingly more accessible for us to visualise the possibilities for new, more inconspicuous medical devices.

3.2. Conspicuity of Testing in Public

In the interviews, both participants were not concerned about testing in public; participant 2 responded: *"I don't mind testing in public, because I feel like it's something you need to do."* It is important to respect the adolescents' experiences; however, there is a nuance to attention. Some adolescents might not feel embarrassed but do not want to be forced to disclose their type 1 diabetes or made to answer questions at that moment. We recognise that there is a variety of opinions, and the preferences of other adolescents' that have not been interviewed should be considered.

The adolescents interviewed were also aware of this; participant 1 had been diagnosed at a young age but was aware that someone who had been recently diagnosed might have different opinions about testing in public. *"I've had it for 11 years, but if someone had it for three months or something, it might become more awkward for them, and they might want to go off and do it privately."* Therefore, it is essential to consider the occasions when the participants do not want to be asked questions about their medical devices or type 1 diabetes, as they might be busy, not in the mood or embarrassed.

One of participant 1's first thoughts about creating a conspicuous device was: *"I think the whole thing of this is trying to make sure people do not look at it and immediately think 'oh it's medical, what's wrong?'"* Participant 2 was less concerned about the device being medical and more interested in making the device "innovative and stylish." Current devices (fig. 5) available in New Zealand use colours, materials, shapes and interfaces that make the device appear traditionally 'medical'.

Type 1 diabetes devices are frequently a blue colour, as participant 2 explained: *"Well you know how there is a blue theme going through it, because it's clean, but it doesn't need to be because people don't want all blue."* Participant 1 also mentioned that *"there is like six colours for the pump, but it's very basic navy blue, green, black and grey."* Although participants are not concerned about testing in public, they still desire a device that provides them with the autonomy to disclose their type 1 diabetes when they chose. A combination of the semantic strategies would provide them with a device that matches their preferences for conspicuity.

3.3. Preferences for Semantic Strategies

The participants did not gravitate towards a specific strategy in their interview, collage or sketches. Both participants preferred a combination of strategies. Two of the themes generated from the interviews involved technology and aesthetics; these were the preferred strategies from the participants combined with aspects from other strategies. Several ideas were discussed that generated ideas which combined aspects of the strategies.

Preferences for Strategies as Discussed in Interviews. Participant 1 was interested in exploring the possibilities of either making the device inconspicuous and not seen by the public or conspicuous and onlookers know what the device is. Participant 1 believed when a medical device is conspicuous and appears medical such as a wheelchair, crutches or even a tracheostomy; onlookers typically do not ask questions as they are aware of what the item is. Questions are also not asked when the onlooker cannot see an item at all. People will begin to ask questions when they are unsure if the object is medical or not.

P1: *I think the main thing is that there is something where it's so obvious it's not medical- where people don't ask about it. Then there is a period where it shows that it's medical, so people don't ask about it, and then there's that middle zone, where people are unsure whether it's medical or not, so people ask you about it. But if you make it really discreet or really obvious people won't ask you about it.*

One of the ideas Participant 1 discussed to demonstrate this, was to make a conspicuous phone case disguised as a blood-glucose meter:

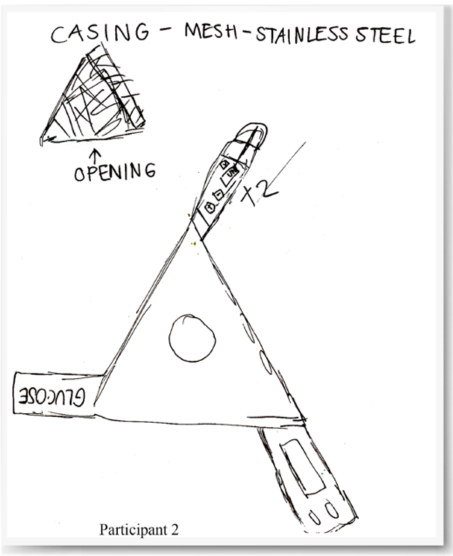
P1: *Putting a sensor on your phone, but you can also use it to see your readings, so you would unlock your phone and see the readings, have something that is made for one use, like this one the fingerprint detector, making it able to be used for another thing.*

This concept would allow the adolescent to use the medical device in public in a very conspicuous way. Combining the medical device with an object that used daily such as a cell phone, would also be more convenient.

Both participants were interested in how technology could make their blood glucose meters smaller or concealed. They both thought of ideas that would allow for a blood-glucose sensor to be implanted into their veins. Participant 2 thought of an idea similar to a bracelet: "What if it was like a bracelet and the bracelet was in your vein? I don't know that would be painful though" and participant 1 had already seen tools that could be powered by blood and was intrigued by that prospect: "There are tools where it can be powered by blood, so if the sensor was a microchip it would be self-sustainable." These ideas show how the participants are interested in exploring the possibilities of technology creating smaller and more inconspicuous devices.

Both participants placed the images of the Hue inhaler (fig. 3) and Epipen (fig. 2) on their collage, as they both liked the colour options and that it did not immediately appear 'medical'. Participant 1 said that the Hue device offers personalisation *"A lot of these are quite subtle. I think this one with all the colours, it doesn't make it look like its medical. It provides that personalisation."* Participant 1 also said *"The EpiPen, that model will be good for an insulin pen. You look at it, and you don't think anything medical, it looks cool. It gives a different vibe."* Both of these images show how personalisation and enhancing aesthetic appearance are strategies that could be explored in the future design process.

Adolescent Preferences for New Concepts as Shown through Sketches. Both participants sketched the idea of an "all-in-one" device. They both found their current systems inconvenient, and participant 2 regarded carrying everything with them as annoying, *"obviously there is not a time when you wouldn't need your insulin pen."* Convenience is a theme that was mentioned repeatedly by both participants. Participant 2's "all-in-one" device (fig. 6) is a portable testing and administering device. *"You could have a three in one tool! So, it would be like your injection, finger pricker and blood glucose meter."* This device would not only be convenient but also a more beautiful device that would not be recognised as easily by the public due to the casing surrounding the device.



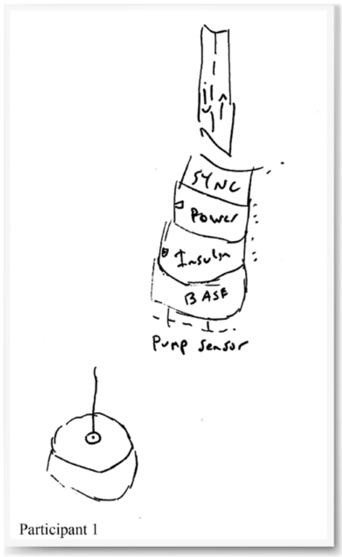


Fig. 6. Participant 2 all-in-one sketch;

Fig. 7. [above right] Participant 1 modular sketch

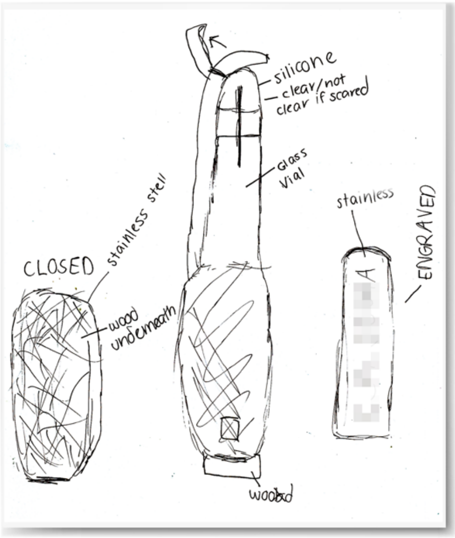


Fig. 8. First concept drawn with participant 2

Like participant 2, participant 1 wanted a convenient device and linked all his current devices together. They wanted the opportunity to create an all-in-one modular continuous blood glucose meter (fig. 7). The modular device would be worn on the arm, like the freestyle Libre. Participant 1: *"Yeah, you could have lots of pieces! Ones got the insulin, ones got the battery, and ones got the Libre."* The participant liked the idea of technology developing far enough in the future where all their devices could be in one spot on the body and all linked to a phone app to control blood glucose levels, and insulin administration. This device combined two strategies: technological advancements and concealed the medical device from the public to create a more inconspicuous and convenient device.

Participant 2 wanted to sketch a device that could be more "more innovative and stylish." The participant was interested in materiality, texture, patterns and colours to create a more beautiful device. In the sketch (fig. 8), the participant wanted to engrave their name onto the insulin pen design. Naming the device demonstrates a sense of ownership over the concept and shows that they are proud of the idea they have generated. The participant even said they were proud of the work: *"Wow, I've never done art, but I am kind of proud of this."* The device they have designed could fit into the personalisation category but also the "enhance the aesthetic appearance of the traditional medical device" as a metal mesh encases it. The device could also fit into the strategy "disguise as an accepted non-medical device."

4. Discussion.

The participants were comfortable testing their blood-glucose levels and administering insulin in public. However, they both had experienced questioning from curious people at school and sports practices regarding their medical devices. The participants both saw these questions as harmless. However, there are occasions where participants are not in the mood to be asked questions.

Adolescents had different preferences towards the five strategies developed and explored in this paper. Participant 1 was interested in technology, and how it could be used to make a more inconspicuous and convenient medical device and system. This was evident in the current devices the participant uses, which include a Freestyle Libre, insulin pump, MiaoMiao sensor and a smartwatch to receive constant readings. The participant did not want a device that appeared immediately "medical", and their preference towards inconspicuousness included wearing the device underneath clothing such as the Freestyle Libre. The semantics of using technology would allow their device to become smaller and more inconspicuous.

Participant 2 had a different preference for their chosen strategy. They preferred a conspicuous device that is more "innovative and stylish." They were drawn to colours, patterns, textures and materials. This was seen in their sketches (Figure 6 & Figure 8), as they annotated specific materials and patterns that they would like to be seen in their concepts. Participant 2 was also interested in combining the personalisation strategy to allow for their device to be engraved with their name.

Both participants had similar opinions about conspicuity. However, they recognised that this is not representational of all adolescents with type 1 diabetes. Only two adolescents took part due to time constraints and access to participants. Although only two adolescents participated in this paper, the interviews were successful in understanding the participants' experiences of type 1 diabetes and provided a level of detail and story-telling that might not have been achieved through a questionnaire or survey. Participatory design methods also contributed to the detailed results. It allowed for the participants' opinions to contribute to the designing process, and the concept sketches are tailor-made to their needs.

The next step is to explore further how the strategies can be applied to type 1 diabetes medical devices. The participants interviewed in this paper found the questions and activities engaging and will be returning for future feedback sessions with higher-fidelity prototypes. Further research in this area would be interesting to see how designers could operationalise the strategies. Additionally, medical devices may not be the only area where a conspicuous product is preferred, other areas of design such as safety products, assistive products and wearable technology might be other areas to explore how the semantic strategies could address the conspicuity of products.

5. Conclusion

In this study, five semantic strategies that address the conspicuity of medical devices were developed and explored with adolescents who have type 1 diabetes. Thematic analysis of literature that explores stigma in product design was used to develop the strategies. The strategies are: enhancing the traditional medical device to make it more beautiful, disguising the medical device as a non-medical item, concealing the medical device from the public, personalising the medical device for the user, and using technology to advance the medical device. These strategies all aim to design conspicuous or inconspicuous medical devices for adolescents with type 1 diabetes.

Two participants took part in semi-structured interviews, collaging, and sketching to explore the five semantic strategies. The semi-structured interviews successfully created an open discussion around testing in public, conspicuity and their preferences for their medical devices. The participatory design methodology allowed for a detailed conversation and provided more context and insight on the topic in addition to the sketching of potential ideas.

Participants valued different strategies, in particular, using technology to advance the medical device and to enhance the traditional medical device to make it more beautiful. These strategies were often combined with aspects of other strategies to produce their ideal concept for a conspicuous or inconspicuous medical device. Continuing this research will require further exploration of the semantic strategies, to determine the best combination of strategies for future concepts of medical devices. Designers will also play an important role in the next phase of the research to understand if the strategies can be used in other design disciplines and by practising designers.

While the medical devices currently used by adolescents' do little to meet their preferences for conspicuity in public settings, this research has explored new strategies that could help to design new medical devices for adolescents with type 1 diabetes that can match their preferences for conspicuity.

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Sitting Still: Seat Design for a New Head-Only MRI Scanner

Abstract

Magnetic resonance imaging is the gold standard in medical practice for tissue imaging. However, current devices are expensive and require users to be in a supine position during the scanning procedure, with users often reporting claustrophobia and anxiety. This study reports on the design of a patient handling system for a new kind of head-only MRI scanner, which allows users to be seated. This poses a unique challenge in seat design: the design should allow the user to be still to attain accurate MRI scans. We investigate the aesthetics of interaction in this complex dynamic system to yield a comfortable user experience. We followed a human-centred design process comprising two main design phases. An experimental setup was used to evaluate possible upright positions of the user. A refined functional prototype was consequently built and tested with healthy participants. Our results indicate that the position required to sit in a lounge chair is most comfortable and allows subjects to remain still for an extended time period. Our chair prototype provided sufficient support during the 20 minute procedure but needs further refinement to improve the user experience and usability of the system.

Keywords

MRI, medical design, seating design, design prototype, user experience

1. Introduction

Magnetic resonance imaging (MRI) is a tremendously versatile technique for tissue imaging, with applications as diverse as cardiac health monitoring through to brain tumour detection. MRIs are used in five major anatomical regions: central nervous system, musculoskeletal, body, cardiovascular, and breast imaging [1]. To obtain accurate images of the human body, existing MRI scanners require the patient to remain motionless in a confined horizontal space. The enclosed space and extended time period that the patient is asked to remain still can cause enormous anxiety prior to and during the scan [2]. Techniques used in clinical practice that aim to reduce anxiety and motion during the scan include the provision of relevant information, playing music during the procedure [3]–[5], providing a mirror to look outside the bore [6] and adding foam pads [4], [7]. However, the process can be extremely challenging for patients. A feeling of lack of control [8] as well as lying on a stretcher during the procedure [4] have been identified as negative factors in the user experience and aesthetics of interaction.
The development of a seated, head-only imaging system dedicated to brain imaging, which is one of the most common applications for MRIs, would offer a less restricting scanning procedure. It could furthermore contribute to a feeling of control due to the upright position and being able to look outside

the magnet using a small window. Such a novel system could be transportable, increasing access for a wider population, especially people living in isolated areas. The proposed new kind of MRI scanner is currently under development by a world-leading team of MRI experts [8].

We report in this study on the design of the seating user-experience from a human-centred design approach [9] and with consideration to the aesthetics of interaction [10].

2. Background

Patients who are scanned with an MRI are required to lie on a stretcher, which is then moved inside the bore of the magnet. There are few MRI applications that allow a prone instead of the standard supine position such as the MRI breast scanner [11]. Further variations allow a seated position [12] or offer detachable and MRI-compatible seating elements to scan patients that cannot be imaged in the traditional position, or to gather specific imaging that requires gravity, for example, spine scans [13]. Extremity MRI systems [14] seem to provide a comfortable experience for the patient but do not allow a stable and upright position for the patient's head, which is one of the technical constraints that our design needs to address.

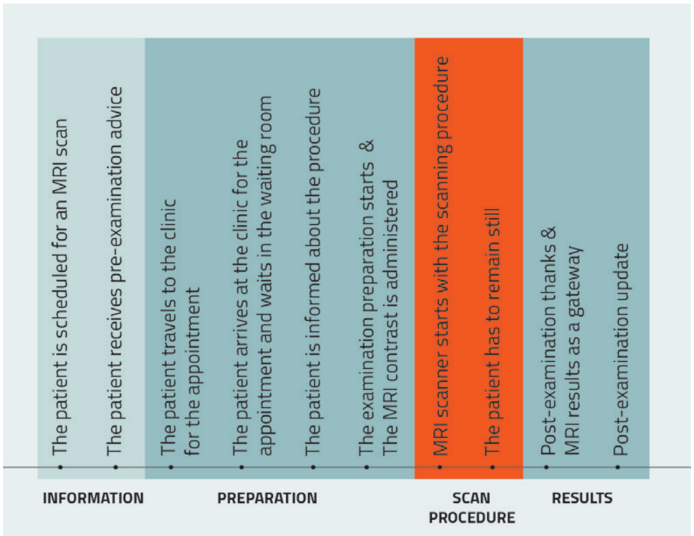

Fig. 1. Milestones of the user experience. We focus in this study on the orange part of the experience.

The aesthetics of interaction refers to "the way an object speaks to us, calls us, affords us, puts us into contact with others, is meaningful to us" [10]. Aesthetics of interaction is experienced at the ongoing interaction space where the physical characteristics of the product and the information it conveys (functional, augmented, inherent) meet and converse back and forward with the user's context (general knowledge, aesthetic preferences, cognitive and affective states, personality, motivation) and sensory-motor system [15]. We reviewed design variables of MRI systems and other industrial chair designs, medical chairs and automotive car seat designs that would allow an upright position. Currently no other seating system exists that could be used as part of a head-only MRI scanner, let alone one that addresses the aesthetics of interaction. Interestingly, automotive car seat designs pay much more attention to the aesthetics of interaction than other reported medical device designs, by trying to create a beautiful experience as well as addressing the highly demanding technical constraints of car seat design.

A number of studies focus on the experience of MRI systems and user experience of patients as well as technical staff [2], [4], [6], [8], [16]–[20], but fail to mention explicitly how to design for the aesthetics of interaction. We developed a customer journey map based on these studies, see Figure 1 for an overview of the main milestones. The studies indicate that the MRI user experience is often extremely challenging, see Table 1 for details relating to the scanning process, which is the main focus of this study. It has been reported that up to 37% of patients experience a moderate to high level of anticipatory anxiety [2]. The main contributor seems to be a feeling of claustrophobia [17] and associated negative emotions already start to set in before the actual scanning procedure takes place [19]. The anxiety can even manifest itself after the scan affecting the daily routine of the patients [17]. It has been pointed out that anxiety and claustrophobia are strongly influenced by a feeling of suffocation, ideas of control and the potential for harm to be caused by the machine [8]. Our new design system aims to address the aesthetics of interaction by providing elements that evoke a feeling of control to improve the MRI user experience and remind the user of similar systems they are familiar with. In particular, we took car seat design as an area to draw inspiration from for comfort, familiarity and aesthetics of interaction.

3. Aim

The aim of this study was to suggest an optimal upright seating position for a head-only MRI scanner, which contributes to an improved MRI user experience while securing minimal motion of the user in combination with a head restraint system we will describe in later work.

4. Study Context

This study (funded by the National Institutes of Health (USA) and Kiwinet (NZ)) is part of a multi-institutional research project taking place in the United States, Brazil and New Zealand. The novel head-only MRI system is currently under development and could therefore not be used as part of our testing protocol. However, we used a physical non-functional representation of the scanner bore as part of our user testing sessions. We report in this paper specifically on the design of the seating for the new MRI system. The study was carried out by a team of industrial designers with experience in developing medical technology and a technical expert in the development of MRI magnets.

Constraints defined by engineering and clinical factors included: to design comfortable seating; head should be aligned to the magnet bore and its movement restricted; magnet cannot be moved when positioning the patient; maximum width and height of the seating area; materials need to be hospital graded if fabric and nonmagnetic if structural. This differs from traditional seating as users are not free to move their heads.

5. Materials and Methods

In the context of developing new medical devices, an iterative design procedure assessed by a number of usability methods is an ideal setup as part of a human-centred design approach despite being expensive and time-consuming [9]. We followed a human-centred design approach [21] with two main design phases: 1) an initial design exploration phase to investigate possible positions of the user in a sit-up MRI scanner

Table 1. Customer journey milestones

Step	Positive factors	Neutral factors	Negative factors
Start of scanning procedure	1. music used as a form of distraction 2. entering the bore feet first can decrease anxiety		1. lack of control over the situation 2. not liking or not having any music at all
The patient has to remain still	1. possibility to have a nap 2. noise cancelling headphones 3. mental distraction 4. support from others 5. rewards and/or bribes 6. music 7. breath holding techniques 8. constant reassurance that the patient is in control of the situation 9. sedation 10. eye masks 11. physical touch by the MRI technician or family member 12. buzzer that allows to contact staff 13. trust in staff	1. not all patients want to actively participate in the scanning process 2. there can be a preference to hand over responsibility to expert	1. amount of time spent in the system 2. inability to keep still 3. pain 4. claustrophobia 5. feeling unable to breathe properly 6. panic symptoms 7. threat to self-control 8. enforced nature of having to remain motionless 9. desire to scratch an itch 10. thoughts about the (negative) consequences 11. having panic symptoms 12. lying on a hard bed 13. temperature is too hot or too cold 14. thoughts about the potential harm caused by the MRI machine.

through observation, idea generation and low fidelity prototyping; and 2) a refined fully functional prototype evaluated by healthy participants.

5.1 Design Development Process

In a first step, we used an experimental design process to investigate patient positions in the novel MRI scanner that would allow an upright and stable position of the head for up to 30 minutes. A low fidelity prototype [22] was used to investigate where support needs to be provided in a seated position, within the specific constraints provided by the engineering team. We used pillows, a raised horizontal platform, cardboard boxes and polyurethane foam sheets to investigate how support may facilitate motionless yet comfortable sitting positions.

In a second step, we used expansive design concepts [21] exploring different designs and positions of the chair in the overall system based on the initial results. We followed a systematic approach whereby we assessed the design concepts against a list of design criteria [23] developed for this project and experience prototyping [24] to refine the design concepts until the prototype had reached a level where it could be tested with participants. A full scale of the chair was produced using a foam core and fibreglass laminate to provide the required stiffness and robustness. Adjustable upholstery was provided to the participants using a selection of different foam thicknesses. Similarly, elements for the lumbar region and movable inserts for the hip area were used in the assessment process.

5.2 Evaluation

A combination of different evaluation methods is helpful to determine a range of usability issues [25]. We chose a multi-method approach in the form of an ergonomic analysis [26] and formative usability testing [26] with participants. Even though the role of good design is recognised in the context of developing medical devices, it seems that ergonomic principles are often under-used [9]. We employed standard data sets of human dimensions [27] and results of a study on overweight populations [28] for the ergonomic analysis process. An additional qualitative scale of comfort and discomfort, which was adapted from Helander and Zhang's chair comfort scale [29], was used as part of our testing protocol with healthy participants to confirm the results of the ergonomic analysis process. The aim of our formative evaluation process with a full-scale prototype was not the collection of quantitative data for comparison, but instead to refine the design [30]. We took the participants through a simulation of an MRI examination and asked them to remain as motionless as possible in the MRI bore during the 20 minute testing. The testing included the sound of an MRI scanner, arm movements to evaluate the degree of movement tolerable and semi-structured questions about comfort, discomfort and feelings of anxiety in regards to the chair and overall system to address aesthetics of interaction. Participants could leave the system at any stage. We used the system usability scale (SUS) [31], and an MRI-Anxiety Questionnaire [32], which measures anxiety and relaxation during the MRI examination as part of the evaluation process. We used a 10 points Likert scale as part of the questionnaire. The testing was video and audio recorded for later analysis.

5.3 Recruitment

This study was approved by the human ethics committee of Victoria University of Wellington (VUW). Participants provided informed written consent before taking part in the testing. We recruited healthy participants through VUW. Ideal sample size suggestions for usability testings vary between 3 to 20 participants with 5-10 participants being a sensible approach for most studies [33]. Four participants took part in our first design experiments and seven in our formative usability testing.

5.4 Analysis

The photos, videos, notes of observations and semi-structured interviews were analysed using thematic analysis in a deductive form [34]. Thematic analysis is used to identify, report, and analyse patterns and themes within the data. Themes were generated by the first author and reviewed by the remaining authors. The initial themes were translated into design criteria [23] as per Table 2 below. The design criteria were used at different stages of the research and design process to systematically assess the design concepts and refine them. The results of the scales and the questionnaire were analysed using descriptive statistics [35].

	Criteria description	Based on
1	Chair fits below the MRI scanner	Physical project constraints
2	Width and height fits the 5th to 95th percentile	Literature: Human factors
3	Positions the user correctly in the middle of the bore	MRI usability constraints
4	Minimises movement of the user	MRI usability constraints
5	MRI safe materials and medical appearance	MRI usability constraints
6	Reduces feelings of control and anxiety	Literature: MRI user experience
7	Allows arm movement of the user	Literature: MRI user experience
8	Easy entering and leaving of the magnet more	Physical project constraints

Table 2. Assessment of design concepts against design criteria

6. Results

6.1 Design Development Process

Experimental Design. Four participants took part in the initial phase of our experimental setup involving the use of low fidelity prototypes to test possible comfortable positions that ensure a straight and stable position of the head. Two participants were female and two were male. Their age range was between 22-23 years. Participants indicated that a position required to sit on a chair is the most comfortable for an extended period of time in the given physical constraints of this research. The participants mentioned that support is required for the lower back and the regions around the lumbar, neck, under the legs and buttocks to ensure comfort. Armrests and support around the thighs were identified as unnecessary. Participants acknowledged a requirement of softening of the seating-pan edge to reduce discomfort. All participants acknowledged a need for leg support however results were inconclusive as to the degree of support needed.

Expansive Design Concepts. For phase 2, we developed a range of concepts based on the results of our low fidelity prototyping. The concepts were then assessed against the updated design criteria detailed in Table 2.

Full-size Prototype. The findings suggest a position similar to a car seat or lounge chair may be appropriate to facilitate head movement restraint. This gave us the opportunity to address the aesthetics of interaction similarly to (and expand on) the car seat industry. The final chair design consisted of a seating pan and a separate, moveable backrest, see Figure 2. The chair was positioned on an electric lift column that allowed the user to be positioned correctly inside the magnet bore and could be controlled by the participant or by a research assistant. This approach was chosen based on the feeling of lack of control that multiple studies indicated. The chair prototype was tested with a physical representation of the final magnet bore and frame. We used an air ventilation system that ended just below the bore entrance, which could be regulated in terms of its intensity to provide sufficient air flow. For reference, the seat and upholstery are coloured black to assist in motion tracking of in-scan participant

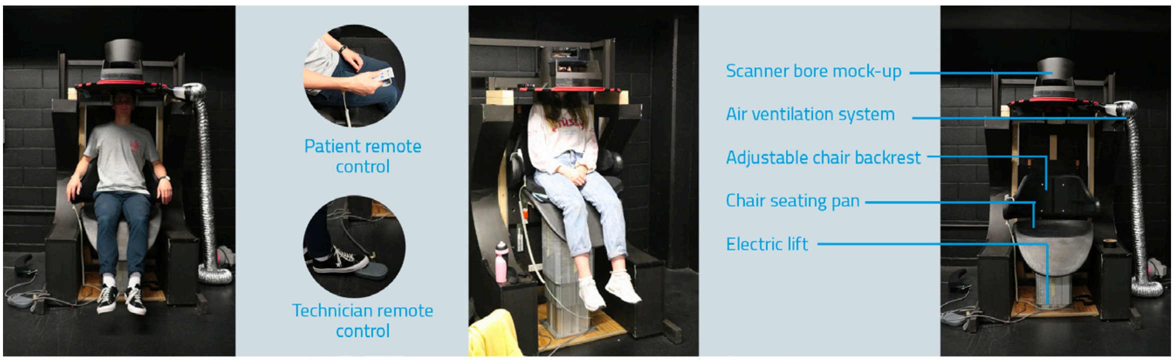

Fig. 2. Fully functional test rig with removable lumbar support and upholstery inserts.

movement, which we are planning to carry out in the second stage of this research to confirm that our system minimises head movement to under 1mm. Seven participants took part in the testing. Two were female and five were male. Participants were between 20-58 years and had a height between 168 -190 cm. Their weight ranged between 50-90 kg.

System Usability and User Experience. The results of the SUS indicated a high degree of overall usability of the system, see Table 3. However, a few participants expressed a need for more relevant information on how to use the system and a low level of confidence in using the system. The results of the MRI-Anxiety Questionnaire [32] was used to evaluate factors of anxiety due to the enclosed space and prolonged time that participants had to remain still. The results suggest that participants felt mainly relaxed, however, some participants expressed concerns regarding the ability to breath; control over the situation; and the feeling of being safe, see Figure 3.

Physical Usability Issues. We informed participants before the testing that the armrests were not completely weight bearing, which caused most to use the raised edges of the seating pan to lower themselves down into the chair. Participants had no issues leaving the chair system, however, some participants noted that some of the provided larger upholstery inserts created difficulties in entering the system.

The feet, neck and shoulder region at the back were pointed out as body parts that most participants felt a moderate to high level of discomfort with. Most body parts started to feel uncomfortable over the extended period of the testing session when the participant had to remain motionless inside the magnet bore. In particular the footrest was requested to decrease physical stress on the ankles and feet while the participants were elevated off the ground. Further notable areas for improvement were:

1. The angle of the backrest should be reclined;
2. The length of the seating pan needed extension;
3. The chair seemed to be positioned too high when at the lower travel limit of the lifting column (50cm); and
4. The armrests should be designed in a way so they 'hugs' the user.

Table 3. SUS value: 0 = low and 100 = high , n = 7

Participant	01	02	03	04	05	06	07
SUS value	70	95	77.5	90	72.5	85	72.5

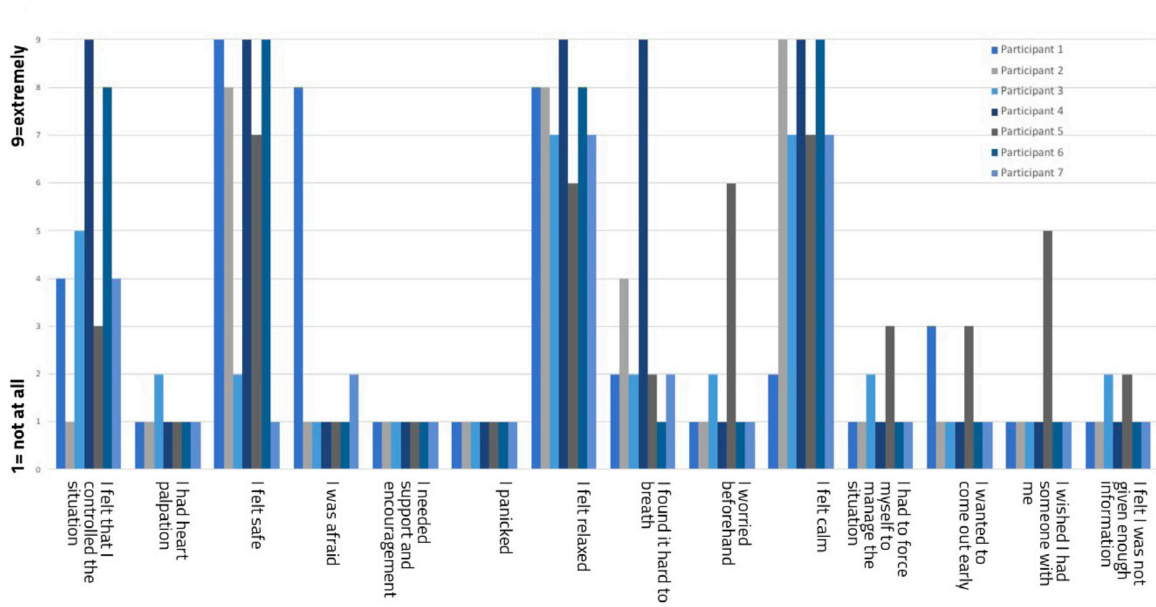

Fig. 3. MRI Anxiety questionnaire with a 10 points Likert scale (n=7)

7. Discussion

This study reports on the development and evaluation of a chair for a sit-up, transportable MRI scanner, with the very specific requirement of keeping the user's head still for a period of time. This study is based on two design phases which informed the design of a full-scale prototype that has been tested by participants.
Our formative usability evaluation indicates that the chair provides sufficient support and comfort for a 20-minute scanning process, but requires further refinement to improve the user experience, level of comfort and usability of the system.

The SUS indicates a high level of usability of our proposed chair design. However, there were a number of observed usability issues that require further refinement. The entering and leaving of the system requires the user to bend their head in order to sit down. Arm rests were observed as an important feature that allowed a secure lowering of the user into the seating pan. The participants could use a remote control to position themselves inside the magnet bore, however, just a small number of the participants chose to do so. This might explain why some participants mentioned a lack of control over the situation, which is an important aspect in this design related to the aesthetics of interaction. The controller was difficult to use while being inside the scanner due to a lack of tactile feedback of the button that made it impossible to know which button needed to be pressed to move up or down. The participants were provided with a variety of upholstery elements to increase comfort. Some of the thicker upholstery parts compressed over the testing period consequently lowering the user further down, which meant that they either started adjusting themselves during the testing or could not look outside the scanner window anymore. The airflow was described as sufficient by some participants but not all of them. It was furthermore noted that the air felt very cold due to the high intensity. A different position of the air hose could potentially direct the air further inside the bore.

The assessment of the aesthetics of interaction produced mixed results. Car seat design was a starting point to relate users to a familiar object they would know how to interact with; this was successful in part due to the anthropometry and posture required for this project, similar to that of a car seat. However, the travel necessary for the chair to bring the patient into the magnet, our requirement to fit 95% percentile of the population, and the fact that the controls to move the chair are in a handheld remote control, meant that the aesthetics of interaction were different to a car seat.

Some of the chair features were experienced to become uncomfortable over the 20-minute testing sessions such as the 90 degree position of the seating pan in relation to the backrest that required the user to sit upright evoking lower back pain in some of the participants.
A recent study focusing on the development of an extremity MRI scanner [14] suggests a reclined position for the user. The study suggests a leg rest angle between 130-148 degrees which we are going to take into consideration for the next iteration of the chair. Most of the participants recommended adding a leg rest and a foot support to avoid their feet dangling in the air during the examination. The lack of footrest evoked a high level of discomfort during our testing sessions in nearly all of the participants. This is an interesting finding as the first application of reclining chairs was for sick patients and for pregnant women to find a comfortable position without having to lie down (34). This form of chair has become associated with a level of comfort allowing the user to elevate his or her feet to increase comfort (34). Our study indicates that if the user of a chair cannot touch the ground, a leg and a footrest are essential feature to increase the user experience.

Limitations include that the initial testing had a small (< 10) sample size, with healthy and mostly young (< 30) participants. The mock-up of the MRI scanner simulated user experience in a lab environment.

Based on the feedback of the participants we are currently changing the design of the chair for a second phase of usability testing. Further studies are required to confirm the usability of such a chair in a clinical environment, where patients and MRI operators are interacting with the system. However, given the high SUS scores of our current chair solution, we believe that following a final design iteration we will significantly improve subject experience during brain MRI examinations. This will have been achieved through consideration of the aesthetics of interaction in the critical chair design feature of our novel MRI system.

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Designing Research Prototype for the Elderly: a Case Study

Abstract

This paper describes a research study regarding intergenerational story sharing of the elderly living in the nursing home, including four iterations, applying a Research-through-Design approach. It started from an exploration prototype named *Interactive Gallery* (1st iteration), and its findings helped to narrow down our research area and define our research question. To answer it, the prototype named *Slots-story* (2nd iteration) and *Slots-memento* (3rd iteration) were designed and implemented, which focused on life story and memento story of the elderly respectively. While the 4th iteration aimed at facilitating intergenerational story sharing and sustainably. The above research iterations offer an example of how research prototypes supports to focus research area, and answer the research question in stages. We finally conclude with a discussion of insights on designing prototype for the non-tech-savvy elderly.

Keywords

Research-Through-Design, Research Prototype, Elderly, Storytelling, Tangible Interface

1. Introduction

The aging society is coming. The worldwide population over age 65 is expected to more than double from 357 million in 1990 to 761 million in 2025, and with up to 50% of those over the age of 85 likely to be placed in a nursing home at some point in their lives [1]. However, social isolation is widespread among older adults in nursing homes, and older residents have limited involvement in social connections [2]. Living separately with their children also makes it difficult for younger and older family members to communicate with each other because of different interests, stereotypes of aging, geographical distance, and the fast pace of contemporary life. Since social interaction of the elderly is a broad research area, our research focuses on its subset: intergenerational storytelling of the elderly living in nursing homes.

Given that one of the most precious characteristics of older adults is their memory of events, people and places [3], intergenerational storytelling could act as an effective way to keep them stay in touch with their children. Our target group is the aged non-tech-savvy people living in a nursing home. While younger seniors are embracing online social technologies, the Internet and social media use drop off significantly for people age 75 and older— Only 34% of people in the G.I. Generation (born in 1936 or earlier) use the Internet, and 21% have home broadband [4].

In this paper, we describe our three-year research study of intergenerational story sharing of the elderly, in a Research-through-Design manner. It offers an example of how research prototypes support us to focus research area, answer research question in stages. We then present our insights on designing research prototype for the non-tech-savvy older adults.

2. Related Work

Social technology for the elderly. Existing research indicates that their social interaction could be promoted either by strengthening connections between older adults and their existing social circles (friends, family, etc.), or expanding their social circle by knowing more friends [5]. Since TUI (Tangible user interface) has been identified as having great potential to improve older adults' acceptance of technology acceptance [6], related applications for non-tech-savvy older adults mostly adopt tangible interface.

Research-through-Design. R-t-D is described in the literature as an approach for scientific inquiry, taking advantage of the unique insights gained through design practice [7]. Although the term of R-t-D is not a new concept, it is until recent years that it has been widely discussed and used in the HCI field, and became an increasingly recognized approach in design. R-t-D is conceptualizing research done using the skillful practice of design activity, revealing research insights [8]. One of the features lies in that it acknowledges and embraces professional practices' contributions to knowledge[9].

Research Prototype. R-t-D also highlights the importance of research prototype. The use of designedly prototype within the research process has been well acknowledged. Prototypes are defined as research instruments created by the researchers, tailored to each individual study [10]. Prototypes serve multiple functions within the research process: Prototypes make abstract theory concrete as they could involve people in research process, and they are 'like products' in the sense that someone can interact with them and experience them [11]. Prototypes are also seen as embodying designers' judgments about valid ways to address the possibilities.

Summary. Our research focuses on the storytelling between older residents in the nursing home and their children. The older adults are story producers, while their children are the memory trigger producers. R-t-D and research prototype have been widely discussed and used in HCI field, but there are few research that specifically discuss the application study of R-t-D for the elderly people. In the next section, we explain how our R-t-D cycles evolve in detail.

3. Iterative Design Cycles

The research question of our project is: *How can we use design to facilitate intergenerational storytelling and preservation for older adults living in the nursing home?* To answer this question, three sub-questions are formulated: *(1) What are their stories about? (2) In which ways, can design facilitate them to tell and preserve stories? (3) In which ways, can design involve their children?* The entire research project, including the above research question, was done in a Research-through-Design manner.

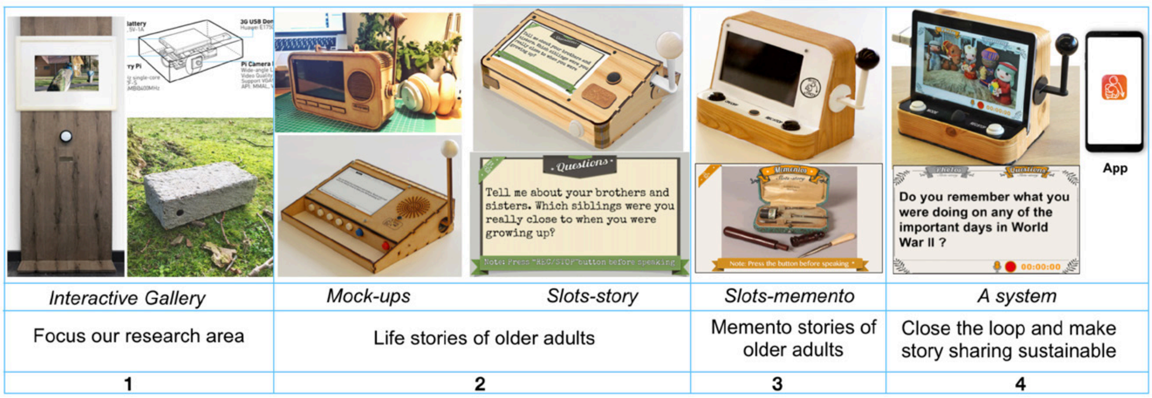

Fig. 1. Overview of our research iterations

3.1 First Prototype: Focus Our Research (Define RQ)

As social interaction of the elderly is a broad and macroscopic research area, our first prototype *Interactive Gallery* was an explorative prototype, designed to uncover the related potential factors, narrow down research goal and define the research question. Details process could be seen in [12], and the following is a short description.

Contextual inquiry. We firstly conducted semi-structured interviews with seven older adults and two caregivers in a Dutch nursing home. We found older adults encountered difficulties in connecting with their fellow residents. The nursing home was not a fully open community, which made it a relatively isolated and independent. Most of them couldn't operate digital devices, and they still highly relied on physical operation.

Prototype. In response to this, we designed the *Interactive Gallery* system (Figure 1-(1)), which consisted of a set of scenery-collectors and a gallery-like interactive installation. The formers are distributed to volunteers from local communities to share real-time scenery photos with older adults, and the latter is placed in the nursing home which enables older adults to watch and start conversations. Communication between sharers and receivers will also be connected through a "postcard-sending" metaphor: The older adults could print scenery photos as postcards by simply pressing the button. They could choose to send back to sharers, or keep them.

Field Study. It was implemented in a Dutch nursing home for five weeks. Direct observation method (including baseline observation and intervention observation) were conducted, and semi-structured interviews were contacted semi-structured interviews with 13 older adults (ranged in age from 71 to 86).

Finding. The field study proved the tangible interface employing metaphor reduces using barriers for them. Their memories were evoked by the familiar scenery photos. They preferred to share memories with their children, rather than the unacquainted volunteers.
The above finding inspired us that the elderly could be deemed as content (memory, story, etc.) producers, and their children were the story listeners. This drove us to narrow down our research goal and further identify our research question.

3.2 Second Iteration: the Elderly's Life Stories (Answer rq1,rq2)

The following is a brief description, and a detailed process could be seen in [13]. We firstly conducted semi-structured interviews with both the older adults and their children, and the following design requirements were defined: Memory trigger. Tangible interface employing metaphor. Using audio as the storage medium of stories. Could be used either face-to-face or separately by older adults and their children. Then three concepts were built based on the design requirements and were developed to be mock-ups(Figure1-(2)). Older adults were consulted to evaluate them. *Slots-story* employing metaphor of slots-machine was chosen and further detailed. *Slots-story*, a slots machine-like device, aims to facilitate inter-generational life story sharing and preservation. It utilizes with the metaphor of slots machine, and integrates functions of memory cue generator, story recording, and preservation. By default, there are 40 trigger questions covering most aspects of an entire life. It could either be used face-to-face or separately by older adults and their children. In the field study, eight pairs of participants from a Dutch nursing home were recruited to use the prototype for around ten days, and each pair consisted of an old adult (six female and three male, ranged in age from 77 to 89) and his/her child. Semi-structured interviews were conducted with both older adults and the young. Stories were transcribed and analyzed.

Reflection: As some stories were related to their mementos, such as album, souvenir, etc., which were also ideal memory triggers as they provided visual clues. This inspired us to explore their mementos and related stories in the next iteration. Additionally, the appearance of porotype should be refined according to older adults' feedback.

3.3 Third Iteration: Their Memento Stories (Answer rq1,rq2)

Research Prototype. We interviewed older and young adults separately. We first asked them to arrange a brief guided tour of their homes, aiming to examine their mementos for displaying and stored in hidden places. The prototype was refined based on the interview and feedback of the 2nd iteration: Prototype's decorative effects needed to be highlighted to make it unobtrusive when putting it at older adults' home (Figure1-(3)). It was used in a cross-generational operation manner: the young took photos of older adults' mementos and copied them to the prototype, while older adults used the prototype to tell stories related to the mementos [14].

Field Study. Ten pairs of participants (each pair consisted of an old adult and child) were recruited to use it for around seven days, and mementos and recordings were collected. Semi-structured interviews were conducted with older adults and their children. Mementos were categorized and analyzed. Stories were firstly transcribed, then were analyzed.

Reflection. Sustainability of the intergenerational sharing was necessary. Next, a cellphone application will be designed for the young side.

3.4 Fourth Iteration: Involve Their Children (Answer rq3)

Aim. In this iteration, we close the intergenerational storytelling loop by designing an App for the young generation, aiming to facilitate intergenerational story sharing and preservation in a sustainable manner.

Prototype. A system consisting of a slot machine-like device used by older adults, a cellphone application used by the young. It integrates life story and memento story sharing (Figure 2)[15].

4. Discussion

We have illustrated our R-t-D cycles including four research prototypes, which provide insights on how R-t-D is applied to research practice, especially for the elderly people. In this section, we present the implications in two parts: Prototype as tools of identifying and answering research question, and designing research prototypes for the non-tech-savvy elderly.

4.1 Prototype as Tools for Identifying and Answering Research Question

Prototype Acts as a Means of Narrowing Down Research Focus. First, Design research is a way to ask larger questions beyond the limited scope of a design problem, through the practice of design itself. Our research focus and detailed research question were identified through the first prototype *Interactive Gallery*. As mentioned, social interaction of the elderly is a broad and macroscopic research area: their social connections with fellow residents, with family members, old friends, people from the local community, caregivers, .etc. *Interactive Gallery* was firstly implemented, and its findings helped us to focus our research on intergenerational storytelling of older adults

(Section 3.1). Next, new and unexpected findings emerged during the implementation of prototype, which guided our follow-up research. Our second prototype was regarding life stories of the elderly. However, new and unexpected findings emerged during its implementation: some stories were related to family

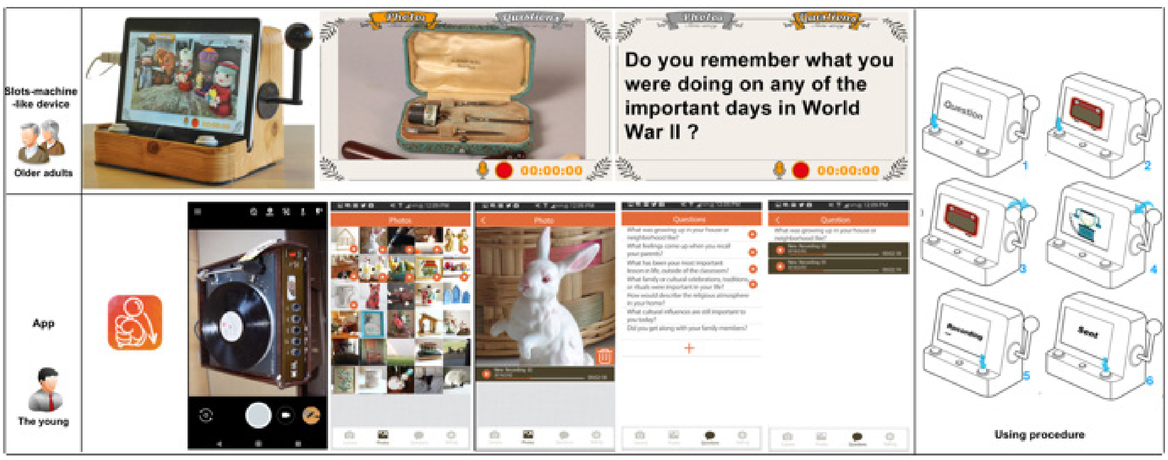

Fig. 2. Prototype of 4th iteration

Fig. 3. Interview with older adults in different iterations

mementos, such as album, souvenir, artwork, etc. This inspired us to explore their mementos and related stories in the next iteration (Section 3.3).

Answering Research Question in Stages through the Evolution of Prototypes. Our overall research question was answered in stages. RtD itself has highly iterative character as the design evolves while conducting RtD-led research [16]. As mentioned, we break the overall research question into three sub-questions. To answer *rq1* and *rq2*, we designed and implemented the 2nd and the 3rd prototype, which focused on older adults' life stories and memento stories respectively. To answer *rq3*, we designed the 4th prototype, to fully involve the older adults' children. The evolution of prototypes is not only a response to the development of research questions and insights, but also the feedback of the participants. For example, the appearance of the 3rd porotype was refined based on the feedback in 2nd iteration, as the elderly thought it should be unobtrusive when putting it at home, therefore decorative and vintage effects needed to be highlighted.

During the research process, we switched between reflection and practice. Knowledge is gained by conducting a design exercise and continuously reflecting on direct and indirect observations, beliefs and experiences[16]. In our R-t-D cycles, reflection is the output of the implementation of the current prototype, also the input for the next prototype. Therefore, reflection is the dividing line between analyzing and practice: it is the end of a phase of study, but the beginning of a new phase of study. The reflection is a catalyst for knowledge generation.

4.2 Designing Research Prototypes for the Non-Tech-Savvy Elderly

Non-tech-savvy Older Adults. One thing to note is that, since people above the age of 65 years old are diverse regarding cognitive ability, they compromise a group that is considerably more diverse than people of the general (younger) population. As such, the experience of using technology of each individual older person is unique, and their level of technological mastery varies. Therefore, they could be roughly divided into the non-tech-savvy and tech-savvy group. Our target group is older adults in nursing home, according to literature and our investigation, most of them are non-tech-savvy users.

The following are some insights on designing prototypes for the non-tech-savvy elderly derived from our research practices. Since all of our prototypes adopted tangible interface, the presentation of our insights is partly based on Eva Hornecker et al's framework on tangible interaction. The framework is structured around four themes: *Tangible Manipulation, Spatial Interaction, Embodied Facilitation, and Expressive Representation*. Each theme concludes serval concepts[17].

Providing Haptic Direct Manipulation through a Tangible Interface.

It has been well acknowledged that tangible interfaces are more accessible and suitable for the needs of elderly people, as they could provide a natural style of interaction [1]. The elderly are suffered from declines in motor control and accuracy, while physical contact with an interface gives elderly users confidence in their abilities[18]. Current touch-based interfaces are mainly visually guided without physical feedbacks. This lack of tangible feedback often leads to several errors and frustrations that are accentuated in older people. *Haptic direct manipulation* refers to tactile contact, haptic feedback, and material qualities when manipulating the interaction objects[17]. All our research porotypes adopted tangible interfaces providing *haptic direct manipulation*. *Interactive Gallery* was equipped with big buttons, and the elderly could manipulate it by a simple hand-press. *Slots-story* and *Slots-Memento* provided tangible interfaces and intuitive interactions through the lever. Both operations were accepted by the elderly users according to our field study. As one older adult said in our interview: *" Its function is simple. I especially like the lever, and the knob is easy to hold."*

Providing Representational Significance through Metaphor. *Representational significance* refers to the interrelation of physical and digital representations, and how users perceive them[17]. It is important to communicate information with analogies and metaphors that are relatable to the systems that older adults are familiar with, and a new product that is designed in familiar metaphors can reduce the barriers of elderly users to use [14]. Metaphors of the gallery, postcard-sending, and slots-machine were applied our prototypes respectively. The interaction styles were based on the elderly's familiar knowledge to help them understand easily. During our interview of the first iteration, one older adult said: *"It's like a photo art gallery, and it is better because the photos are dynamic."* For our second iteration, one older adult said: *"The slots-machine-like operation raises me a sense of expecting and curiosity for the unknown."*

Providing Paper Instructional Manual. As our prototypes were used by the elderly independently, the instructional manual was needed to tell them how to operate the prototypes. During our interview of the first iteration, one older adult said: *"It is too novel for me, I dare not use it."* Another said: *"Actually I dare not to press the button and I ask others or my son to print postcard for me."* Research also indicated the elderly have reported that they are afraid of using new technological devices as they are afraid of damage the device [19]. Therefore, in the 2nd iteration, we provided the elderly participants with paper instructional manuals, which consisted of step-by-step instructions and corresponding illustrations (Figure 4). The paper manual could also afford easy annotation, which was the elderly were generally more familiar with, compared with online content. During our study, we found older adults in the nursing home still relied on newspaper to get information. The instructions in paper manuals are static, which are easier for some older users, as it matched their learning style. Research indicates that older adults have a stronger preference for using the device's instruction manual over trial-and-error because it matches their learning style.

Tailoring Interface to the Elderly: Aesthetic and Visibility. User interfaces need to be tailored to the specific user group—the elderly. Two aspects were considered in our case, aesthetic and visibility.
Firstly, according to our study, elderly people were still interested in traditional physical objects, vintage and old-fashioned were in line with the aesthetic view of the elderly. Therefore, the vintage style was applied in the appearance of the *Interactive Gallery.* While in the interview with the elderly regarding the appearance of *Slots-Story*, its decorative and vintage effects needed to be highlighted as they hoped prototype could be unobtrusive when putting it at home. As one older adult said during the interview of the 2nd iteration: *"I think I have enough house appliances in my home, I don't want another one." "I don't use digital devices, and I think the vintage style could bring a sense of mysteriousness." "The vintage style could give indications of past things."* Secondly, big and bold fonts need to be adopted considering fading the eyesight of the elderly. The capability of the eye to focus on near objects is diminishing for the elderly. The visual presentation of information should consist of large text, big and clear buttons. During our interview,

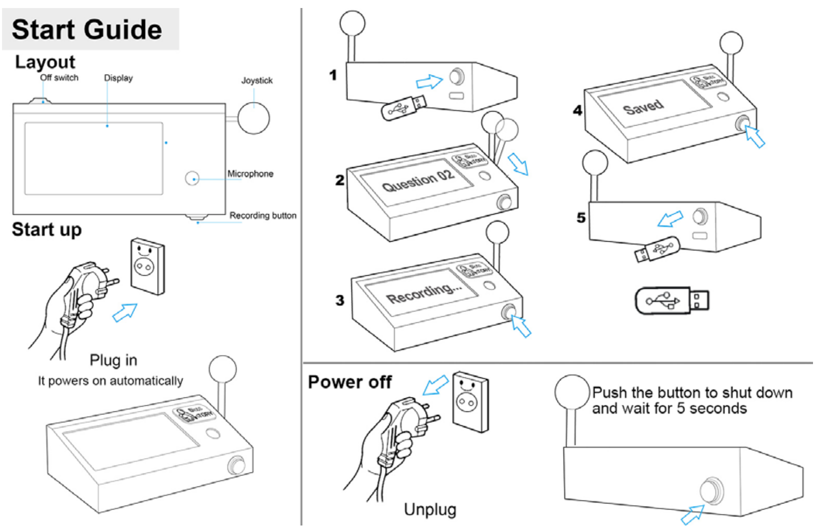

Fig. 4. The paper instructional manual of Slots-story

the older adults were suffering from a decreased vision: *"Two things that have great influences on my life, bad mobility and bad eyesight."*

Avoid Accurate Operation. Large movements rather than delicate operations were applied in our prototypes. The elderly are suffering from the decline in fine motor skills and accuracy of movements, which makes it harder to use small buttons and switches. In our case, big button and lever were designed in *Interactive Gallery* and *Slots-story* respectively, to compensate for the elderly suffering from the decline in the accuracy of movements. As one older adult said during our interview: *"I used to listen to radios, and I still have one in my room. But I feel difficult to operate precisely when I scroll through stations by turning a knob."* Some older adults mentioned the sensitivity of the Slots-story's operation should be reduced, as their hands were clumsy.

Providing Embodied Constraints through Minimization of the Number of Interface Components. Embodied constraints refer to the physical set-up constraining users' behaviors. This restriction eliminates the possibility of making errors, and eliminating the possibility of errors could lower the anxiety brings to the elderly. Our experiences of providing Embodied constraints is minimizing the number of interface components: In *Interactive Gallery*, there was only one interface component--a big button. While in *Slots-story*, there were only two operation components: a handle and a group of buttons. During our interview, older adults appreciated the simple interaction.

5 Conclusion

In this paper, we report our research study regarding intergenerational story sharing of the non-tech-savvy elderly people living in nursing homes, applying R-t-D. We first discuss the research prototype as tools of identifying and answering the research question, including prototype acting as means of narrowing down research focus, answering research question in stages through the evolution of prototypes, and switching between reflection and practice. These lessons have a universal significance for R-t-D application study. We then present our lessons of designing research prototypes for the non-tech-savvy elderly, including providing *Haptic direct manipulation* through tangible interface, providing Representational significance through metaphor, providing paper instructional manual, tailoring interface to the elderly: aesthetic and visibility, avoid accurate operation, and providing Embodied constraints through minimization the number of interface components.

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Topic 7.

Designing with Humans, Machine Intelligence and Data

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PLUG-INS JUNGLE
Algorithmic Design as Inbuilt Dynamism Between Human and Artificial Creativity

Abstract

The paper seeks to define the concept of *plug-ins jungle* as generative background in computational design for new forms of dynamic relationship between human and artificial creativity. This definition will be conducted through the use of theoretical references and practical case studies with the intent to show that the current evolution of a *plug-ins jungle* is affecting design results at all its scales – from product design to urban design – and at all its stages – from design conception to construction and fabrication.
In the past twenty years, the creation of software applications during the design process has exponentially increased in every design-related disciple and the use of plug-ins is giving birth to a new algorithmic evolution of creativity. One of the most interesting examples regarding such matter corresponds to the graphical algorithmic editor Grasshopper and the generation of a series of animal-named plug-ins through which graphically editing the coding process. Grasshopper and its plug-ins represent the touchstone of the ongoing evolution of a new digital jungle in which new software applications are not only augmenting human creativity, but they are also generating new forms of artificial creativity in themselves.
The evidence suggests that the increasing use and creation of software applications during the design process is giving birth to new forms of dynamic relationship between human and artificial intelligence, an inbuilt dynamism through which the human mind and the machine constantly interact with each other producing unexpected and emergent design results.

Keywords

Plug-Ins, Algorithmic Design, Human Creativity, Artificial Creativity, Design Ethic

1. Introduction

In 2014, Andrew A. Smith publishes his book *Grasshopper Jungle* [1]. Despite being a young adult fiction and coming-of-age novel quite unusual and original for its literary genre, its title sounds particularly familiar if referred to algorithmic design and robotic fabrication. In fact, the graphical algorithmic editor Grasshopper currently represents one of the most popular and developed algorithmic editors for designers available on the market. Its use is widely spread throughout the majority of design-related disciplines which are now developing new algorithmic techniques to explore new ideas and opportunities during the design process. The rise of such algorithmic approach is transversally affecting the design process at all its scales, breaking down boundaries between disciplines which were far from each other during the past years. As a

matter of fact, from urban design to product design, algorithms are providing new platforms of research contributing to the generation of emergent and autonomous design results.
The popularity of an algorithmic editor such as Grasshopper lies on a series of opportunities which it is able to provide to its users. First of all, Grasshopper allows the creation of graphical-based algorithms generated by an inductive process which allows the user to intuitively connect pre-coded nodes. Secondly, it allows the user to personally code new scripts through the use of several programming languages such as C#, Python, and VB. Finally, the generation of new and totally customized plug-ins is then promoted inside a unique platform in which the same plug-ins can interact with each other. The inbuilt connection with a 3D modeling software such as Rhinoceros ultimately provides the user with the opportunity to physically produce the designed object through several production techniques, such as the creation of STL files for 3D printing or specific scripts to program robotic arms.

The innovation which this approach is bringing into the design process is clear and significant, and it is giving birth to new forms of relationship between human and artificial creativity. These new forms of evolution require an analysis able to consider algorithms not only as mere mathematical tools, but rather as examples of the rise of a new human progress in design conception based on the influence of artificial intelligence over human mind and perception.

Nowadays, the interaction between human and artificial intelligence represents an open field of debate and investigation, and such ongoing discussion about people in favor of or against to one side or the other has been well depicted by Max Tegmark in his book *Life 3.0. Being Human in the Age of Artificial Intelligence* [2]. In such a background of interest and research, a series of questions arise: what is the nature of this new relationship between human and artificial intelligence? How is it affecting the design process and the new forms of creativity generated from it?

The answer to these two questions requires the use of two concepts, one theoretical and one practical. The former is related to the theoretical point of view to adopt in evaluating the relationship between human and artificial creativity, while the latter refers to the practical ways through which such relationship is manifesting itself. The first concept is the concept of inbuilt dynamism between human and artificial intelligence, while the second one corresponds to the idea of *plug-ins jungle*. Since the former represents the theoretical point of view through which looking at the latter, a note on the inbuilt dynamism between human and artificial creativity is required before explaining the factors which are influencing the rise of the current *plug-ins jungle*.

2. Note on the Inbuilt Dynamism Between Human and Artificial Creativity

The expression 'inbuilt dynamism' refers to the analysis done by the cognitive scientist Margaret Boden in regards to the work of Harold Cohen and his AI system AARON, one of the first example of computer-generated art developed by the British artist during the 1970s. Commenting on Cohen's work and developing the same theoretical construction in her book *The Creative Mind. Myths and Mechanisms* [3], Boden highlights the fact that computational processes – including scripts, frames and semantic nets – are helpful to understand how the brain works and how some aspects of human creativity are possible. The reason for it is "because symbolic and representational structures and transformations are the focus of computer programming, the essence of creativity may not be so far removed from computational processes as is usually assumed" [4]. Although the existance of similitudes between the human brain and computer was something already well presented in the studies of computational pioneers such as Alan Turing and John Von Neuman [5], Boden provides an interesting interpretative key through which reading such complementary relation between artificial and human intelligence:

A functioning program has its own inbuilt dynamism. Its activities can be both flexible and constrained, and a proper amalgam of flexibility and constraint is central to creative intelligence. [6]

Then, flexibility and constraint as the two main factors to understand the real measure of complementarity between artificial and human intelligence, a balance which can only be fully appreciated through the awareness of their inbuilt dynamism.

Another important contribution to the idea of dynamic complementarity between human and artificial creativity is provided by Kostas Terzidis. In his book *Algorithmic Architecture* Terzidis focuses the attention on the new computational process in architecture describing the use of algorithms not only as mere step-by-step problem-solving procedures, but rather as ontological constructions with philosophical and sociological repercussions. Starting from clarifying the distinction between computation and computerization – something already well explained by the author in his previous publication talking about 'algorithmic form' [7] – Terzidis coined the term 'algotecture' to highlight the use of algorithms in architecture. Proceeding through the explanation of a brief history of such 'algotecture' as something substantially different from the more common Computer-Aided Design system – the former not necessarily dependent on the computer, while the latter dependent by definition on it – Terzidis gives evidence to the fact that there are certain levels of problems which cannot be solved by standard CAD systems, but their complexity inevitably required the use of algorithms. His words are particularly significant in this regard:

There are some problems whose complexity, level of uncertainty, ambiguity, or range of possible solutions required a synergic relationship between the human mind and a computer system. Such synergy is possible only through the use of algorithmic strategies that ensure a complementary and dialectic relationship between the human mind and the machine. [8]

Such 'complementary and dialectic relationship between the human mind and the machine' highlighted by Terzidis explains the role of algorithmic design in comparison with human creativity through a critical point of view which can be reasonably reconducted to Boden's concept of inbuilt dynamism in functioning programs and their creative intelligence. This critical point of view is based on mutual persuasion and compromises which are able to generate new forms of creative dynamism inbuilt in the new artificial dimension of human creativity.

The analysis of these theoretical references has been conducted with the purpose to clarify the complementary relationship between human and artificial creativity. Such point of view represents the foundation upon which looking at algorithmic design and evaluating the results coming from it. The ongoing phenomenon of mathematization of the design process is based on the creation of software applications and this approach is characterizing the most advanced researches in contemporary design. New plug-ins are created and grouped together inside bigger platforms – such as Grasshopper – and sometimes they are even programmed to constitute stand-alone applications. Both cases represent the evidence of an exponentially increasing 'plug-ins background' which is progressively evolving the traditional conception of human design: this wide and open landscape is represented by the *plug-in jungle.*

3. Plug-ins Jungle

The expression *plug-ins jungle* refers to AD Profile 222 *Computation Works. The Building of Algorithmic Thought* guest-edited by Brady Peters and Xavier De Kestelier in 2013. Inside the issue, a series of examples are presented to analyze the effects of computational design inside the architectural discipline. In the article *Design Eco-System. Customizing the Architectural Design Environment with Software Plug-ins*, Daniel Davis and Brady Peters describe the evolution of architectural design towards the use of scripting and personalized plug-ins:

This defines an entirely new landscape in which 'cathedrals' (monolithic applications) are challenged by 'bazaars' (generative-modeling editors) populated by animal-named plug-ins. [9]

In the following pages, a series of Grasshopper plug-ins are described such as Kangaroo, Pachyderm Acoustic Simulation, Weaverbird, Geco, Firefly. If now we add to them other Grasshopper plug-ins – such as Goat or Bowerbird, just to mention a couple – and even compound software such as Rhinoceros and its rendering extensions – Penguin or Flamingo among the others – the definition of a *plug-ins jungle* seems pertinent and appropriate for a computational environment dominated by animal-named applications.

Inside the same AD Profile 222, a series of case studies are proposed with the purpose to highlight the effects of such algorithmic tools over the final design results. In this regard, particularly interested are the examples explained by Giulio Piacentino and the use of the Grasshopper plug-in WeaverBird [10], and Thomas Grabner and Ursula Frick and the use of another Grasshopper plug-in such as GECO [11]. In the first case, the use of the plug-in gives access to surface subdivisions and transformation operators which allow a topological editing of the starting design creation. In doing so, the exploration of a series of design options comes from the action performed by the algorithm itself, which therefore becomes a fundamental factor in design creation. In the second case, the use of the plug-in GECO in conjunction with the software Autodesk Ecotect allows a constant interaction between modeling and software analysis, and such interaction produces effects in terms of design results – such as in the case study analyzed in the article, that is the Shenzhen Boarder Station competition entry designed by SPAM, where the plug-in has been used to run a solar access analysis through which roof openings have been located and designed. In both cases, the use of plug-ins significantly influences the final design results, and therefore they are clear examples of how the action of the *plug-ins jungle* is a touchstone of the rising phenomenon of hybridization between human and artificial intelligence in the current evolution of creativity in computational design.

The examples which can be mentioned to confirm such fundamental influence of plug-ins over final design results are numerous and almost unlimited. In fact, nowadays the use of Grasshopper and its plug-ins is becoming part of the standard practice in many architectural firms, and it is very often the case to see such applications embedded into the workflow from the very early stages of the design process constituting basic tools of design exploration and investigation. Having said that, the concept of *plug-ins jungle* goes far beyond being a definition related to a single algorithmic editor such as Grasshopper, but rather it represents a more complex working model towards which both the design profession and the construction industry are evolving too. Algorithmic creations and software applications constitute by now the core of any advance research related to the built environment, and this aspect represents a clear confirmation of the fact that the ongoing process of mathematization is not only producing new forms of development inside the single discipline, but more importantly it is linking together different disciplines inside new algorithmic platforms.

4. Extended Examples of Plug-Ins Jungle

In the current evolution of computational design, there are several fields of research in which the action of the *plug-ins jungle* plays a central role in the realization of final design results.

First of all, *plug-ins jungle* is the natural habitat for the complexity of design generated in the last twenty years across all design-related disciplines. Promoted by the rise of a mass-customized production system, sophisticated software applications and new digital fabrication technologies have enables designers to build experimental structures with a high level of complexity. Such complexity is based on continuous and seamless forms, and although nowadays such trend seems to be overtaken by the rise of a more discrete approach – in this regards, Lei Zheng offers an interesting comparison between the two models [12] – the digital turn of design in the last two decades has been based on a constant exploration of complex shapes and structures. For instance, the work conducted at ZHACODE is particularly significant in this regard. The computation and design group at Zaha Hadid Architects is a research group which focuses its attention on invention and innovation through the use of computer software programming and physical computing, considering algorithms as exploratory phases for the discovery of new design and production opportunities. Among a wide range of projects, the installation 'Thallus' exhibited in Milan during Salone del Mobile 2017 represents a perfect example of the research conducted by ZHACODE in terms of customization and mechanization of the design process. The installation is composed by a 7km long continuous line made of an extruded structural strip produced by 6-axis robotic 3D printing technology. The design of the structural strip is based on differential growth methods dictated by an algorithm which uses specific parameters – such as proximity to boundaries, angled direction of ruling, and structural requirements – to establish density gradation and direction of growth.

Other than representing the field of action for complex forms and structures in digital mass-customized production, the *plug-ins jungle* is also the place for the creation of tools through which promoting open-source design. The rise of open-ended and adaptable systems based on sharing software, ideas and models is becoming one of the main field of research in the current evolution of computational design throughout all the disciplines. An interesting example of this approach is represented by the work done by Enriqueta Llabres and Eduardo Rico in terms of urban analysis and design. Through their multidisciplinary London-based office Relational Urbanism, Llabres and Rico developed a design approach to digital forms of urban documentation based on Relational Urban Models (RUMs). As explained by the authors in their article *Relational Urban Models. Parameters, Values and Tacit Forms of Algorithms* [13], RMUs are design models based on the new forms of digital urban documents which collect inputs from designers, government bodies and members of the public, allowing information sharing and feedback from the end user to the design team and vice versa. This new form of shared authorship in design conception is possible through an application based on a generative algorithm able to analyses data and parameters to elaborate new urban configurations. For instance, parameters based on the proximity of the street network allow to retained certain blocks and to remove certain others, or again the final configuration of a tower can be sculpted on top by constraints of sunlight exposure. The final design is the result of the action of algorithms able to mediate the effects of environmental parameters with the starting requirements coming from human inputs.

Another field of research in which the plug-ins jungle plays an important role is automation and digital production. For example, the wide use of 6-axis robotic arms in design production and assembly is made possible by the use of algorithms and software applications which not only allow to program robots according to specific design requirements, but also influence the final design results through the control of the robot's action and movement. For instance, the Grasshopper plug-in Robots is a clear example of this process and it allows programming ABB, KUKA and UR robots. Always talking about robotic fabrication and the influence on design played by algorithms to program such machines, an interesting example is provided by the heterogeneous multi-robot systems which constitute an open field of research at the ICD/ITKE at the University in Stuttgart. As explained by Maria Yablonina and Achim Menges [14], such multi-robot systems are based on the use of bespoke design machines in conjunction with standard industrial robots. This mix during the fabrication process allows a higher level of flexibility and scalability compared to the exclusive use of industrial robotic arms. An example of this process is provided by the ICD/ITKE Research Pavilion 2016-17. In this case, the use of a path correction algorithm relying on camera-based tracking system controls the flight of the mobile robot which is represented by an unmanned aerial vehicle (UAV), while other software applications are used for analysis and optimization of the Pavilion structure dictating robots' movement through the location of the primary and secondary structures, both made of carbon tensile filament structures with the primary one realized in carbon fiber-reinforced ribs.

Finally, another field of research in which the action of the *plug-ins jungle* plays an important role in the creation of final design results is represented by optimization and form-finding techniques. As already explained by Mark Burry describing the works of Antoni Gaudí and Frei Otto as main precursors in computational design in terms of form-finding and structural optimization [15], nowadays such techniques are widely used in contemporary design conception and they are based on several software applications. For instance, Kangaroo is one of the most popular plug-ins for Grasshopper and its use allows to modify design in response to engineering analyses simulating aspects of the behaviour of real-world materials and objects. Always regarding such matter, the work of the Digital Structures research group at the MIT Massachusetts Institute of Technology represents an important example in terms of structural optimization and the different design configuration generated from it. Group leader Caitlin Mueller pays particular attention to the relationship between structural optimization and design conception in her article *Distributed Structures: Digital Tools for Collective Design* [16]. Highlighting the fact that the creation of new computational tools is shifting the role of computation itself from representation and analysis to creative idea generation, Mueller provides a series of examples in which the use of multi-objective optimization techniques offers the opportunity for the designer to choose between different options generating during the optimization process. Such opportunities are made possible to the use of plug-ins specifically developed for such purpose. For instance, the web-based design application StructureFIT and the Rhino and Grasshopper plug-in Stormcloud – both developed by the MIT Digital Structures research group – allow to designers to explore new design typologies and forms with high level of structural feasibility.

The examples described so far represent only four instances belonging to a wide range of case studies in which the final design is the result of a very close relationship between the human input and the computational calculation belonging to the machine. From this relationship, a new design world is rising and the *plug-ins jungle* represents its natural habitat. Such habitat is based on the constant interaction between the human mind and the machine which effects design right at the very beginning of its conception. Inside such contextual background, plug-ins are the places able to host new forms of emergent creativity coming from a new relationship between the man and the machine.

5. Conclusion

The theoretical considerations and practical case studies analyzed so far represent a critical point of view through which looking at the current evolution of computational design and the increasing use of software applications during the design process. The rise of the *plug-ins jungle* is affecting computational design at all its scales – from product to urban design – and at all its stages – from design conception to automated fabrication. Software applications are becoming indispensable prerequisite for any design process and the fact that the authorial role of the human designer may not survive to this digital turn is a concrete possibility for the future of any design-related profession. As already explained by Mario Carpo in his book *The Alphabet and the Algorithm*, the more frequenwt use of algorithms may eventually transform human designers into IT developers, i.e., changing their role from creators to mere plug-ins users/generators [17]. This scenario may not represent an alarming point for those ones who believe that the future will not belong to human beings but to machines. On the other hand, this point of view may not be supported from those ones who believe that any technological development is first and foremost a matter of human progress.

The theoretical construction of the entire paper is built upon the association between two apparently dissimilar species – such as the man and the machine – and the inbuilt dynamism which regulates such relationship. Considering the design process as a field of investigation has constituted an appropriate point of view to understand the dynamic complementarity between such species and the creativity which arises from them. After all, as already explained by Nicholas Negroponte at the very beginning of the computational evolution of design:

The partnership is not one of master (smart, leader) and slave (dumb, follower), but rather of two associates which each have the potential for self-improvement […]. Eventually, a separation of the parts could not occur; the entire 'symbiotic' system would be, as Gordon Pask described, an artificial intelligence that cannot be partitioned. [18]

According to Negroponte, from the rise of this new form of artificial intelligence, a new 'extended designer' (the man) and 'artificial designer' (the machine) will be generated in favor of a constant and mutual design complementation, augmentation, and interaction between the human mind and the machine. Today, such 'extended designer' and 'artificial designer' are two actors of the same reality and their interaction is constantly producing new forms of inbuilt dynamism between human and artificial intelligence. The complementary approach between them seems to be a more appropriate point of view from which looking at the ongoing evolution of algorithmic design, and a closer look into its natural habitat, namely a walk in the *plug-ins jungle*, may provide an effective starting point for further research.

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Defining a Data Impact Tool for Design Courses

Abstract

Wearable product/service solutions are increasingly spreading in everyday life aiming at supporting and tracking activities, also increasing self-awareness about behaviors and body parameters. The amount and variety of personal data generated and collected by these digital services is unprecedented in human history, and impacts on individuals, societies and organizations can now be only partly predicted. The design of data management in these solutions has so become a critical task for both designers and service providers. This paper presents the results of the application of a design tool, as part of an Impact Anticipation Method, created to foresee problems and opportunities so to improve design choices in quick design processes and design courses. The tool aims at stimulating the discussion on impacts related to the use of personal information. The results point out the usefulness of the method's tool in raising awareness in designers, elicit critical thinking fostering the discussion on the topic, and provide insights for improvements. It demonstrates the need of more agile ways to address the topic in the design process. Students faced their lack of knowledge about how and when personal information is implied in their solutions, and on potential impacts that such information could have.

Keywords

Personal Information, Design Tool, Impact Anticipation Method, Ethical And Societal Impacts

1. Introduction

Wearable product/service solutions are increasingly spreading in everyday life aiming at supporting and tracking activities mainly for wellbeing and healthy purposes, also increasing self-awareness about behaviors and body parameters. Data-driven solutions commonly employ personal data to provide value within services, and the management of such data has become a critical task for designers and service providers. The design of a new product/service is often carried on with the purpose of responding to needs of people and communities; in other words, design for innovation is often directed toward utopian goals. However, innovative solutions and functionalities, when implemented in the society, can lead to unexpected consequences related to some elements that compose the solution, or to the use of the solution itself. As pointed out by visionary technologists and scholars [1] [2] [3] [4], the use of personal data in services has a social relevance as an agency that could have impacts on the way people perceive themselves [5][6] [7], on how the perceive the contexts they interact with, and on how they participate in social life [8][9][10]. It also changes actions and behaviors [5][6][11], as well as roles and relationships between people and between people and organizations [12][13][14][15]. Ackoff's DIKW model [16] defined data as "symbols that represent the properties of objects and events and their environment". Data "are useless until they are in a useable (i.e. relevant) form" [16]. Taking persons as carriers of properties, we consider personal data as raw material to be processed so to be useful. Personal information is then the signifier extracted from the elaboration of personal data. While the authors of this paper are engaged in an extensive research about the use of personal data in design [17][18], in this paper we focus on personal data involved in wearable devices. Wearable technologies and sensors embedded in wearables gather data about individuals and process them so to create personal information that is valuable for the users and for service providers. Personal information is interpreted by services through analysis and comparison with rules, reference knowledge, statistics and algorithms; in this way, it becomes knowledge that can be used to provide added value through service functions or provide awareness to the user itself. The amount and variety of personal data that are generated and collected by digital services is unprecedented in human history, and the impacts on individuals, societies and organizations that can now be only partly predicted. From the design point of view, the management of data is therefore a new dimension of social responsibility in design, requiring suitable attention and efforts. In other words, as designers, we argue the importance of developing design approaches apt to exploit the potentials of data to produce value for individuals and communities, and, on the other hand, to learn how to predict the possible – utopian and dystopian - impacts of functionalities and services employing data, so to adopt suitable design choices. The main research developed an approach (knowledge, method and tools) for the anticipatory investigation of the potential impacts of the management of personal data in product/service design [19][20]. In this paper we focus on the use of a light (reduced and adapted) approach, to be adopted in education and whenever the design resources do not allow the use of our main methodology. The paper reports the results obtained applying the light approach in an education workshop, and the main features of the proposed approach. The results demonstrate that the anticipation activities provide design hints and guidelines for the responsible development of services and systems.

2. Exploring Impacts Related to Personal Data in the Design of Wearable Products/Services

To foresee the impacts that an interactive service could have when implemented in the society, we defined the Impact Anticipation Method (IAM). The method brings the society's point of view into the design process to encourage and support ethical discussion on future impacts of solutions that imply the collection and use of personal data and personal information. It identifies insights to raise awareness and stimulate critical thinking during the design phases enabling the identification of the potential impacts. Using this approach, for each specific project brief, we can identify critical themes related to the use of personal information that we consider as relevant for the assessment of features of a new project [19][20].

For the specific topic of this paper, we report here the critical themes that can significantly be related to the design of wearable devices involving the use of personal data. Each theme should be considered during the design process so to orient the creation of a new solution toward the optimal satisfaction of user needs and to the maximum respect of basic individual right.

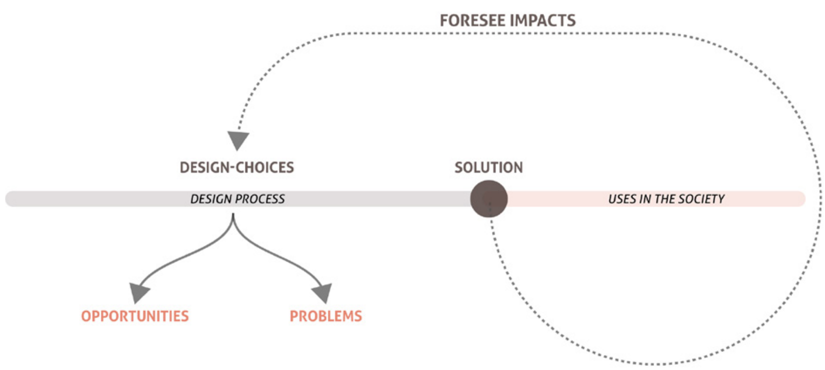


Fig. 1. The IAM aims to foresee issues (opportunities and problems) during the design process

Awareness of Data Tracking, Sharing and Use. The users of a wearable connected object are supposed to be well aware of detection and tracking of behaviors and biological data in real-time. What if they are not fully knowledgeable? Some issues arise when users are not completely conscious about when the tracking occurs, which data is collected, with whom every kind of data is shared or sold, who is using it and what kind of profit can be obtained by providers and partners.

Altered Cognitive Load. Proactive and reactive services can lower cognitive load allowing the user to shift the focus from tasks to the user experience. However, especially in the case of wearables, the use of the technology itself can increase the cognitive load due to information and knowledge returned as visual feedback or insights. Furthermore, wearables can raise stress due to information and suggestions related to problems, options and situations the user wasn't aware of.

Self-mirroring into Data. The users' self-perception changes and relates to the self-knowledge they acquire while understanding their own's data [21]. When the users access the data, their ability to conveniently interpret the returned information is crucial with respect to the improvement of self-knowledge and to avoid misinterpretation. Services should therefore provide the information consistently with the user's interpretation skills.

Altered Attitude and Quality of Life. Tailoring and automation can improve already existing services and, as well, enable the creation of new ones for specific purposes. The increasing availability and pervasive use of sensors can change users' attitude in actions and behaviors. People behave in a different way when they know (or think) they're being observed [22]. A system can however take advantages from the 'observer effect' aiming at changing users' behavior for their good according to goal settings.

Creation and Management of Community of Value. The interaction of people through their data often creates or reinforce a community thanks to the sharing of values related to the purpose of data tracking. As an instance, a community of runners can sort out clusters based on running performance. Crucial tasks are to ensure that the exposition of data among the community is volunteer and to consider, in the design process, possible issues related to self-exposure and self-disclosure; as well, the lack of representation in the community of people that don't track themselves should be considered.

2.1 The Impact Anticipation Method

The Impact Anticipation Method is the main outcome of a PhD research [23] and it eventually aims to elicit critical thinking in designers so to support decision-making during the design process of innovative solution. The raising of awareness of possible impacts, allows designers to create more robust and reliable products strengthening also the image of the company that is providing the service. The method is a twofold system: the first one consists in the *Potential Issues Database* aimed at the **creation of knowledge** about the possible consequences, - problems and opportunities - that the use of personal information in connected services might produce. The second part of IAM consists in the **application of this knowledge** in the design process through the *Data Impact Tools* so to raise awareness in the designers about possible impacts. The Potential Issues Databases is a rich collection of references, reporting situations associated to the use of personal data in services and connected products, coming from real world discussions and from future scenarios extracted from fiction. The references are classified and therefore explorable through an interactive platform [24]. The knowledge included in the Potential Issues Database ranges between different application fields and can be employed in different design contexts. Following the IAM, the impacts related to the use of personal data and information can be expressed in four layers: i) user's self-perception; ii) people's behavior and performance of actions; iii) interpersonal relationships; iv) social agency [19][20]. The iteration of the tools' design has been performed applying and refining them in use cases of research projects and design courses. This paper focuses on the second phase of the method and reports results of a research investigating the potential of the approach suitable in design contexts with string constraints of time and resources. Possible applications of the knowledge contained in the Potential Issues Database refer to four main activities of the design process:

Analytic. In the preliminary analytic phase, designers explore the context for which they have to design the interactive solution. In this phase, the Potential Issues Database provides suitable refences through research filters (Impact Layers) of use cases and situations, so to foster the discussion on user's rights and produce design guidelines for the subsequent design phases.

Creative. Designers ideate the concept through the envisioning of context scenarios of application. In this design phase, the Potential Issues Database supports the envisioning of scenarios through the analysis of insights coming from eight macro-scenarios that we created to represent in a synthetic way the most important situations that can be associated to data management [18].

Refinement. Designers deal with specific choices (physical design) and formalize the solution through prototyping and refinements. The knowledge contained in the database support the decision-making about functionalities. The application of the Data Impact Tool in this phase is the specific focus of this paper.

Assessment. The assessment phase allows designers to evaluate the solution and test it with users through prototypes. The Potential Issues Database supports the evaluation of features and the preparation and conduction of user tests so to center the attention on ethical and social elements to create guidelines for future iterations of the project.

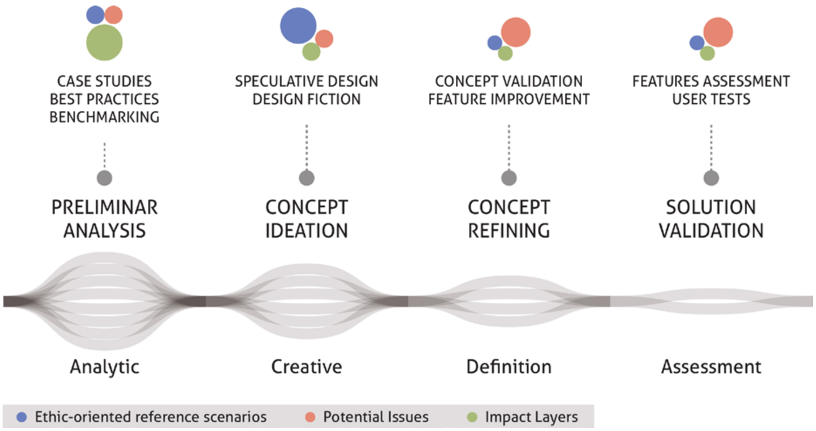


Fig. 2. Application of the knowledge of the Potential Issues Database in the design process

3. A Light Approach to the Investigation of Impacts Related to the Use of Personal Information

Design tools are the means by which designers preside over the cornerstones of the process, so to ensure that all the most critical and important aspects are nevertheless carried forward and considered. Designers use visualization to develop design thinking, to share knowledge with project partners, to create consensus with stakeholders, and to guide the development and implementation of the material parts and those not tangible of a system [25][26]. In other words, design tools are a designer way to produce knowledge and to support the suitable development of projects. The IAM approach is not just focused on the production of knowledge, but our research also includes experiments to investigate how the knowledge can be applied through design tools in different contexts. For these reasons, we have developed a light tool to be used in design education and in the design-contexts with limited resources.

3.1 The Creation of the Light Data Impact Tool

In previous work we described some applications of the method [19] and its iteration [20] that led to the creation of an In-depth Data Impact Tool meant to be used by expert designers in complex and long design processes. However, the validation of the In-depth Data Impact Tool highlighted limits related to its complexity and time needed for its use. We created the Light Data Impact Tool that is meant for the design contexts where the full data-base is not available or when the time and resources for design are limited, consists in some design activities, specifically focused on the investigating

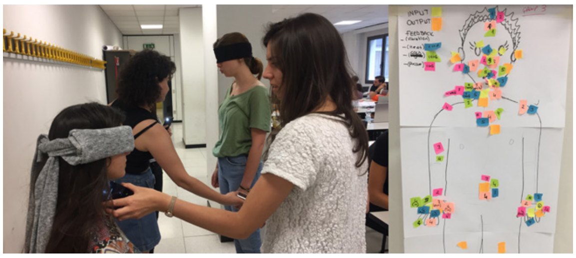


Fig. 3. Students working on on-body sensations and related body map of stimuli used as reference for the creation of the concept

the potentials and criticalities connected to the use of personal data for a specific design brief. The features of the light tool are explained in the following of the paper through the report of its application in an education experiment.

3.2 The Workshop About On-Body Interaction Design

The workshop "In Close Proximity" was conducted by Professor Patrizia Marti and Laura Varisco at Politecnico di Milano in June 2018 with a class of students (around 40) of the master's degree program in Digital and Interaction Design as a reflection on the experience of use of on-body technologies [27]. It guided the students through a research-through-design exploration following a step-by-step process to design wearable solutions, from the initial idea to the interaction dynamics using various design tools (e.g. Body Map, Mood board, Personas, Bodystorming, Wizard of Oz, interviews, and questionnaires).

The students dedicated one full day of the two-week workshop to the exploration of possible impacts of the use of personal information of their designed solutions. We used this workshop to validate an agile Light Data Impact Tool that can be use in education and by professional designers. The tool has been used during the definition phase, when designers already had a clear concept for their solution and were defining features and details. The application of the tool followed four steps:

Step 1 – Lecture. A lecture to clarify the topic of the use of personal information, and the related types of opportunities and problems.

Step 2 – Identification of Implied Personal Information. A template was distributed, and students had 30 minutes to fill it with: A written description of how and why their solution implies personal information; The identification of all the actors involved in the service and their motivation; The list of technologies implied to gather and manage personal information.

Session 1 (Teams 2,4,6,8)	Session 2 (Teams 1,3,5,7)
(1h) Group conversation	(1h) Template 2 fulfillment
(1h) Template 2 fulfillment	(1h) Group conversation

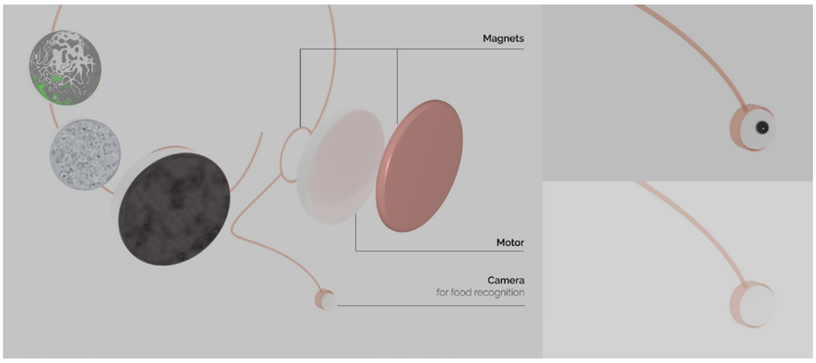
Table 1. Organization of the activities for the two sessions

Step 3 – Exploration of the Potential Issues. In order to have comparable results, we divided the 8 teams of students in two sessions. The first session spent one-hour in a conversation leaded by one of the teachers, informing them about the Potential Issues Database. After the conversation, students had one hour to fill a second template, reporting elements related to the consequences of the use of personal information that they identified as relevant for their concept. The second session of students performed the same activities, but at first, they fulfilled the second template without the support of the Potential Issues Database, and, later, they had the group conversation (Table 1). We compared the outputs (templates produced with and without the support of the knowledge contained in the Potential Issues Database) so to verify the usefulness of the conversation on issues.

Step 4 – Selection of Issues and Discussion of Improvements. As a last step, we asked the students to select, for their own project, the issues they considered as most relevant and worth of discussion. We also asked them to list the improvements they would propose for their concept in a third template. At the end of the day, we collected student feedbacks in a questionnaire about the activities performed. According to the answers, the students found useful both the content and the discussion.

4. Results of the Use of the Light Data Impact Tool

The results of the workshop, together with some further experiments, confirmed the usefulness of the IAM to orienting designers toward improvements of their concepts, and to raise awareness about the consequences of their design choices. Furthermore, the workshop produced evidence of the effectiveness of the light tool, since: i) all the students stated that the lecture and the group discussion allowed them to find interesting correlations between the use of personal data and possible impacts; ii) the interactive exploration of the Light Potential Issues Database [28], organizes in critical themes [20], reduces the complexity related to the amount of information allowing designers to nimbly access the knowledge saving time and effort; iii) the students were able to improve their projects considering aspects related to the privacy and rights of the user (pointing out the advantages of avoiding storage of unnecessary data, and the importance of giving users the control on data sharing to avoid the perception of being exposed – e.g. deciding to allow users to clog a camera while not used – Fig. 4), but also including aspects related to impacts that goes beyond privacy concerns such as avoiding overload of information through careful redesign feedbacks from the system (e.g. reducing the amount notifications, deleting data after 4 hours, and creating interaction summaries in the form of abstract artworks that aggregates data avoiding useless details and comparison between involved users – Fig. 5); iv) although many of the improvements focused on avoiding problems, others aimed at increasing features of the concept as result of discussing about opportunities given by the use of personal data. Working on eating experience for people with impaired taste [29], a team proposed that the service could consider user's food preferences to provide additional features. Another team, working on an automatic translator for slang and common language phrases [30], considered storing translated sentences to allow users to recall them when needed.



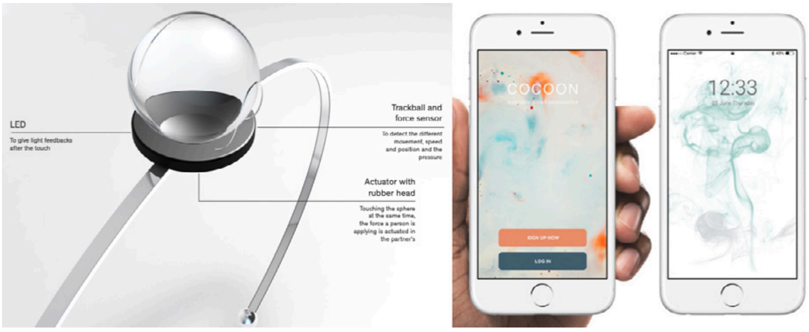


Fig. 4. (above)Tasteless' [29] is a project of a neckless that imply image recognition for food experience. After the use of the tool, the students included the possibility to clog the camera while not used so to protect the user's privacy concept.

Fig. 5. (below) 'Cocoon' [31] is a project of a bracelet aiming to improve physical communication between people in long distance relationships. The use of the tool led the students to carefully design notification mechanisms so to preserve meaning while avoiding information overload.

5. Conclusion

The validation activities and feedback from students provided useful insights about strengths and criticalities, supporting the Light Data Impact Tool and the IAM method approach producing evidences about two topics: First, the results of the identification of personal information involvement in the concepts, show that students struggled in understanding what personal data their concepts use, how the information flows work in their solution and what are the involved actors. They have little prior awareness about the role played by personal information in their solution, and about the criticalities and potentials. The introduction of a tool for representing data and their flows in the system, enables thinking and addresses the attention on this subject. Secondly, the students had difficulty on exploring the numerous issues and clusters of information contained in the Potential Issues Database; the knowledge generated by the research is huge and difficult to access. On one hand the observation and the students' responses to a further online survey related to the activities and during informal interviews, point out the importance and usefulness of the development of the Light Potential Issues Database as a valid tool to support their awareness on both the use of personal information and its possible consequences. On the other hand, they demonstrate the need of agile ways to address the topic in the design process. Students faced their lack of knowledge about how and when personal information is implied in their designed solutions, and on potential impacts that the use of such information and the derived knowledge could have. This made clear that there is a need of critical thinking for the design of solutions implying the management of personal data. The design of tools that help designers in envisioning and foresee impacts demonstrates to be a valid contribution for the design culture to allow designers in creating responsible solutions that consider ethical and social issues in the design process and stimulate the conversation about responsibility in the design field.

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Interactive Demo Sessions.

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Prosumeristic Publications: alt+yd

Abstract

This article describes the design process followed in the making of a prosumerist publication. Alt+yd is a printed zine that goes beyond one-way communication with its readers. It takes into account the reactions of Instagrammers to its digital publication and using a program, incorporates it into its printed self. Inspired from the Open Source and Open Data culture, project alt+yd reflects upon the kind and medium of content most consumed today, and the relevance and possible adaptations of traditional media to keep in pace with emerging digital culture.

Keywords

Prosumerism, Internet Culture, Design Process, Print, Editorial Design

1. Introduction

In this article we present to you an experiment in editorial design, the output of which is a zine named alt+yd. The experiment involved integrating social media as a programmed content source for a print publication. Simply put, we created a program that would convert Instagram profile data into printable publication spreads. We believe writing about this editorial design process is of importance as our experiment is potentially one of several precursory examples exploring the future of print publication.

2. Background

The National Institute of Design is India's premier design education, service, and research institution. Every year at the school, hundreds of students sit for the annual campus recruitment event, colloquially called the 'placements'. There are two kinds of opportunities at the event: for students seeking graduation thesis internships and for graduates seeking full-time jobs. Those who fit the cookie-cutter requirements of the industry are selected and often offered large starting packages.

The 'placements' is a good platform to meet potential employers if what the student seeks is to work in these said companies. However, most students are in the process of figuring out what they want to do and find themselves to not fit the demands of the campus recruitment companies. Students whose portfolios do not adhere to the traditional interpretations of their disciplines find it difficult to market their design approach and practice. Furthermore, younger design students inadvertently begin looking up to the industry norms thereby preventing themselves from exploring the field independently.

In light of these micro-conflicts, discussions arose and a shared desire was expressed by the authors to create a platform that showcases alternative projects and celebrates experimentation. The aim was to highlight projects that touch upon non-mainstream subjects and methodologies but often go unnoticed. Therein the idea of a publication documenting such projects emerged. The name alt+yd is a take on the Young Designer (YD) book, a compilation of all the graduation projects, published every year by the National Institute of Design (NID).

3. Intent of the Zine

Alt+yd is a curation of graduation thesis projects done at NID that explore emerging design practices and futures of the country. By showcasing alternative possibilities of graduation projects, alt+yd aims to be a source of inspiration for budding design students and is intended to be a statement to the design industry on the fresh possibilities that the field provides.

4. An Experiment in Editorial Design

Publication has traditionally been a one-way communication platform where the printed material communicates to the reader. The authors decided to ask- what might a book look like if every reader, in some way, could contribute to the published content? In the ever-connected world of the internet, how might one achieve that?

Hopping from the concept of shared Google docs to crowdsourced[1] content, the authors landed on the concept of Prosumerism[2].

5. Prosumerism

A Prosumer[3] is a person who produces as well as consumes a product. In the context of the early 21st century, the term 'Prosumerism' blurs the meaning of the term 'product' itself. On almost all digital platforms today, the consumer of the digital content is often also the producer of the said content. A give and take of data to and from the people runs most systems today. Interesting results can be seen if the concept of prosumerism is applied to other, traditionally one-way media.

6. Prosumeristic Publication: A Note on Production Methodology

What might we get if we 'Ctrl+P' an Instagram profile? Given its wide reach and ease of use, Instagram was chosen as the social media platform to display alt+yd. An Instagram page (@altplusyd) was created for the project. The primary content of the zine- a curated collection of provocative projects was regularly updated on the page. The aim of the page was to elicit dialogue and reactions to the digitally published projects.

An application was custom developed in the Processing Development Environment (PDE)[4] to extract all the content of the Instagram page and convert it into print ready spreads. This application exploited Instagram data available to its users in the form of JSON[5] files. These files helped with the extraction of two kinds of data- 1) The metadata: the project title and the department was extracted from the hashtags, 2) Project information: the project description, comments and likes were pulled from the post. The consequent spreads therefore contained not only the projects but also the reactions and comments they had garnered on Instagram,

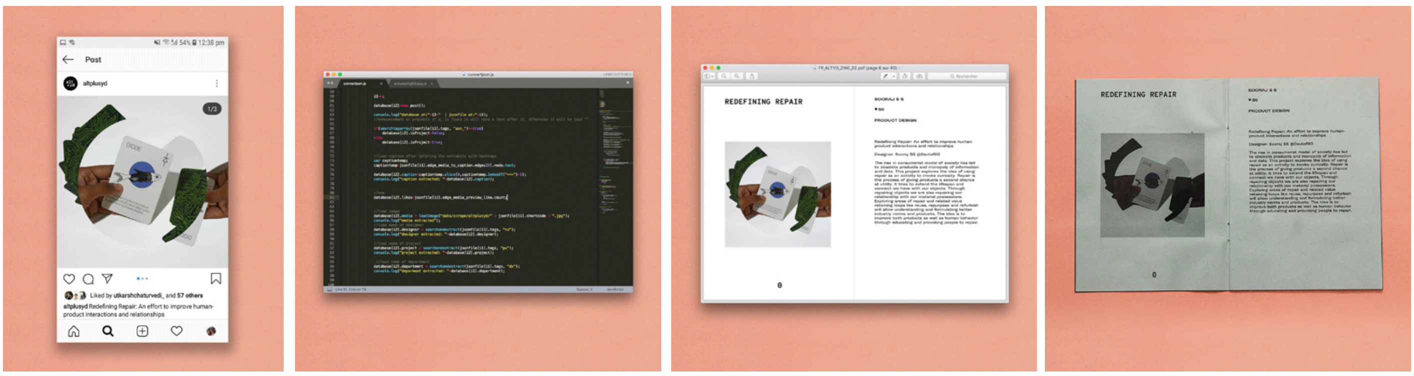

Fig. 1. (left to right) The Instagram post, the program, the generated spread, the printed book

ensuring that the same audience who would read the book in the future could contribute to its contents in the present.

The additional standard pages of a publication such as the title, conclusion and print notes were created in InDesign and added to the generated PDF of the main text block. The technique of foiling was used for the cover page, each cover was foiled by hand, giving each copy a unique appearance. The cover and the text block were then center-stapled and cut.

The first edition of alt+yd was available at the 39th Convocation Ceremony of the National Institute of Design, 2019. Every printed edition thereafter will be different from its predecessor due to its ever evolving content.

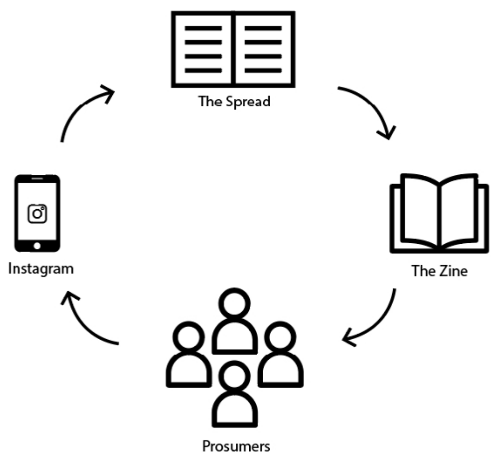

Fig. 2. Production cycle of alt+yd

7. Freedoms and Constraints of the Project

The authors had total freedom on the design and production of the project. Constraints were few but hefty. The project was conceived on December 1, 2018 and had to be delivered by January 10, 2019. The entire timeline for conceptualization, prototyping, and production was all within a month. The budget of the project was restricted to 5000 INR, i.e. around 70.44 USD.

8. Reflections

The eye is well acquainted to how a book reads. So much so that the mind forgets that the book is the way it is, owing to the freedoms and constraints of design and production dating back to the era of the printing press.

A prosumeristic publication comes with its own quirks on how it reads. These quirky elements are not entirely new. It was observed that they merely seemed misplaced to the eye in the context of a printed booklet. The following are the observations and feedback of the readers of alt+yd as well as the authors:

1. The emoji '❤45' (heart icon + a number) is a familiar symbol. Most are aware of what it signifies in the digital world- that 45 people have 'liked' the post. Yet, finding it on printed paper was a new experience.

2. Proper nouns were no longer just words. Any name which had an Instagram profile to it was tagged with an '@'. This is a common practice in the digital world, yet, seemed uncommon when every name was followed by the Instagram counterpart of it.

3. Comments on the digital platform are another regularly occurring phenomenon. Yet, printed comments seem unusual, even more so when on reading them one realizes that they could be written by bots!

4. The usage of '#hashtags' to control the content flow from the Instagram posts to the publication- Since not all posts could be a part of the publication due to certain editorial decisions and constraints, a new system was devised to control this content flow using hashtags. These hashtags helped the custom-developed program

Fig. 3. Printed copy of alt+yd, first edition (2019)

to identify the posts that were to be fully incorporated in the publication, the posts to be included partially as well as those that were supposed to be excluded completely.

5. Comments that tagged other people, thanked someone or were emotionally charged, suddenly seemed to have relatively more gravitas in a printed publication than online. An indication of how we still take printed content more seriously than digital?

9. Conclusion

This zine explores a future of print publication where the boundary between the digital and the physical medium is blurred. The physical is not merely a tangible copy of the digital. Rather, the physical could borrow from the evolving reactions to the digital, making 'reactions' another form of content. With a future-oriented outlook, the approach with which alt+yd was made asks the following questions:
'In what ways might the boundary between the digital and the printed be blurred?'
'How might 'open source' be interpreted in the world of print publication?'
'Can a reader contribute to a book even after it has been printed?'

NAMRATA PRIMLANI

♥ 38

NEW MEDIA DESIGN

Society of Objects: Designing the Social Internet of Things

Designer: Namrata Primlani @za.zen_
Self Sponsored

In an age where computers are shrinking in size, sensing is cheap and data abundant, the author investigates the concept commonly known as the Internet of Things. The author dissects the Internet of Things from social, cultural, economic, technological, political and ethical standpoints. Through prototypes, the author attempts to gain insight into how the Internet of Things technology is intertwined with social, cultural, ethical and political aspects of human life and how the technology gains relevance when viewed from these perspectives.

COMMENTS

brn.ai
Do you want to start a chatbot company! DM me!

Fig. 4. Example of a printed comment, potentially from a bot account, alt+yd (January, 2019)

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Swimming Coach: An Immersive Swimming Learning System

Abstract

Swimming is a common activity to keep fit. To assist hydrophobic users to overcome the fear of learning swimming, and to give full play to the advantages of land swimming practice, we propose a swim learning system which includes VR system, wearable devices and frame structure to provide users with an immersive and interactive learning experience of swimming without water. Users' real-time postures can be detected by using the body gesture recognition system, while visual and haptic feedback are also available to users. Preliminary investigation shows that the proposed system has demonstrated potential in the field of swimming learning.

Keywords

Swimming Learning, Virtual Reality, Immersion, Head Mounted Display, Gesture Recognition

1. Introduction

Swimming is a popular activity that offers physical and mental benefits. It ranks as one of the sports activities that people like most [1, 2]. People learn to swim not only for health and recreation [3] but also for self-rescue [4]. However, swimming is a complex sport that requires a flow of quick, smooth and accurate movements, so swimmers need external guidances and constant practices to build muscle memory [5] by land swimming practice. Due to the lack of related scientific learning system, beginners are hard to overcome the fear of water. Besides, they do not receive immersive swimming feedback, which do not suffice for fast improvements.

Thus, we propose "Swimming Coach," an immersive swimming learning system. The system can help beginners to learn to swim with an immersive and interactive swimming learning experience.

2. Related Work

Some researchers created virtual immersive underwater environments to mimic the real visual feeling. For instance, Shogo Yamashita et al. designed a cave system with multiple stereoscopic projections on surrounding acrylic walls, providing swimming environment with swappable scenes, such as coral reefs and shark cage diving [6]. Similarly, Lisa Blum et al. presented a system using augmented reality techniques to simulate a regular swimming pool with virtual objects [7]. The above works made users feel that they were in water environments visually, though researchers did not provide other sensory experiences.

Some works used certain physical structures to simulate swimming in water under the condition of waterless. In the system of Tzu-Pei Grace Chen et al., the user was suspended in a real swimming apparatus which simulated the swimming condition in a virtual Pacific Ocean environment [8]. Dhruv Jain et al. also used the suspended system, but they placed an inflatable airbag under the user's belly, which allowed the user's body to rise and fall in sync with breathing [9]. These two works allow users to move limbs, but they do not include swimming poses in different scenes.

To create a real experience for users, and to let users realize the transition from not being able to swim to swimming, the feeling of immersion and presence of users should be taken into account when designing the swimming learning system [10].

3. System Design

Based on previous works, we designed "Swimming Coach", which includes four components: body support prototype, Head Mounted Display, multi-scene swim learning application, as well as human gesture recognition and matching module. Our system can help swimmers to learn swim in various swimming scenarios, and learn multiple postures (competitive swimming and practical swimming).

3.1 Swimming Support Prototype

We designed and made a body support prototype. In this support prototype, a support frame is attached to the user by a harness which allows the user's hands and feet to move freely. Notably the support frame can be rotated so that the user can learn how to swim in any vertical angles.

To simulate water resistance, we designed a wristband (Fig. 1), which is connected to the safety belt through an elastic band. What's more, to simulate the feeling of floating in the water, we added an inflatable air cushion on the support prototype (Fig. 2). The inflatable air cushion is connected to an inlet air pump and an outlet vacuum pump through the air pipe. When users are learning, they can experience the feeling of flotation through the expansion and contraction of the air cushion.

3.2 (Head Mounted Display) HMD

To enhance the feeling of immersion and increase the interaction of "Swimming Coach" provided by tactual, visual and auditory feedback, we develop the HMD (Fig.1). It includes VR glasses and a breathing mask with an airbag.
We set the completion time for each set of actions,

Fig. 1. A user is wearing HMD and experiencing Multi-scene swimming learning.

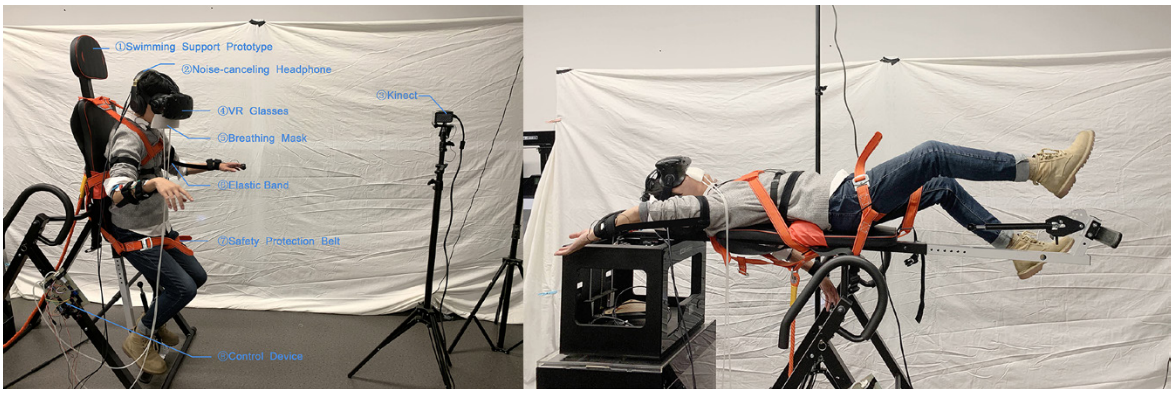

Fig. 2. The inflatable air cushion.

during which the user needs to complete the corresponding action.

In the VR glasses, the user's main field of view is his or her first-person view (Fig.3). The upper left corner of the interface is the matching between the image from the third-party perspective and the correct posture. If the user's action is inconsistent with the standard action, the interface will present voice prompt.

The airbag of the breathing mask (Fig.4) is prompting the user to inhale and exhale correctly while swimming. The time interval between airbag expansion and contraction is consistent with the standard swimming breathing rate. We use this device to prompt the user to inhale and exhale correctly while swimming.

3.3 Human Gesture Recognition and Matching Module

Based on Kinect and Unity, we designed a set of human gesture recognition and matching module, which can identify the user's bone nodes in real time, and then match the recognition results with the bone nodes of standard actions to determine whether the user's swimming action is correct or not. VR glasses will also give users corresponding hints.

3.4 Multi-scene Swimming Learning Application

According to previous research, locations of drowning by different age groups were categorized into the swimming pool and open water (such as a lake, river, or pond) [11]. In our system, we use multiple scenes in VR vision to help users practice swimming in different kinds of water. We use Unity to create our scenarios, such as the swimming pool and ocean (Fig. 5). Besides, we design an oxygen value (green bar) and a health value (blue bar). This setting can simulate the real status of swimmers in the water and provide data for the HMD.

4. Evaluation

20 volunteers (female 7, male 13) with an average height of 173 cm (SD=9.2) and an average weight of 58 kg (SD=11.7) were recruited from Zhejiang University, China. In order to test the effectiveness of the system. (e.g. In the experiment, the volunteers used the Swimming Coach one by one for 30 minutes

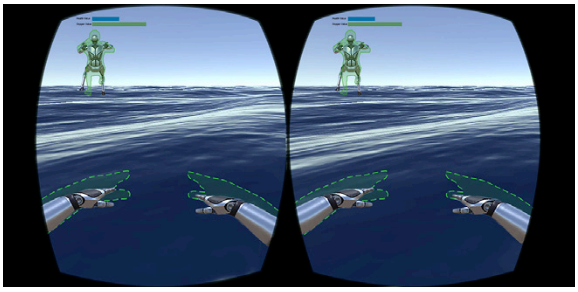

Fig. 3. A scene from the HMD when users learn freestyle swimming.

under proper instructions from the researchers. The volunteers tested two different swimming scenarios). After experiencing this system, the volunteers were asked to complete a questionnaire [12] and then interviewed concerning their feelings and feedbacks about the swim learning system. The data were later analyzed using a chi-square ($\chi2$) test [13]. The reported overall rating of presence across all participants was 4.79/7 (SD=1.59). It indicated that they were positive about the system and felt immersed.
Meanwhile, according to the interview, 17 of 20 volunteers can learn the basic swimming posture, 3 volunteers said the discomfort caused by the safety belt could affect learning to swim.

5. Conclusion and Future Work

In this paper, we present an immersive and interactive VR swim learning system, a combination of HMD, human gesture recognition system and multi-scene swimming learning application. Through the experiment of 20 participants, the system proves to be effective to swimming learners. However, we are aware that certain problems do exist. For example,

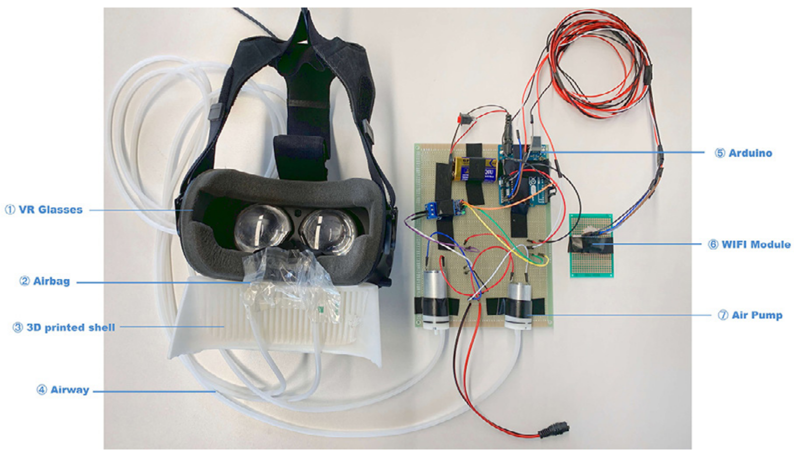

Fig. 4. The breathing mask.

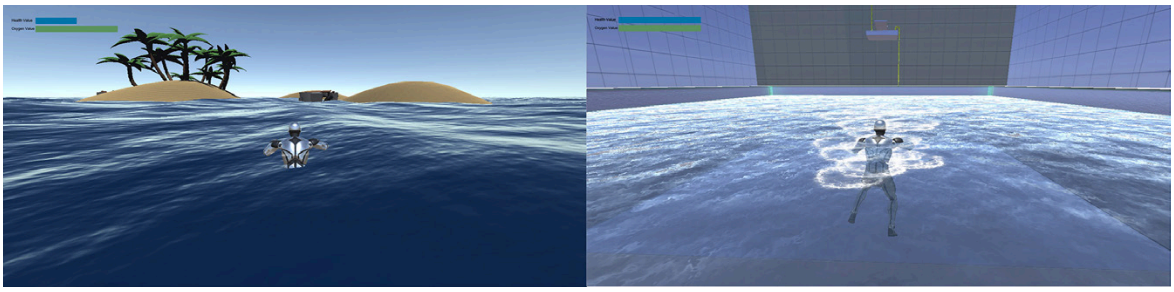

Fig. 5. Multi-scene: swimming pool and ocean

the swimming movements of participants often made wrong movements, leading to the massive warning voice prompt from the system, which might impair the immersion experience of the users.

In future work, we will improve the body support prototype, and change the form of error reporting from voice prompts to color changes of characters in VR scenario, and conduct more tests to perfect our "Swimming Coach". Besides, we plan to upgrade this equipment into a more general device, which can be used for parachuting, gliding and other sports.

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Designing Transparent Collaborations – Weave

Abstract

We are eager to converse about the approaches we may need to take when designing for complex intelligent ecosystems, their meaning, experience, and ethics, but I would like to invite you to a conversation on rethinking and redefining how we and our tools in our collaborative processes could better handle complexity, ethics, and transparency among each other before intelligent ecosystems are brought into the picture. After all, the design solutions we propose are really a collection of our lenses, our framing capacities, and the quality and ethics of our decisions, all derived significantly from our collaborative practices and the tools we use – and the collection of decisions from which they are made.

This document contains detailed information about the creation of Weave. Weave brings designers and developers together at the beginning of product development, enabling them to co-create the system architecture, thereby adding clarity and transparency throughout the collaboration. The goal is more effective, more efficient processes, and a deeper, more trusting relationship among collaborators.

Weave was created through a detailed study of the current design and development tools, primary research with Designers, Developers, and Project Managers, and four rounds of testing with 39 participants who follow agile processes.

Keywords

Ethical Collaborations, Transparency, Ethics, Systems Design, Designing for Complexity

1. Overview

1.1 Current Practices

Currently, the majority of the collaboration that takes place between designers and developers begins after most of the foundational design and implementation decisions are made. Currently, collaboration begins once a designer hands over a final interface prototype to the development team for implementation. This pattern creates a workflow that is full of uncertainty, paving the way for misunderstandings and creation of assumptions to understand the decisions made by both parties. This is where both parties often end up with outcomes they did not intend.

Organizations encourage designers and developers to work together in the same place, at the same time to help develop a shared understanding in designer-developer collaborations. However, this is not a viable option when the two work remotely. Some companies spend resources, time, and money to fly a designer from one office to another simply to converse in person with the development team about UI/UX specifications, and decisions. However, this approach is, once again, not always viable, and it typically happens once, when a deliverable deadline is approaching. Weave proposes a collaboration process that is not only consistent and continuous but also meaningful and comprehensive, where the focus of the collaboration is on the foundation of decisions rather than the surface-level actions that lead to the decisions.

In the design process the act of prototyping has multiple purposes. Purposes of prototyping consist of, evaluating and testing the design (both within the team/internal and with the users, aka, usability testing), communicating the idea/design with others (includes selling the idea to the business), setting design priorities, and clarifying production costs and issues. Even though the Design industry, specifically firms that build interface prototyping tools, have been showing that they are thinking about collaboration and workflow, they, currently, do not encourage or help designers and developers to understand each others' workflows and priorities and tend to find very surface-level solutions that do not consist of any variety or at least the appropriate variety. When prototyping, the *highest level goal* of the designer and the developer is reaching the production stage. Also, current interface prototyping tools, lack in consistency when it comes to features offered, and purposes for use. For instance upon selecting a prototyping tool, a designer might have to predict any potential design changes that may come up in the process in the future, such as importing an interactive graph, because only a few tools may be capable of doing this.

1.2 Project Goals

The goal of this project is to bridge the gap that currently exists in Designer-Developer collaborations in order to improve their relationships. Improving Designer-Developer relationships is made possible by increasing their understanding of each others' approach, which can, in the long-term, increase the trust that exists between them. Increasing trust in Designer-Developer relationships is made possible by ensuring that they can truly collaborate in a workflow which can reveal where they are aligned and where they are not aligned with each other early on in projects by working together to make determining decisions, before either one has individually made determining design and implementation decisions.

2. Project Framing and Convergence

2.1. Initial Hypothesis

The following formed the initial hypothesis in this project:

1. Designers and Developers do not have a deep understanding of the logic that exist behind each others' decisions.
2. Designers and Developers are not able to actively propose changes to each other's' work.
3. The meaning of collaboration has changed today. In the Designer-Developer collaborations there seem to be more attention to details rather than conveying the framework of what their decisions, such as the logic of their constraints that will shape their goals.

Initial Hypothesis: Therefore, if there is a common ground on which Designers and Developers can collaborate, where both know how to propose changes to, then a they can begin to build a foundation for their collaborations throughout the course of projects.

3. Problem Definition

3.1 Problem

The major problem with the current workflow of Designers and Developers, mentioned above, is that the initial collaborations tend to stay on the surface level and do not go deep. Designer-Developer collaborations, currently, become more detailed and more frequent once the Developer receives clickable prototypes from the Designer and needs to understand and make sense of them in order to implement them. The point at which Designer-Developer collaborations become more detailed and frequent is a problem because this is when most of the design decisions and perspectives have been made and formed. When a Designer communicates her design decisions with a Developer, she is communicating three layers of information all at the same time. The layers being communicated are,
1. The architecture of the system
2. The user interface specifications, such as colors, fonts, and dimensions

3. The specific user interactions
Communicating three layers of information all at the same time with Developers is a major problem, because it divides their attention, deferring the recognition of inconsistencies that exist in any of the layers mentioned above. Currently, Developers face a great deal of difficulty trying to understand the three layers of information that are communicated to them. Therefore, a lot of back and forth occurs between design and development, where many parts of the design decisions in each layer are changed as the result.

4. Value Proposition

4.1 Benefits of Weave

The most important goal of this product is to help change some of the current ways of thinking with regards to prototyping tools and the process of collaboration from design to implementation as a whole. It is important to note that, today, there are no products in the market that are looking at this issue with the level of depth Weave is addressing it. Weave:

1. Views collaboration and conversation as a two-sided process, where not only developers have the opportunity to learn about designers' logic and approach, but also designers have the opportunity to learn about developers' logic and approach.
2. Allows both designers and developers to work together to propose changes to the system, and not only collaborate by giving each other written feedback or feedback that focuses only on constraints.
3. Provides an opportunity for both designers and developers to collaborate in their workflows as part of their natural process, because the foundation of this collaboration is rooted in the co-creation of system architecture.
4. Provides an opportunity for both designers and developers to document their entire process on contextual levels so that they can have access to everything in the future when needed.
5. Uses only one of the information layers to begin the designer-developer collaborations, therefore it is able to focus on a less complicated collaboration process, where the development of trust can be highlighted. [1-13]

5. Primary Research

5.1 Details and Findings

Research was conducted with a total of 15 Designers, Developers, and Product Managers who work at technology-based, agile companies in order to learn about the current problems that exist in the workflow and collaborations, as well as to test the hypothesis mentioned earlier.

Some of the most important insights gained from the research conducted are:
1. Designers and developers both expect each other to add knowledge about their domain.
2. They express expectations after something has gone wrong, exhibit lack of ability to avoid deferred recognition of misunderstandings and disagreements, a lack of motivation to convey key information, and documentation.
3. In-person communication is their most preferred type of communication.
4. Design sprints are often expanded causing development sprints to compress, where developers experience a great deal of stress.
5. Designers experience a lot of frustration when needing to revise design decisions a few times after they have already finalized them.
6. Developers often end up making most of structural and architectural decisions that UX designers need to make.

6. Usability Testing

6.1 Details and Findings

There are four phases of usability testing, all of which were conducted with a total of 39 designers and developers. The four phases of usability testing were conducted in order to 1. test the first design concept, 2. understand users' mapping logic and behaviors, 3-4. and to test the interface flow and its learnability. Prior to testing phase #2 the Unified Modeling Language (UML) were studied in order to understand how current mapping systems work, and what their logics are. UML is a standardized modeling language enabling developers to specify, visualize, construct and document artifacts of a software system. [14]

Fig. 1. Contextual documentation of work through Weave

The overall feedback are as follow:
1. The mapping of systems is necessary and where most of the problem lies, because no mutual understanding and agreement between the designer and developer is formed at this step.
2. Limiting the designer's choices may be possible for more explicit development frameworks, mainly with interface frameworks such as Material Design or iOS, however this is not technically possible with interaction frameworks because they tend to be loose, and therefore hard to be used for drawing any comparisons with visual designs of a designer in order to detect any "design errors". Limiting a designer's choices may be efficient, but it will not encourage any collaborations and is not ethical.
3. It is crucial to communicate the activities that take place in a system as well as the states that it is in throughout its design process.
4. Add a motivation factor for designers and developers to continue to collaborate.
5. Ensure smoother user adaptability by adding multiple initiation points to the system, i.e. allowing users to enter the system from anywhere they are in their workflow.
6. Focus more deeply on "agreement" and "disagreement" functions.
7. Add more user control by providing brief note-writing for conveyance of messages.

7. Design Solution

7.1 Details and Flow

Weave is a platform that enables Designers and Developers to begin their collaboration at the beginning of projects, before any design decisions have been made, by co-creating the system architecture. Designers can use Weave as a plugin within interface prototyping tools, and Developers can use Weave through its web app.

There are five major phases that the user of Weave goes through, they are:
1. Weave Activation: This is point at which, the designer activates Weave as a plugin in the interface prototyping tool that she/he is using.
2. Weave Initiation: At this point the designer begins to create a user scenario, which Weave, using natural language processing, will then turn into a map that represents the initial system architecture. The designer inputs a user scenario by inputting individual user actions, broken down to verbs, system parts, and functions. For instance, "signs in to the app". Signs in: verb; app: system part. Or for instance, "presses Reserve". Presses: verb; reserve: function. The designer can further edit the map that has been created by adding more actions to it, replacing or deleting actions from it.
3. Collaboration Initiation: At this point the designer will publish what she has created, allowing her to share it with her collaborators. Once shared with other collaborators, they, specifically the developer can propose changes to the architecture that has been created, either by adding more actions under each map, or by adding variations to each map beyond the user scenario that has been created, in order to encourage progress to be made in the creation of the entire architecture so that the developer can begin to become more certain about her next steps and to begin to frame her code.
4. Collaboration Progression: At this point both the designer and developer collaborate continually by responding to each others' proposed changes.
5. Documentation: At this point designer's responses in the user scenario section, publishing section, as well as the progress made on collaborations through adding attachments, notes, expressing agreements/

disagreements, and creating integrations with other project management tools, all result in the documentation of the process of a project and collaboration. This is shown in Figure 1.

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Huxley: Intelligent Book as Essentialist Artefact

Abstract

Huxley is a system that uses measurement of a user's focus and interest throughout the day in order to alter a 'smart-book' in their home space to make it more engaging. By tracking user interaction with the book over time, the home environment also learns to alter peripheral cues in imagery, lighting, and sound—controlling the character of the space and the visual salience of the book— in order to encourage its use. Huxley is an environment that is informed about user goals and works to encourage better decisions and deeper focus in line with those intentions. It is an artefact of an essentialist, attention-centered design philosophy.

Keywords

Attention, Salience, Smart Home, Persuasion, Cognitive Affordance

1. Introduction

A decade ago Nicholas Carr first raised the alarm about negative impacts of the information age on human cognition and phenomenology. [1] It is now a chorus in the popular tech literature—our focus and concentration has been hijacked by our information and communication technology (ICT). Carr argues that the rapid, non-linear navigation of a hyperlinked internet has already predisposed us away from deep, focused reflection on singular topics. Ad-driven business models—which necessitate addictive design patterns and a diversion of users away from their intent—intensifies a trend towards fractured attention that is native to the medium itself.

Unfortunately, the research bears this out. Most websites are visited for less than 15 seconds; all websites average less than a minute. [2] Moreover, hyperlinked content detracts from learning outcomes while increasing interaction time. [3] Smartphone research is more directly disheartening— Ward et. al.'s 2017 work [4] showed that having one's phone in the visual periphery significantly reduces one's available cognitive capacity for other tasks.

Against the backdrop of behavioural economics, we can frame the internet and the smartphone another way—their structures impose a state of constant decision-making on the user. These designs force a regular re-evaluation of the task at hand; with instant and limitless access, they also prevent us from full commitment to any one task. We know from the work of psychologist Barry Schwartz that too many choices lead to paradoxical dissatisfaction. [5] The ability to renege on our selections also leads to greater unhappiness, despite our tendency to keep options available. [6]

How should this knowledge impact future design? While there are many open questions about the nature of the relationships between an artefact's symbolic information, conceptual model, [7] and its cognitive effects, it is clear that we *certainly* should avoid conceptual models and addictive design practices that are linked to cognitive overhead, and *likely* should avoid the corresponding symbolic information that has been rigorously paired with fractured attention over the last decade. More research needs to be done to answer many important questions:

- How tightly coupled are conceptual models and cognitive load? Is the relationship binary or continuous? *(If your phone decreases your focus, will a similar phone? Any phone?)*
- Have we learned a direct association between symbolic information and cognitive state? Do new conceptual models alter it? *(Does a 'phone form' induce high cognitive load, even with no phone functionality? Is this reversible?)*
- What aspects of these devices are most damaging to focus? *(How much does the type and nature of a device's functionality versus addictive design choices like variable reward structures, badges, and infinite scroll contribute to cognitive load?)*

In the spirit of 'Calm Technology', [8] Huxley is designed against the backdrop of these provocations, both as a tool for inquiry and as an example of attention-aware design. Other theories of design offer notions of psychological pairing between an object's sensory features and a user's emotional response to it; [9] we submit this idea logically extends to the user's *resting attentional demand* when using the object as well. We believe the psychology supports a move toward *essentialism* [10] in design—environments and artefacts whose choice architecture promotes fewer, longer, deeply engaged experiences in line with a user's priorities for themselves.

There is a rich confluence of cause-and-effect to disentangle given the current state of screen-based, multifunction artefacts. We hope Huxley will spark fruitful conversation about the cultural and aesthetic implications of the Attention Economy's addictive design tradition and move us towards an empirical design language based on behavioural economics and cognitive models of deep engagement.

2. Huxley

The Huxley system is composed of three main parts: a *chrome extension* to track focus and interest during the day, the *smart book* artefact itself, and a *peripheral lighting and video* system to alter the affective quality of the reading environment and book salience.

2.1 Interest Tracking

The first part of Huxley is a chrome extension that runs in the browser on the user's primary work computer, collecting and storing data including the number of tabs and windows open, the websites visited, the number of task switches, and overall active and idle behaviour. This information is processed to give a measure of *focus*, the *duration worked*, and the *topics the user is engaging with* based on Google queries, time on 'timewasting' or 'productive' domains, task switching, and other browsing behaviour.

2.2 Smart Book

Huxley (Fig. 1) is a book with three e-ink displays, a single button, and a charging USB port. It behaves like a book—its spine and cover display the title and cover of the book contained within, and once opened the

Fig. 1. The Huxley Smart Book, showing updating e-ink displays on the cover, spine, and inside. A USB port on top is available for charging, one button is available for turning pages. Huxley only updates when the user is away and the current book has been completed or ignored. Its selection is based on the measured interests and affective state of the user at work.

internal e-ink page can be turned with a button press. There are no indicators of battery state or wireless connectivity, no menus, and no way to change the book contained within.

Instead, Huxley broadcasts an API over the local network—once loaded with PDF/EPUB files, it can be directed to become a random selection (favoring new books) or become a relevant book based on provided queries (using Doc2Vec embeddings as a similarity metric).

Huxley was created with a few motivating principles in mind:

Minimized Choice. Good technology helps curate our world and eliminate the ill effects of the paradox of choice when we're trying to focus. There is no ability with Huxley to summon any book in the universe, and no leaving the option in front of you behind.
Permanence. Huxley only switches *when the user is away.* The interaction is designed to make it feel like a single, permanent object that *doesn't* have the ability to access any external information.
Simplicity. The conceptual model is very simple-- it works like a book. It doesn't have WIFI or battery indicators. The affordances are equally simple—one button, one possible interaction.
Evocative Aesthetics. Huxley evokes the conceptual model of a book without false affordances (it's clear there are no pages to turn). This helps frame the interaction as 'book-like' instead of 'screen-like'.
Increased Cost. Many of our services allow us ephemeral access to unlimited media. The 'zero-cost' model (time, space, money, and effort) disincentivized attribution of value to any included content. Huxley takes up space in the home, a physical cost that ascribes worth to its content and incentivizes focused engagement.

2.3 Peripheral Guiding and Intelligence

Users prefer different lighting for different tasks; [11] we hope that priming the mood also encourages the associated activity. Increasing a behaviour like reading usually involves more frequent 'triggers' to perform the action. [12] By manipulating book salience, we aim to draw the user's eye to the book more frequently— the more they notice and consider it, the more likely they are to engage with it.

Lighting, visual imagery, and book spotlighting are controlled using a custom video looping/DMX lighting control server running on a Raspberry Pi. Though the system is capable of a full range of expression, for simplicity we've devised two basic conditions (Fig. 2). The system uses a running average to bucket *focus* and *time worked* from the interest tracker into four categories (i.e. high focus, long day). Each of these categories is treated separately with a Bayesian Bandit optimization over *lighting choice* and *book relatedness to work queries*. We seed the system with common sense priors— for example, we expect long focused days to benefit from a calming off-topic book, short focused days to benefit from a high-energy related book, etc. By monitoring page turns, we update our model each day to choose the best lighting and book pairings to encourage use for a given user state.

Fig. 2. Left, a high-energy scene of a city, with blue lights and a white spotlight on the book. Right, a warm scene with a fireplace and without book spotlighting. Mood and book salience are selected based on the Focus Tracking extension.

3. Discussion and Next Steps

Huxley is an adaptive system that nudges you towards a deeply engaged reading experience through peripheral cues, content selection, and artefact design. Its design principles are derived from *essentialism* in reaction to the current paradigm of attention hacking. We plan to study this interaction and quantify the its effect on the number and depth of book interactions compared with books, e-readers, and iPads in situ. We hope to disentangle the influence of conceptual models and symbolic information on deep engagement—mostly learned, modern associations with ramifications for future design.

We also plan to introduce eye tracking to explicitly quantify saliency's effect on behaviour and attempt to quantify the benefits of peripheral cues, alongside richer measures and models of user state. This will pave the way for more accurate and sophisticated analysis of dynamic causal intervention, and lead to a more effective overall system.

4. Conclusion

How do we design systems that increase our likelihood of doing the things we aspire to more frequently and with deeper focus? Can we marry the best of iPads to books, Spotify to records, or email to letters? Huxley was created with an understanding of the inherited problems of attention economy design, with a goal of promoting deep engagement. It attempts to preserves the value of connected information technology, and behavioral nudging without the negative cognitive impacts. It is an artefact of a design philosophy built for focus.

Huxley strives to feel like a close friend selected a single book for you every night after work; *not* an open portal to limitless options. We hope more technology moves towards essentialism and away from the fractured attention characteristic of the modern technology landscape.

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OlfacEnhancer: A Vision-Based Scented Necklace for Cross-Modal Perception and Olfaction Augmentation

Abstract

Smell disorders are common, which can impair the quality of life. In this paper, we propose OlfacEnhancer, a pendant for hyposmia patients, which augments real-world olfactory perception synchronizing visual information. We present the compact hardware design that can release seven different scents and the implementation of a machine-vision-based self-sufficient system, which includes automatic image capture and real-time object recognition. Besides, we discussed its validity in promoting healthy olfaction and pleasantness through a brief user study. Finally, we present other application possibilities of OlfacEnhancer in the future.

Keywords

Olfaction Augmentation, Mobile Object Recognition, Cross-Modal Perception, Smell dysfunction, Olfactory Interface

1. Introduction

Hyposmia, or decreased sensitivity of olfaction, is common among both elderly and younger people, which has affected their quality of life. It is also a potential symptom of Alzheimer's dementia as well as other neurodegenerative diseases [2], as olfaction is intimately connected to the brain system and associated with emotion and memory [1]. Researchers have proved that daily exposure to certain odors would improve olfactory perception as well as the condition of related diseases [3], while "vision-smell" multisensory stimulation in the natural environment could further increase pleasantness [4] and enhance the healing effects [1]. However, few devices have been developed for that in spite of the emerging technology of computer vision.

In this paper, (1) we propose OlfacEnhancer, a wearable olfactory interface for hyposmia patients, which can release seven different scents synced to visual information. It's a novel application of computer vision. (2) And we develop an automatic system that doesn't require any manipulation during use. (3) A brief usability test indicated that OlfacEnhancer could create "smell-vision" synaesthesia experiences, improve the quality of life and olfaction health, which supports many other unique application scenarios.

2. Related Work

Cross-modal solutions for sensory augmentation have been widely discussed. Recently increasing studies focus on olfaction enhancement for notification, memory recalling, interpersonal communication, emotion regulation [10], and contextual interaction [5]. These systems evoke or augment the sense of smell linked with memory and emotions [1]. However, in a real-world environment, context-based scent delivery, with correspondence to other senses, would enhance immersion in more practical and promising application scenarios.

The applications of CNN models on embedded vision system become feasible since Depthwise Separable Convolution and MobileNet [9] were proposed. Now mobile object recognition devices have been widely developed, some of which create cross-modal immersive experiences. To connect vision and olfaction, Kim et al. [6] improved CNN method to recognize odor-evoked objects from images and emit particular scents. However, users are supposed to take photos themselves with an Android device before a sniff, which may interrupt synaesthesia. We propose a compact design integrated camera and multi-scent display to be a self-sufficient system, which requires fewer steps and is easier to use, especially for the elderly.

3. Design Description

To enhance olfaction synced to visual data for daily use, OlfacEnhancer includes a camera for image capture, scents releasing system and a control and data processing center based on Raspberry pi zero. (Fig.1)

3.1 Multiple Scents Releasing

To be an individual-scale multi-scent output device, OlfacEnhancer has a compact design. A scent is selected when the servo-driven turntable makes its only vent exactly align to the scented division. Each division contains pre-packaged essence and has an air passage of stuffed cotton sandwiched between waterproof and breathable membranes. Vaporized essence spreads through the membrane and is temporally absorbed by the cotton until diffusing into the air when the vent is opened.

During this process, cotton plays an important role to control the volatilization speed and scent intensity, as olfaction threshold differs with individual and original essence. Between turntable and divisions, a film of adhesive cotton could prevent cross-contamination with minimum resistance to rotation. Besides, to prevent olfactory adaptation, there is 40 seconds' interval between 3 seconds' odors releasing in succession [7]. During the interval, servo rotates and stops at the midpoint between two air vents. Therefore, the odor substances in the air have dissipated before the next release.

3.2 Automatic Object Recognition

We made the preliminary prototype to recognize seven common scent-evoked plants (the labels in Fig. 3) and trained a MobileNet model with 8 outputs (with a blank output indicating “no flowers in the image”). The architecture of the model is in Fig. 2. A pre-trained model with ImageNet dataset accelerates the convergence. We modify the last fully-connected layer of MobileNet and fine-tune it on our own dataset with positive samples of 7 scented objects and some negative samples. Our model gets an accuracy of 79% on test-dataset and is deployed on Raspberry Pi zero with Tengine [8]. Fig.3 illustrates the Confusion for the performance. In an actual measurement, our system identified most of the testing objects no more than 2 meters straight away. Therefore, we improve the system with automatic clipping, and achieve the recognition in an extended range of 3-4 meters, with a reduced processing speed of 2s interval between 2 shots.

4. Evaluation

To evaluate the usability of our preliminary prototype, we conducted a brief study to investigate the experience with OlfacEnhancer.

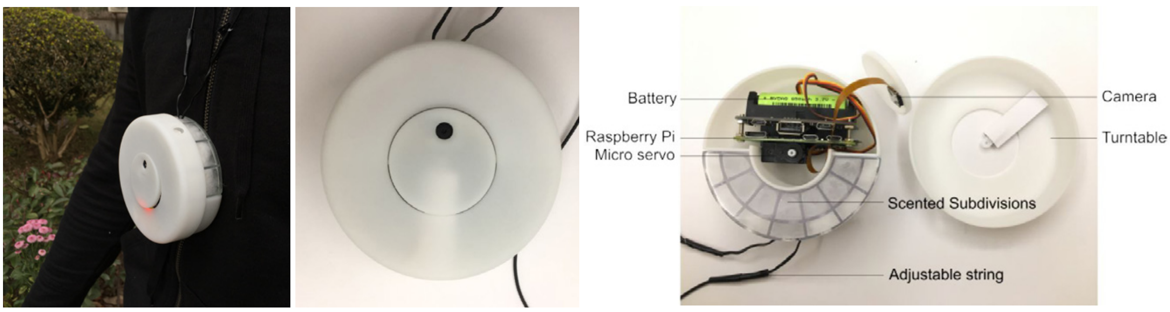
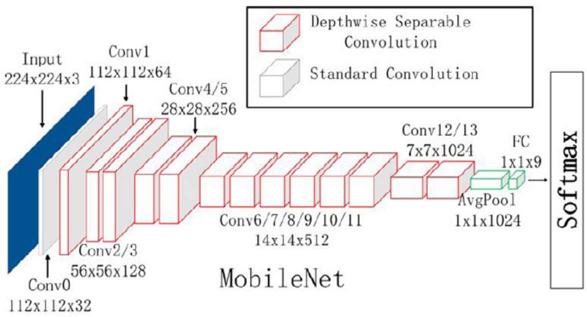


Fig. 1. . Hardware composition and fabrication of OlfacEnhancer as a pendant



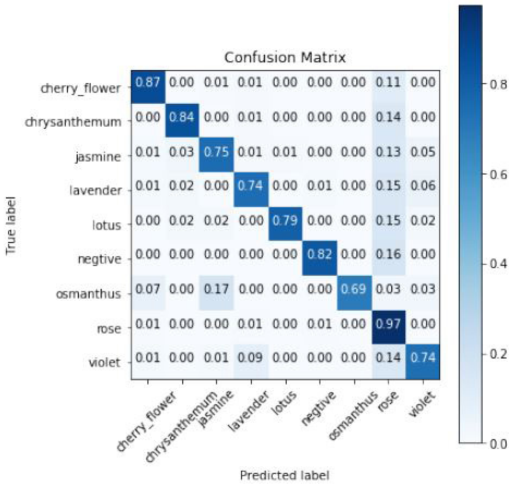


Fig. 2. (left) The architecture of MobileNet. Input: a resized image with the size of 224x224 and 3 channels(RGB); Conv: the output of convolution layer; AvgPool: the output of average pooling layer; FC: the output of fully-connected layer; Softmax: a classification layer that output probability of each class.

Fig. 3. (right) Confusion matrix for the performance of our model. The horizontal axis is the label predicted by MobileNet while vertical axis the true label of the test dataset. All data are normalized by the number of true labels of each class.

We recruited 4 representative subjects (2 males and 2 females, mean age = 32, sd = 10.49). They were required to take walks twice (wear OlfacEnhancer and wear nothing) and meet one of the plants every 5 meters. We evaluated the time it took to produce smell perception by recording the human-object distances when subjects smell the scent. After each walk, they were asked to rate odor intensity, fidelity, degree of comfort, immersion and pleasantness in a visual analog scale (VAS).

The outcome of the human-object distances wearing OlfacEnhancer is 1.5-3.6 meters, while in the controlled trial is no more than 0.5 meter, which indicates that wearing OlfacEnhancer evokes smell perception in a longer distance than not. In addition, results of VAS assessment show that wearing OlfacEnhancer comfortably augments olfaction, enhances immersion and enjoyment although some kinds of scents are not natural enough. According to the experiment by Salminen et al. [4], viewing experience with odors was always rated as pleasant, and the level is affected by odor authenticity. Therefore, we infer that a selection and synthesis of high fidelity essences will improve the prototype.

Overall, OlfacEnhancer performs well in augmenting olfaction and improving pleasantness and immersion. However, we should further test its validity and robustness through more rigorous experiments with hyposmia elderly as well as dementia patients.

5. Applications

OlfacEnhancer is easily reproduced to be a new version for many future opportunities. We present some of the scenarios in this section.

5.1 To Create Immersive Experiences

Immersive exhibition. Wearing OlfacEnhancer in the exhibition, users would have strong enjoyment and impression the artworks. It supports different art forms, such as sculptures, paintings, and videos, and various positions in a distance and from any perspective.

Preserving Cross-Modal Memory. OlfacEnhancer could preserve smell profiles corresponding particular sight during travels that will be the best souvenir to bring back the memory with more emotions loaded.

Enjoying Allergy Seasons. People suffering from hay fever always stay away from floral aromas, which may carry spore or other allergenic ingredients. An OlfacEnhancer containing healthy alternative essences will help them enjoy the aromas in a distance from the scented plants with reassurance during allergy seasons.

5.2 To Evoke Vision-Related Feelings

Building Up Expectations. By giving pleasant scents, OlfacEnhancer could trigger the appetite and curiosity of children, and thus the willingness to explore new food, books or other things in front of them.

Empathizing. If combining expression recognition method, OlfacEnhancer could produce the scents semantic to the emotions of the person in front. That could evoke the same feelings with other people and promote interpersonal understanding.

Scentification. Certain scents could trigger attentive and conscientious emotions. Therefore, OlfacEnhancer could provide real-time alerts and general arousal of attention before some dangerous manipulations.

6. Conclusion and Future Work

In this paper, we present the design guideline and implementation of OlfacEnhancer, a vision-based multi-scent pendant. Our formative tests show that it indeed enhances immersive perception and pleasantness via releasing fragrance when the scented-object comes into view. Overall, we believe our work is a creative exploration. In future work, we will perform further studies to assess the olfactory augmentation effect on multiple user groups with the improvement of the odor fidelity as well as the processing speed. Further, we hope the proposal of OlfacEnhancer could remind readers of the important role of smell and paying attention to olfaction health.

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APOSEMA: Exploring Communication in an Apathetic Future

Abstract

Aposema is a wearable device that speculates on a near-future scenario in which human face perception abilities have been compromised. In this world, everyone wears a device on their face that reads facial expressions and guides social interaction. The device is composed of three elements: The first is the sensory input from the face muscles, followed by a data analysis. The second is the physical output—a soft, colored, robotic inflation pattern. The colors represent the emotions corresponding to the facial expression, and the form change represents the emotional intensity. The third is an augmented reality layer that provides a decrypted emotional analysis to help guide interaction. Aposema is a personally customized device made of silicone and incorporated electronics. The fabrication process involves parametric design, 3D printing, hand casting, and physical computation. This design is proposed as a critical object and a provocation responding to the changing nature of communication in the digital age.

Keywords

Wearable Design, Speculative Design, Face Perception, Soft Robotics, Augmented Reality

1. Introduction

Aposema is a wearable device that is worn on the face (Figure 1). It is proposed as a piece of speculative design and a physical, critical object positioned in the intersection of art, science fiction, and product design [11], [16]. Its goal is to provoke thought and raise discussion regarding the challenges and opportunities for communication that our society may soon encounter as wearable technology evolves in the near future [12]. Motivated by the digital revolution, the information technology age, and more recent developments in the wearable technology industry, Aposema explores an imagined oncoming crisis and the increasingly extreme responses we might take to mitigate it. This scenario draws from our extensive use of personal digital devices and social media. As part of the digital revolution, our communication habits have changed, with individuals increasingly choosing technological alternatives over unmediated in-person interaction [2].

2. Narrative as Design Compass

We imagined a scenario inspired by last century's science fiction cinema and literature to guide the design. Aposema speculates on a near future where we rely on technology to replace our once-natural instincts. In an age of genome engineering and emotion recognition algorithms, our ability to read facial expressions has been severely reduced, limiting our capacity to develop relationships and leaving us struggling to empathize. In this world, we attempt to compensate for this impairment with a wearable technology device. As we developed our narrative, we explored several research areas of wearable devices for guidance. Our starting point was previous work that used soft robotic wearable devices as instruments for speculation on future scenarios, such as Ava Aghakouchak's and Maria Paneta's Sarotis [1]. In addition, we looked at previous work that used wearable devices to guide social interaction, for example Behnaz Farahi's Caress of the Gaze [6]. Finally, we based our design on previous work that explored facial expression recognition through wearable devices, such as Jocelyn Scheirer's, Raul Fernandez's and Rosalind W. Picard's Expression Glasses [7].

Fig. 1. One of the final design iterations of Aposema (Source: Aposema, design by Adi Meyer, Sirou Peng, and Silvia Rueda, the Interactive Architecture Lab, the Bartlett School of Architecture, University College London, 2017)

3. The Three Parts of Aposema

Aposema is proposed as a body extension providing its wearer with an emotional and cognitive extension [3], [17]. It is a device that reads facial expressions and analyzes emotional states to guide social interaction. It is composed of three parts (Figure 2): The first is the sensing part or the input. A system inside the device, composed of a programmed microcontroller and biometric sensors, reads the facial expression and integrates it with other sources of personal data about the user (Figure 3). The device then creates an analysis aimed at replacing the natural complex process of natural face perception [4]. The second part is the presentation of information on the facade of the device. The encrypted analyzed information is presented as a soft, colored, robotic pattern. When the person wearing the device encounters other people, the third part—the decryption—comes into action: the device decrypts the soft robotic patterns on devices worn by others. An overlay of augmented reality viewed through a lens incorporated within the device provides the wearer with a decrypted analysis of other devices around them, which enables and enhances interpersonal understanding (Figure 4). The three elements of the device form a system meant to compensate for the loss of the ability to read facial expressions (Figure 5).

4. Replacing Face Perception for Social Interaction

The device aims to replace the complex process of natural face perception through simplification. Face perception is, at its root, an individual's understanding and interpretation of the human face when encountered as a visual stimulus. The ability to process information

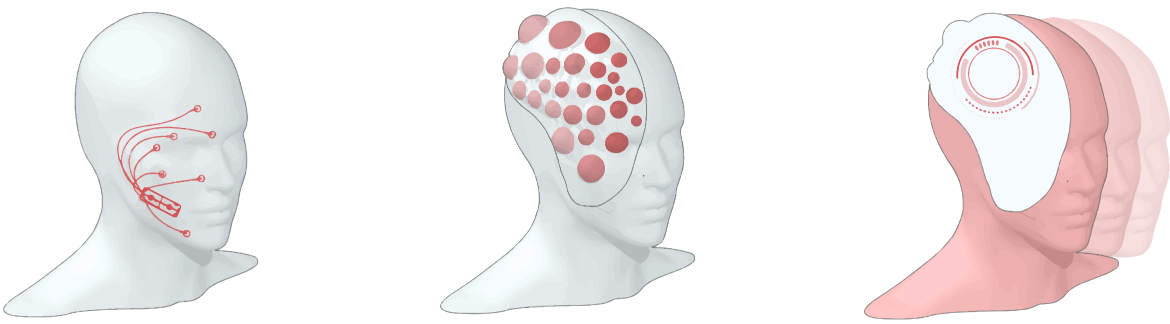

Fig. 2. The device is composed of three main parts. (Source: *Aposema*, 2017)

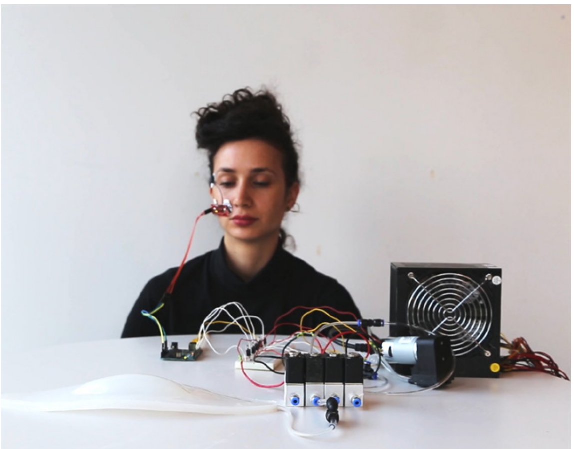

Fig. 3. (Left) Sensors integrated within the device read facial muscle movements and analyze them. (Source: *Aposema*, 2017)

Fig. 4. (Right) An overlay of augmented reality provides a decrypted analysis of other devices. (Source: *Aposema*, 2017)

from faces by recognizing facial expressions involves extensive and diverse areas of the brain [4], [8-10]. The sensors in the device read facial muscle movements, process them, and translate them into simplified emotional states according to the universal emotions identified by psychologist Paul Ekman. Ekman ascertained six universal core emotions—that is, emotions that are perceived and expressed in a similar manner in every human culture. These emotions are disgust, sadness, happiness, fear, anger, and surprise. Through his research, Ekman classified facial expressions by motion cues corresponding to these distinct emotions [5].

After the wearer's expression is read and interpreted, an emotional analysis is presented on the device. The facade of the device is made of silicone and has a colored pattern with inflating pockets of fluid. It reacts when the wearer interacts with another individual, representing emotion by changing color and shape. Each color that appears on the device represents one of Ekman's universal emotions, and the degree of shape change indicates the intensity of feeling (Figure 6).

The device constantly scans the wearer's environment, recognizes soft robotic patterns presented on other devices, and decrypts them in real time (assuming that, in this future world, we are all wearing those devices). The goal of the lens over the eye area of the device is to provide an augmented reality overlay that equips the wearer with further interpretation and an emotional analysis of encountered individuals (Figure 7). Alongside the analysis, a prescribed guideline for social interaction is provided. When the device recognizes an expression of anger, it might suggest pacifying hand gestures; when it recognizes a sad expression, it might suggest comforting words. Through this two-way transfer of information, the device facilitates a new form of expressive communication.

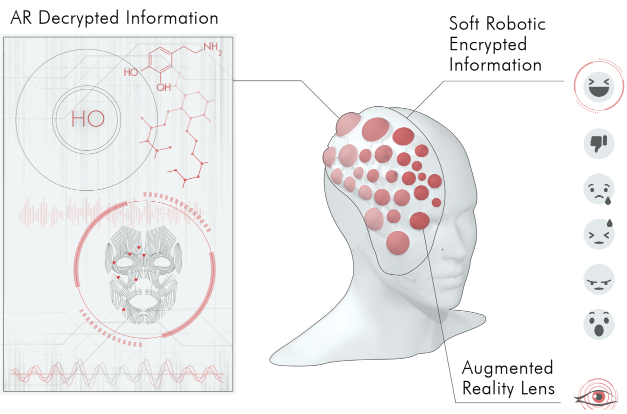

Fig. 5. The elements of Aposema (Source: *Aposema*, 2017)

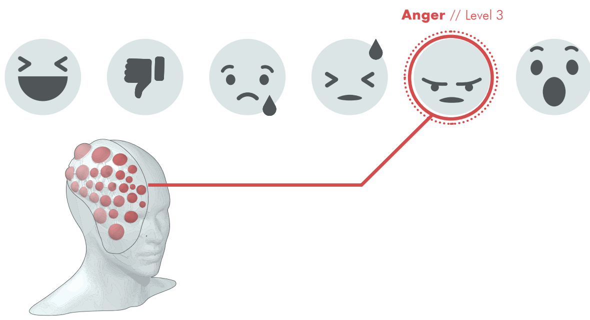

Fig. 6. Each color presented on the device corresponds to one of Ekman's universal emotions. (Source: *Aposema*, 2017)

5. The Technical Process of Fabricating Aposema

The technical process of producing Aposema began with creating a three-dimensional scan of the wearer for optimal personal customization. Once the scan was produced, the device was digitally modeled using parametric tools to guide the pattern design. The digital model was then translated into a physical object by 3D printing a series of molds in which the device would be casted. In parallel, a circuit was designed, and a microcontroller was programmed to sense facial muscles and translate them into physical and digital outputs: the soft robotic inflation and the augmented reality layer (Figure 8).

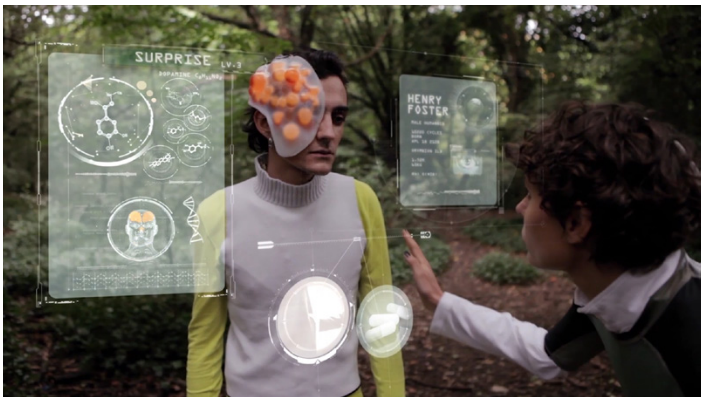

Fig. 7. The soft robotic pattern is read through an augmented reality overlay, equipping the wearer with further interpretation and an emotional analysis of encountered individuals. (Source: *Aposema*, 2017)

6. Learning from the Past to Imagine the Future

Aposema derived its name from nature's aposematic visual warning system and from mask-making traditions. Aposema's notion of dynamic representation is based on Kwakiutl dynamic tribal masks from the 18th-19th centuries. It interprets the concept of dynamic representation through a physical object by utilizing advanced technologies for emotional representation in a device that, like the masks, physically transforms and is worn on the face. The Kwakiutl Indians of North British Columbia produced spectacularly designed masks that were a constant feature of their rituals. Their masks were viewed as a way to change the wearer's identity; they contained a dynamic transforming element, as they could be opened to reveal an inner layer [13-14]. The dynamic quality of these masks was an important precedent for Aposema. The Kwakiutl masks helped us imagine an abstraction of current wearable technology to throw a spotlight on our changing relationships with the virtual and physical worlds.

Although the speculative scenario that drives Aposema is grim, in a sense, it resembles our current reality. It is not to be mistaken for a technophobic dark prophecy. It is merely a provocative narrative aimed at addressing the issues accompanying the rapid technological advances that our society has been experiencing in the decades since the digital revolution. While we acknowledge the contribution of digital devices to our well-being, the way that individuals consume information has deeply changed, and we as a society hold the obligation of overseeing the impacts of this transformation. We must be aware of the extent to which our communication paths are managed, directed, and manipulated so that we can assess the challenges and opportunities presented by future developments in wearable technology.

7. Conclusion

We are more connected than ever, yet our connections rely on brief, rapid exchanges of information. Connections in the near future will be shaped in unpredictable ways. This development may have consequences that we do not yet have the ability to comprehend. As a piece of speculative design, Aposema encourages further research on the influence of digital

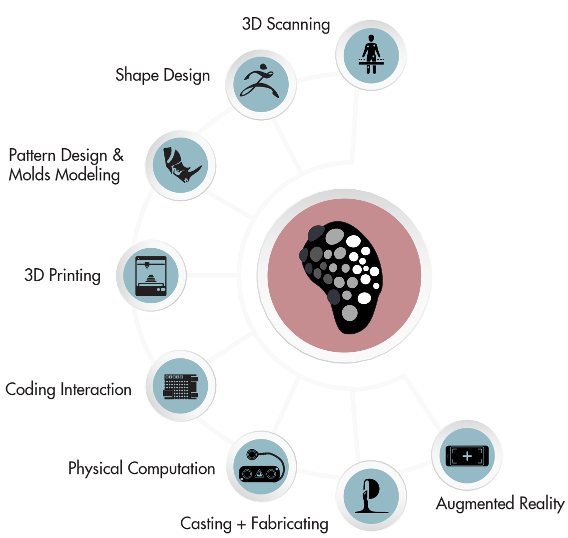

Fig. 8. The stages in the process of fabricating Aposema (Source: *Aposema*, 2017)

devices and wearable technology on our interpersonal connections, as well as the ethics of wearable design related to possible violations of privacy as the device collects personal data. From increasing surveillance to the rapid growth of intelligent wearables, the human experience of our immediate environment is changing. These technologies combined with social media play a pivotal role in shaping our relationships [15]. The conclusions of this research should be taken into account when designing products that have deep implications for our social and psychological well-being.

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HuValue: A Toolkit to Facilitate Considering Various Human Values in a Design Process

Abstract

Human values play an integral role in any design that aims to improve the quality of human life. To support designers' addressing human values in their design, we created a design tool based on a comprehensive value framework. This tool helps to raise designers' awareness about human values and provide tangible materials to actively use selected values in a design process. An experimental study with design students showed that the project groups that had been supported with this tool addressed human values in their design concepts significantly stronger compared to the control groups. Results of the evaluation indicate that the tool is not only applicable in a design process but also effective at enriching design concepts with human values.

Keywords

Design Tool, Human Values, Value Framework, Design Process

1. Introduction

Nowadays, life without technology is hardly imaginable. Technology is interwoven with all aspects of life, and people perceive the world via artifacts [1, p. 235]. As artifacts are not self-formed phenomena, emphasizing on the role of these products in human's life brings the responsibility of designers in the light [1, p. 234]. Nevertheless, while design in its origin "aims at changing existing situations into preferred ones" [2, p. 111], there are very few agreements on what a preferred or better situation means and how it could be achieved. In this respect, human values can be introduced as a touchstone. In fact, values can be embedded in artifacts [3], and values expressed by the designer should be interpreted by the user [4]. We use these points to argue that considering human values behind every human action, goal and decision can provide a wide and sensitive view. This view has implications for design as the designer needs to understand what is preferable for the end-users and to make appropriate decisions [4]. Despite the significance of human values in everyday life and consequently, in design [5], they mostly remain implicit and unarticulated in design projects [6]. Only few design approaches concentrate on human values and aim to address them in their design: Value Sensitive Design (VSD) [7], Value-led Participatory Design (VPD) [8], and Value-Centred Design (VCD) [9]. Nonetheless, there is very little agreement between them to identify values. In this respect, the lack of an established and accepted fundamental grounding [10] and a comprehensive list of values [11] can be considered as a major unresolved issue. Accordingly, our research intended to support product designers considering human values consciously and explicitly in the design process. The core assumption in our study is that a wide view on human values and facilitating using this concept in design would help designers to take human values into account.

2. Exploration of a Design Tool Based on a Value Framework

Since the term ‘value’ is widely used for different purposes in various disciplines, and there is no comprehensive value framework for design, we considered the need for supporting product designers regarding human values: a general list of human values to cover diverse views as well as a well-classified framework to summarize the list in a brief, understandable and applicable model and simplify thinking about and discussing them. A holistic view of the values of different aspects of human life [12] is important to improve the quality of humans’ life, and this improvement is related to progress in all aspects of life [13]. Due to the natural distance between the abstract level of human values and practical level of design, we considered the need for a tangible medium to bridge this gap and facilitate using a comprehensive value framework.

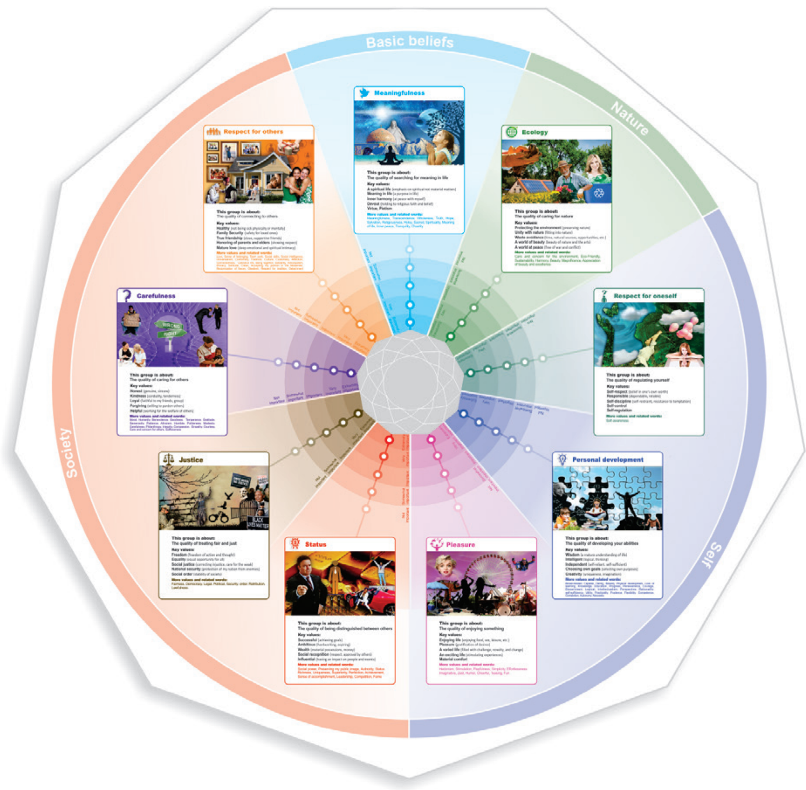

Fig. 1. Value wheel (Size: A2), with nine value clusters and five-point Likert-type scales.

The HuValue tool is designed in the form of a card-based design tool (Fig. 1 and Figure 2). The form of a card-based tool was selected for the design tool since cards are low-tech, tangible, and approachable design materials which are an effective medium to bridge the gap between theories and practice [14]. The HuValue tool contains a value wheel (Figure 1), 45 value words, and 207 picture cards (Figure 2). This tool is grounded on a comprehensive value framework for design [15]. This framework was created and developed via various theoretical, empirical and design-based approaches to compile, classify and structure the existing value lists, including Rokeach [16], Schwartz [17], Peterson and Seligman [18], and ten more value lists from the last century [15]. In the HuValue tool, the value framework is illustrated in a circular structure as the value wheel (Figure 1).

The Value wheel is a circle with nine value clusters, each with an icon, a label, a mood board, a descriptive sentence, five key values, and some relevant terms. This wheel provides an opportunity to express the importance of different human values, which can vary from person to person and situation to situation. The value clusters can be ranked in their order of importance via a 5-point Likert scale: ‘Extremely important’, ‘Very important’, ‘Important’, ‘Somewhat important’, and ‘Not important’. The nine value clusters are ‘Carefulness’, ‘Justice’, ‘Ecology’, ‘Respect for others’, ‘Meaningfulness’, ‘Status’, ‘Pleasure’, ‘Respect for oneself’ and ‘Personal development’. The outer circle indicates the relation of the value clusters to four general themes, including ‘Basic believes’, ‘Nature’, ‘Self’, and ‘Society’.

The Value words are 45 two-sided cards (5 × 7 cm) with a value word on the front and its relevant value cluster at the back [15]. These cards represent the key values mentioned in the value wheel to provide more flexibility for using and emphasizing individual values.

The Picture cards contain 207 cards (7 × 10 cm) of three different types: 66 activities, 66 personae, and 75 products/services. Picture cards, as complementary to value wheel, are examples of activities, personas, and products/services that are presented in the format

Fig. 2. Examples of value words and picture cards: (Left) two-sided cards with a value word on the front and its relevant value cluster at the back; (Right) three different types of picture cards including activity, persona, and product/service.

of cards. Despite the simplicity of their presentation, these cards' role is to link the abstract human values to everyday life. In fact, the cards are supposed to be applied for expressing human values in practice; the activity cards are some examples of the possible valuable behaviors, which can be used to express what does a specific value/group of values mean and how does it appear in a real life; The persona cards are the examples of iconic people, who can be representative of acting based on a specific value/group of values in life; and the products/services cards are some examples that can be used to try expressing how using a product/service in daily life can straighten or weaken a value/group of values.

Generally, the HuValue tool is a mean to facilitate thinking about and discussing human values. This tool supports designers with simple but familiar materials during their design process to analyze everything (object/subject/situation) from a wide value point of view. This approach, referred to as the HuValue perspective, enables the designers to be aware of and sensitive to human values and consider various aspects of their topic and different types of values.

Being aware of the diversity in design processes, the HuValue tool is intended to be used for several applications based on common design activities such as analyzing the situation, defining design goal, generating ideas, selecting a final idea, developing the concept, realizing and evaluating the final concept. In this respect, the tool can be applied for various purposes: the design challenge, the design goal, the context of use, and the user's needs, desires and requirements can be studied from a value-centered point of view for a better understanding of the design situation; human values can be used not only as a source of inspiration to diverge the ideas but also so that they cluster and converge; values can be seen as criteria for deciding on the final idea; the final concepts can be evaluated from a value perspective.

3. Evaluation

To investigate the value of the HuValue tool, a quasi-experimental study was realized to test the applicability and effectiveness of the tool in a design process [19]. A group of bachelor students (N = 64, out of 192 students) were randomly selected to take part in this study. After training them about the intended usage of the tool, the students were supposed to use the tool in their design projects. The data were collected via questionnaires and the students' final deliverables of their conceptual design. The outcomes showed that the project groups who were supported with this tool addressed significantly stronger human values in their design concepts compared to the control groups. Results of the evaluation indicated that the tool is not only applicable in a design process but is also effective at enriching design concepts with human values.

4. Conclusion

Considering the outcomes of our study, we can conclude that raising awareness about human values and facilitating using a value point of view seems to be helpful to emphasize human values in design. However, the current study is limited by time, and further investigations and developments should be realized. Next steps are to digitalize the tool and make it more simple and persuasive to use. We also recommend investigating how to apply the tool for changing behavior and how to use it for preserving and/or changing values.

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Playing with Systems: Tactile Games as System Prototypes

Abstract

The world's most pressing challenges are systemic. Our ability to survive as a species is now linked to how quickly and effectively we are able to address systemic challenges like climate change. The practice of low-resolution prototyping helps designers quickly explore and learn about ideas, but it is rarely utilized when designing for complex systems. At the same time, physical games have often been utilized in service of learning about complex systems, but they have not been used as prototypes for systemic interventions. This short paper and demo provide examples of two games that show how designers can use games as low-resolution prototypes for complex systems. These physical games will transform systems from intimidating, impenetrable, and abstract concepts, to entities that can be explored, engaged, and influenced.

Keywords

Climate Change, Prototyping Systems, Design, Games, Play

1. Introduction

Climate change is a systemic challenge that poses an unprecedented threat to life as we know it. Responses to climate change will require the deployment of an unprecedented breadth of initiatives at a global scale in little over a decade.[1] In order to be successful, we must be able to rapidly explore ambitious ideas as well as the risks they entail. Low-resolution prototypes are well suited to this task and although they are widely used at the product and service scale, they have yet to be employed in the design of systems. This paper demonstrates the ways physical games can be used as a low-resolution prototypes of a systems-level interventions and show how employing this type of practice can help experts and non-experts engage with complex systems in a tangible way.

2. Complex Systems

While complex systems are varied in form and scale, for the purposes of this paper they will be categorized by the work of Yaneer Bar-Yam. According to Bar-Yam, these types of systems share the common traits of a diverse range of functions, interconnections, interwoven elements that each relate, and influence one another.[2] Using this framework, the challenge of climate change is one of our best examples of a complex system. Its causes are layered and inter-related and any meaningful responses to it will require shifts in the way multiple systems (such as national, regional and local governments) behave.

3. Prototypes as Tools for Learning

This work builds upon the notion of prototyping from a design thinking perspective. In this domain, the practice of prototyping can be described as the rapid creation of artifacts to learn about a solution space. Prototyping is widely understood in the product and service design realm as a way to explore, gain understanding, and reduce risk.[3-7] Within this practice, prototypes are broken into low, medium and high fidelity. Lower fidelity, or low-resolution (low-res) prototypes are much faster to build and are easier to make, but they bear little resemblance to the final version of an idea.[8] When creating low-resolution prototypes, designers focus their efforts on building only what is needed to elicit feedback about critical areas of the design from their users. In this way, low-res prototypes allow designers to quickly learn and iterate towards more refined solutions.

4. Educational Games

Although the use of games in service of learning is not new, the work of Dieleman and Huisingh (2006) is instructive for the discussion of prototyping because they highlight the connections between games and experiential learning.[9] Some of the benefits Dieleman and Huisingh attribute to playing games, specifically the focus on experimentation and failing without real consequences, could easily be used to describe the benefits of low-res prototyping.

Learning games and prototypes do share many common traits, but there is an important distinction between the two. Educational games use play in service of a learning objective. While games-as-prototypes certainly offer some educational benefit to the player, their primary purpose is to help the design team understand as much as possible about the design space in the least amount of time.

4.1 Examples of Low-Resolution Systems Prototypes

In the following games, a complex system is translated into a physical experiences and objects that help a variety of stakeholders engage with these systems in a more meaningful way. These games reflect a humility that acknowledges the limitations of our ability to fully understand or account for all of the potential forces and variables within a system. Like any low-resolution prototype, these games do not attempt to replicate the full complexity of a system. Instead, the games are designed with just enough context and game mechanics to spark visceral experiences of system level changes. The simple quality of the game serves multiple purposes. It allows the games to be played by a wide range of users and it minimizes the effort required to create the prototype/game itself. If the game becomes too complicated, the focus will shift from the larger goal and intervention to the prototype.

"Earth Systems and Modern Convenience" serves as a prototype for a hypothetical initiative intended to promote sustainable practices. It utilizes the relationship between gravity and distance from the floor to simulate the ways our planet's natural and human-systems become more fragile as our population grows. The game, grows more challenging at the later phases. As a prototype, the game will be successful if it can help the designers gain greater confidence in a proposed the direction before committing any more time or money than is necessary.

The game has two key parts, a wooden disc balancing on a thin column and a series of small wooden blocks. The 24" wooden disc represents the Earth. The height of the column on which it rests corresponds to the Earth's historical (or projected) populations. The wooden blocks each represent mundane elements of modern life such as owning a car, eating non-local food, or utilizing same-day delivery services. The object of the game is to place as many blocks onto the disc without causing it to topple. Through the course of the game, the players are forced to make difficult decisions which reveal a variety of strategies, connections and intentionality about choices that are often unnoticed in daily life. The tactile nature of the game leverages existing systems, (gravity, the player's nervous system and the uncertainty of the immediate environments) which all become inputs for the game. As an example, a heavy footed pedestrian could throw off a precariously balanced disc.

If the debrief is a critical part of an educational game, as noted by Dieleman and Huisingh, it is absolutely essential for a prototype.[10] The debrief offers the designer a chance to understand more about the player's choices and experiences during the game. The phase of the design process, commonly referred to as "testing", helps designers understand more about their users and their proposed solution. At the Stanford University d.school, the process of testing is often referred to as "empathy with a prop".[11] The debrief after a game serves a similar purpose and the insights gained in this phase help inform the next iteration of a solution.

During the debrief of the game, it is critical that the designer remains open to the variety of discussions that emerge, even if they challenge the premise of the game. For example, in "*Earth Systems and Modern Convenience,"* players may rightfully question why all the blocks are weighted the same when the effects of single day delivery and non-local food may have very different impacts. In remaining open to these kinds of discussions, the designers are able to get a better understanding of the ways which the players view the system and this creates space for the players to become design collaborators as well.

"Critical Responses to Climate Change" comes out of the OneClimate initiative at University of California, Davis which is spearheaded by Dr. Benjamin Houlton, Director and the author who is on the leadership team for the initiative. In order to break down the complexity of climate change into an actionable (although highly ambitious) plan for our species' survival, we distilled the challenge into three key activities. As a planet, we must remove carbon from the atmosphere, change human behavior to adopt carbon neutral lifestyles, and do all of this while adapting to the effects of climate change that are already underway. In order to share this approach with a wide audience, the author developed a metaphor in which the Earth is a leaking boat. To survive we need to bail the boat and fix the leak in the growing turbulence caused by climate change. An animated video describing the approach can be seen here. (https://vimeo.com/270732552)

This game translates the metaphor of a sinking boat into a tangible format that is suitable for elementary school and above (Fig. 1). The leaks in the boat represent carbon accumulation in the atmosphere. The boat will sink unless the players are able to bail the boat (pulling CO2 out of the atmosphere), fix the leak (changing human behavior in order to adopt carbon neutral practices) and shore up the boat (responses to the effects of climate change that are already underway). This game translates some of the climate jargon and abstract concepts into physical experiences that help players experience climate change in a visceral way.

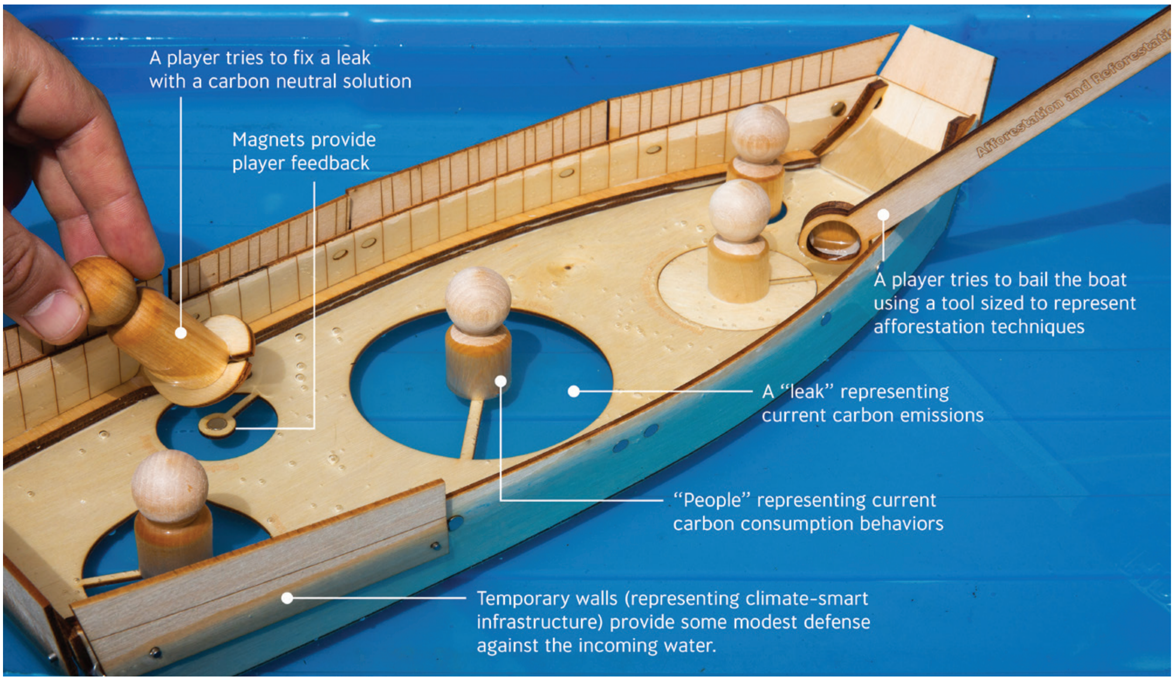

Fig. 1. An image of the game in action with key elements of the prototype called out

Players may work as an individual or in teams. They are not allowed to touch the boat and they have a small amount of time (six minutes) to keep the boat afloat. The leaks in the boat correspond to the proportions of carbon emissions and the bailers are sized to represent the latest figures on carbon sequestration. As with *Earth Systems and Modern Convenience*, the efficacy this game is deeply tied to the debrief and facilitation after the game play. In the game, the role of water, magnets and collaborative efforts between players all become rich sources of insight.

5. Conclusions

In this paper, the author provides a theoretical framework for the ways which games can be used as prototypes for interventions in complex systems. These low-resolution prototypes can provide insight to both players and game designers which provides the ability for designers to gain greater insight into potential system interventions in less time and with less risk. The games themselves have been designed and prototyped, but more follow-up research is needed to explore the potential and shortcomings to this approach. As tools for learning they are not intended to replace the full complexity of a system, but instead offer playful ways of quickly eliciting information about the dynamics, relationships and unexpected influences in the system for both player and designer.

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Attributes of Aliveness: A Case Study of Two Interactive Public Art Installations

Abstract

What elements make people think that an interactive public art installation seems "alive"? To answer this question, the paper examines the design and the reception of two public artworks by the INVIVIA studio: MIMMI and PULSUS. Both are responsive installations that aggregate collective data and interpret it through elements such as vibrations, lighting, and/or mists, but differences in design decisions have led to different perceptions of their aliveness. Through the case study, this paper identifies key attributes in an installation that contribute to the sense of aliveness and discusses the importance of considering aliveness in design. While these attributes are distilled from public art examples, they can generally apply to designed objects that are, through technological augmentation, physically interactive at the human scale.

Keywords

Aliveness, Perception, Human-Technology Interaction, Technological Augmentation, Public Art Installation

1. Introduction

What makes an interactive public art installation seem "alive"? The question of perception of aliveness has been explored by many interaction researchers. The criteria for perceived aliveness has changed over the years, shifting from autonomous motion, to independent intelligence, to possession of the capacity for reciprocal connection [1] and the ability to share control with the human actor as a co-agent in negotiation [2].

In this research context, this paper presents a case study of two public art installations to investigate how design decisions led to different perceived levels of aliveness as experienced by visitors. Through this case study, the paper identifies key attributes in an installation that contribute to the sense of aliveness and discusses the importance of considering aliveness in design.

2. Case Study of Two Installations

To investigate what qualities might contribute to the aliveness of interactive public art installations and how people respond to these qualities, this paper presents two public art installations – MIMMI and PULSUS – designed by the INVIVIA studio and on which the authors have collaborated.

2.1 MIMMI

Overview. The first case was MIMMI [fig. 1], the winning entry to the *2013 Creative City Challenge Art in the Plaza competition* in Minneapolis [3]. It was a large air-pressurized sculpture hovering over the Convention

Fig. 1. Installation view of MIMMI.

Fig. 2. Installation view of PULSUS (in NYC).

Center Plaza. It analyzed real-time emotive information gathered via Twitter from city residents to create changing light displays and mists in response.

Design. MIMMI was designed to be a round, light, cloud-like presence in the middle of the plaza. The installation responded to moods of the city with colored lights and mists. The core algorithm aggregated real-time geotagged tweets from the city, evaluated their emotive state, and translated that state into a dynamic microclimate under the suspended structure.

Responses. The experience was described by visitors as "immersive" and evocative of "wonder." Some compared the installation to "a magical cloud" to comment on its real-time responsiveness. Given the narrative of translating the emotional state of the city, a group of visitors held a yoga session underneath the structure in hope of bringing calming change to the installation and taking advantage of the (literal) mood lighting. The overall sentiment was that MIMMI was a thing that had become "enchanted," as if its qualities of wonder were given to it rather than them being intrinsic. Descriptors specifically related to aliveness were not mentioned.

2.2 PULSUS

Overview. The second case was PULSUS [fig. 2], an interactive installation commissioned as part of the 2017 *SummerStreets Festival* in Manhattan [4]. The large concrete sculpture acted as both a bench and an urban instrument that reflected the activity level of its surroundings. It gathered real-time digital activity of the city and reinterpreted it into an immersive experience with vibrations, mists, and sounds. It was installed in NYC for three weeks before relocating to the Harvard Graduate School of Design for six months.

Design. PULSUS consisted of a series of four sections with each piece made through a fabric-form process with mannequins, resulting in undulations that suggested human forms both above and beneath the drapes. The sculpture composed a dynamic soundscape based on the digital activity of the city, and the soundscape was transmitted via sound transducers through the concrete as vibrations that were also audible through bone conduction. Through an array of piezo microphones, the sculpture was locally responsive to taps on the surface, eliciting mists from embedded nozzles. The intention was to activate the concrete as an interface and engineer surprises into the act of interacting with an architectural material commonly regarded as weighty and inert.

Responses. The design team initially expressed concerns about how people might find the human figures in the concrete macabre, but many visitors actively interacted with the sculpture as if it were something very much alive. Children playing on it were seen with their ears and bodies pressed against the folds to feel the vibrations of a "lumbering creature." Patting the concrete to trigger the mist, several remarked that it seemed like the sculpture was "breathing." Many visitors were delighted to discover sounds akin to "snoring" when they listened with their heads against the sculpture. Some even lay down and snuggled with the human-like forms. The team did not expected the extent to which those who interacted with the installation described the sculpture with words associated with aliveness.

2.3 Different Levels of Aliveness of MIMMI and PULSUS

At first glance, the forms of the two installations immediately set up different expectations. PULSUS incorporated humanoid forms in its concrete folds and invited expectations that these forms might "breathe" or "snore." The toroidal shapes of MIMMI did not resemble common life forms, so visitors tended not to hold similar expectations of aliveness.

The two installations also offered different potentials for relationship development between the visitor and the sculpture. While both installations aggregated and reinterpreted collective data, PULSUS also offered personal intimacy by inviting visitors to physically sit or lie in the concrete nooks. The visitor and the sculpture could form a one-to-one connection through physical contact, and in return the sculpture offered what Turkle coined as the "fantasy of reciprocation" [1] through vibrations and murmurs. MIMMI did not offer similar opportunities for one-to-one connections; the visitor had to interact with MIMMI as one person among a crowd, and there were no possibilities of physical contact between the visitor and the sculpture.

The interaction mechanisms were not immediately decipherable for either installation, and this mystery contributed to the sense that the sculpture might have minds of their own. To a degree, people understood how they might elicit a response: MIMMI required a tweet, and PULSUS read social media and listened to taps on its surface. But the response pattern was never entirely transparent. For both pieces, the algorithms aggregated and reinterpreted the data with sufficient complexity that the lights and sounds produced were more expressive than translational. The PULSUS tap-and-mist mechanism also had an element of randomness in its response delay and duration, rewarding visitors with a level of consistency without becoming entirely predictable.

The different technologies employed in the two installations engaged visitors differently depending on their familiarity with the mechanisms. The light show that illuminated MIMMI was essentially a light projection, a form of technology familiar to the present-day onlooker. In contrast, the sound transduction technology used in PULSUS was less widely known, and this lack of familiarity contributed to a stronger sense of wonder.

3. Attributes of Aliveness

The interaction insights are distilled into a set of four attributes that describe the capacity for an installation to be perceived as being alive.

1. *Superficial Resemblance.* At a superficial level, an installation that exhibits formal or gestural characteristics resembling those of known lifeforms invites expectations and perceptions of it being alive.
2. *Relational Intimacy.* An installation is more likely to seem alive if it offers the capacity for people to interact with it intimately – at the human scale if it is architectural, and in a personal manner if the context is public – and if it suggests reciprocation of that intimacy through its own feedback system.
3. *Ambiguous Predictability.* Human-technology interactivity should be neither entirely predictable nor entirely random. Ideally, the interaction suggests a logic that entices a person to follow along but maintains some element of chance to keep the person intrigued.
4. *Technological Familiarity.* The quality of aliveness is highly subjective, and this subjectivity depends on the observer's familiarity with technology. Whether a mechanism is "sufficiently advanced" to be "indistinguishable from magic," as Arthur C. Clarke has put it, depends on prior experience of the person making the distinction.

While these attributes are drawn from two interactive public art precedents, they can generally apply to designed objects that are, through technological augmentation, physically interactive at the human scale. It is important to note that the discussion focuses on aliveness as an embodied, tangible quality not derived from an external source that employs the object as a software agent.

4. Conclusion

Over the past two decades, there has been a steady trend toward the development of technologically enhanced things that present themselves as having "states of mind that are affected by their interactions with human beings" [1]. As technology in computational systems and artificial intelligence advances, humans will come into more frequent contact with augmentation, and human-technology interaction will become increasingly complex. Thus, the quality of aliveness is important not only because aliveness brings playfulness, a quality attractive to humans, but also because understanding what makes something seem alive will help people build stronger rapport with objects or installations. Designers can use these attributes of aliveness as first-steps in considering their role and responsibility in fostering and mediating this potential relationship.

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Understanding User Customization Needs: Requirements for an Augmented Reality Lamp Customization Tool

Abstract

Nowadays, people are willing to pay for personalized items that satisfy their preferences and distinguish them. Previous work has provided generic customization tool design guidelines. User requirements were gathered for the design of an Augmented Reality (AR) application for lamp customization in context. These are required to define a product configurator that allows users to meet their specific needs. The results of three user studies show that customers' needs are preference fit, inspiration and help; freedom and support during the customization process; and trustworthy visualizations.

Keywords

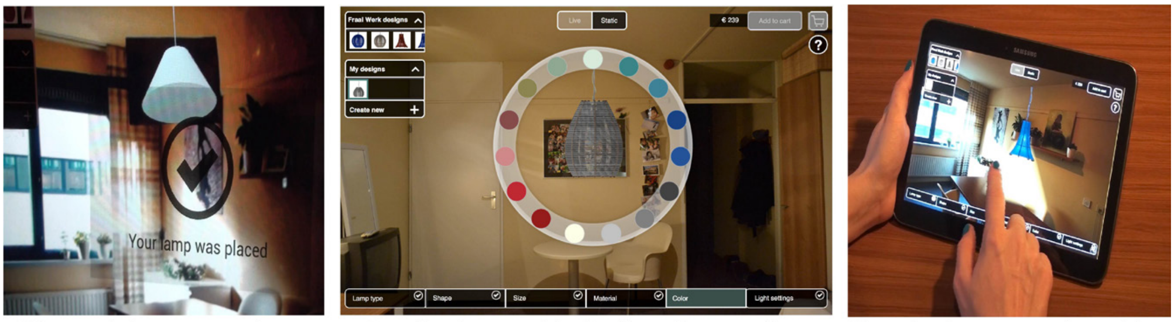
User Research, User Needs, Product Customization

1. Introduction

Small-scale, decentralized and personal production processes are becoming highly valued. Willingness to pay is higher for self-designed products than for standard products. Customers perceive the value of self-design products as higher when they meet their preference system (preference fit) [1]. To ensure the delivery of personalized products with high preference fit, users must have access to customization tools. Albeit rich, previous work's guidelines for customization are generic and insufficient to design customization tools for specific product cases. This work focuses on understanding user needs for the design of a lamp customization tool for citizens who have growth, experience, success, materialism, and enjoyment as core values. Our main goal is to define the requirements for a customization tool of self-designed lamps by (1) exploring user needs and customizable attributes; (2) prioritizing and selecting a set of attributes and needs to define requirements for a lamp customization tool; and (3) proposing a design to cover these requirements. User requirements were drawn from four sources. A Literature Review (LR) provided general requirements. Contextual Inquiries (CI) explored users' thoughts and interests on customizing products. A participatory study (Co-constructing Stories, CCS) gained more insights into the customization process of lamps in particular. Next, a Survey (S) was conducted to prioritize user needs and to define a final set of requirements. Finally, a design of a customization tool using these requirements is presented.

2. Literature Review

Consumers are willing to pay extra for products that they have customized according to their preferences [1]. The added value of customization can be explained with the Ikea effect [2]. However, the effort put into the customization process alone does not increase the



3D model presentation in context using AR

Inspiration and help, freedom and support, trusworthy visualizations

Hands-down comfortable customization

Fig. 1. A mockup of an Augmented Reality (AR) customization tool design providing different starting points, a limited set of customizable attributes, and increasingly realistic visualizations.

perceived product value. An enjoyable customization process and a high preference fit are required as well to result in a higher subjective product value when using mass-customization toolkits [1]. Product customization requires consumers to build their own product. The difficulty of decision-making increases as the number of alternatives and attributes increases, if a specific attribute is difficult to process, or if there is uncertainty about the values of attributes [3]. Considering too many options can lead to decision-making errors because there is too much to decide [4]. An optimal limit of options was found to be six when choosing among gourmet jams and chocolates [5]. Dysfunctional effects of information overload emerge with ten or more alternatives when choosing houses [6]. The order of attribute presentation is also influential. When attributes with relatively few options follow attributes with relatively many options people are more likely to accept default options in the context of custom-made suits and automobile choice [7]. The perceived comfort and preference fit increase with the user's expertise in the context of consumer laptop computers [8]. Not all customers are interested in fully exploiting the potential of customization. Hence, several initial designs should be provided as starting points [8]. By their very nature, customized products are likely to be unique. This makes it difficult for consumers to anticipate their post-purchase experience [8]. Additionally, several product attributes can be intangible which makes it hard to show or explain them on a screen. Also, the context in which the products are presented is important. Because of this, AR systems overall satisfaction is higher than when using traditional e-commerce stores [9].

3. User Studies

3.1 Methods

Participants. 12 volunteers (25-66 yo, 3 designers) visiting, buying, or selling products that could be customized during the Dutch Design Week participated in the CI. 10 volunteers (5 female, 5 novices) participated in the CCS. 29 participants completed the Survey (12 male, Mean = 28.29 yo, SD = 2.49). Detailed protocols are available in [10].

Procedure CI. We observed attendants and inquired about people's preference to customize products and their previous experiences with it. Additionally, designers were asked whether they usually set design limitations for users in the customization process and why.

Procedure CCS. In the sensitizing part, questions about previous experiences choosing and buying lamps and ideas about lamp customization were asked. In the elaboration task, participants were asked to design their own lamp while thinking-aloud. Diverse materials and tools were provided to inspire participants and to enable the observation of the participants' use or interest in (1) different levels of abstraction; (2) prototyping and visualization of tangible and non-tangible tools; and (3) possible lamp attributes. Participants used both lo-fi and hi-fi prototyping tools or a combination of both. For example, participants would draw the shape of their lamp on paper and use a real fabric to explain the material. Also, the attributes or needs mentioned by the participants and the levels of abstraction of the tools and their tangibility was registered.

Procedure Survey. 19 customization aspects elicited in the CCS were rated in random order on a 5-point Likert scale (5: extremely useful).

3.2 Results and Discussion

The contextual inquiry confirmed several customization requirements suggested by the literature. Most participants value the concept of customization, but they still find having a competitive price crucial. People valued the customization of both functionality and style. Style features should promote uniqueness and creativity. Already made products should be also available. Visualizations of the products should provide accurate feedback to let the user see the impact of every choice on the final product. People care about the quality of the end product, so they often seek advice from experts and they value their personal connection with them. *"You need skills, if you cannot visualize it, the disappointment could be big."* - Garment customization designer 1

In the co-constructing stories sessions we observed that trustworthy, full and realistic impressions about the product should include light effects. Decisions on the customization of technical parts of the lamp and other functionalities should be made by an expert. Moreover, users know what they do not want, but they are not certain about what they actually want. Thus, examples are useful to imagine the final product. Additionally, support in the decision-making process is required, by providing a good overview over all the options and allowing comparison of different products. Next, users should be able to iterate and decide the order they want to follow by themselves. They should also choose from a starting point: from scratch, from a basic model, or from a pre-designed alternative. A summary of the obtained requirements is shown in Table 1.

The survey ratings of each customization variable were ranked in order of importance. The top needs and attributes were the beauty of the product, the type of the lamp, the purpose of the lamp, the type of light, the fact that the lamp matches the interior, and price. These are mainly need-based attributes. This is probably because the respondents were novices [13]. Nevertheless, to support expert users as well, these need to be translated to parameter-based customization variables. Therefore, we suggest to use lamp shape, color, material, and lamp dimensions as parameters that can contribute to create a combination that can be beautiful for each particular user.

General requirement	Description	Source
Limited options at a time	Between 6 and 11 options at a time.	LR, CI
Different starting points for different users	(1) scratch or free-form interface; (2) a model or combined configuration; and (3) a pre-designed alternative.	LR, CI
Trustworthy visualizations in context	Increasingly richer, realistic visualizations in context to let the user understand the final outcome.	LR, CI, CCS
Overview of the options for decision-making support	Side-by-side comparison of saved configurations and their characteristics.	CCS
Price and value	Price visible to account for every change.	CI, S
Customer-designer relationship support	A designer or expert should be available to guide or advise the customer.	CCS
Post-editing and iteration possibility	Iterations in the design process, bookmarks, and going back to previous designs.	CCS

Table 1. Final user requirements. The sources are LR: Literature Review, CI: Contextual Inquiry, CCS: Co-Constructing Stories, S: Survey

4. From Requirements to Design

The user requirements can be directly translated into design elements in an AR customization application. First, AR allows to place and show the product in context. A 3D model of the lamp can be placed and visualized in the desired room position (Fig. 1 (a)). The realism of the 3D model can be increased as the user selects the desired attributes. However, the final visualization should be trustworthy and exactly represent the product they are going to receive. Second, multiple starting points should be provided for different types of users. Users can explore pre-designed lamps or start from scratch with their own design. Additionally, tips on each customizable attribute could be shown to provide support to the user. Users can change each attribute in the order they like and go back and forth. However, the set of customizable attributes should be limited each time. In the example shown in Fig. 1 (b), there are only six customizable attributes: shape, size, material, color, and light settings. After selecting one of them, only few options for that attribute are shown around the lamp 3D model. Finally, it is important to prevent fatigue when using AR. Therefore, users should always be able to switch from a Static- to Live-view. The Live-view provides real time visualization of the lamp in AR, allowing the user to see different lamp perspectives. The Static-view shows a picture representing one particular view of the room as a background for the lamp customization (Fig. 1 (c)).

5. Conclusion

This work defined a set of relevant requirements of user needs for an AR lamp customization tool. These requirements are (1) inspiration and help; (2) freedom and support during the customization process; and (3) trustworthy visualizations. From the broad and generic guidelines available, the methods applied enabled us to specify a set of concrete attributes and needs to meet user needs when customizing lamps in context using Augmented Reality. Such methods and techniques can also be used to define specifications for other types of products.

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Speculating on the Future of Graphic Design in the Age of Intelligent Machines

Abstract

Machine learning is set to have a profound impact on the graphic design industry in the near future. Despite its proximity, graphic design education and practice are largely sidelined from participating in the highly scientized spheres of computational aesthetics and applied image processing. Within this context, designer Sekyeong Kwon sought to make visible some of the cultural and practical implications of AI-powered design, *from a graphic design perspective*. The resulting practice-led project, *Michael Barnes*, falls within the subfield of adversarial design, and seeks to provoke contestation and debate around automation in design. The following short paper briefly sketches out the current graphic design landscape in relation to emerging technologies; outlines *Michael Barnes*; and explores a number of issues raised by the project including questions around (inter alia) aesthetics, authorship, and representation.

Keywords

Graphic Design, Automation, Adversarial Design, Practice-Led, Authorship

1. Graphic Design and Automation

The authorial hand of the graphic designer has always been indissolubly linked to the tools and technologies available to them. Since the mid-twentieth century, this causal relationship has been increasingly influenced by developments in human-computer interaction (HCI), and more specifically, 'graphical user interfaces' [1]. MIT's *Computer-Aided Design Project* (1959-1967), for example, which spearheaded much of the early work into these systems, sought to create an interface which would "couple a man and a machine into a problem-solving team for fresh design problems" where each would perform "better than … man or machine alone" [2].

More recently, however, and with developments in machine learning and deep learning in relation to computational aesthetics and aesthetic computing (see, for example, Google's *DeepDream*, MIT's *Nightmare Machine*) the view of computer-aided design software as an aid, is being superseded by its potential to make autonomous or semi-autonomous creative decisions [3-4]. Applied instances of embedded artificial intelligence (AI) technology within the field of graphic design currently include Adobe's Creative Cloud software, which is able to analyze the content of an image or video and make "intelligent recommendations" in order to automate "time-consuming" aspects of design [5]. And, looking ahead, Autodesk is presently developing Project DreamCatcher – a generative design system that will be capable of producing thousands of design options in a matter of seconds and "play an active, participatory role in the invention of form" [6].

Of course, these advancements have elicited polarizing views in the field of design. Typically, debates center around employability and economic productivity, with factions on one side arguing that by relegating time-consuming production activities to computers, designers will be able to expedite their creative work [7]. Others, however, warn of a dystopian scenario with widespread unemployment resulting from increased automation [8].

However, outside of this binary rhetoric, and the pitting of the 'technophobic humanist' against the 'inhuman technologist' [9], what is less often discussed are the potential ramifications of AI technology in relation to the craft of graphic design practice.

Within this rapidly-evolving and highly-contested environment, designer Sekyeong Kwon sought to encourage debate and make visible core concerns around AI-powered design, *from a graphic design perspective.*

The resulting practice-led project, *Michael Barnes*, is outlined below.

2. Michael Barnes

Michael Barnes is a self-titled portfolio website (https://barnes.persona.co/) which includes a manifesto, a curriculum vitae, and a gallery of design work featuring corporate identity, packaging and branding projects (See

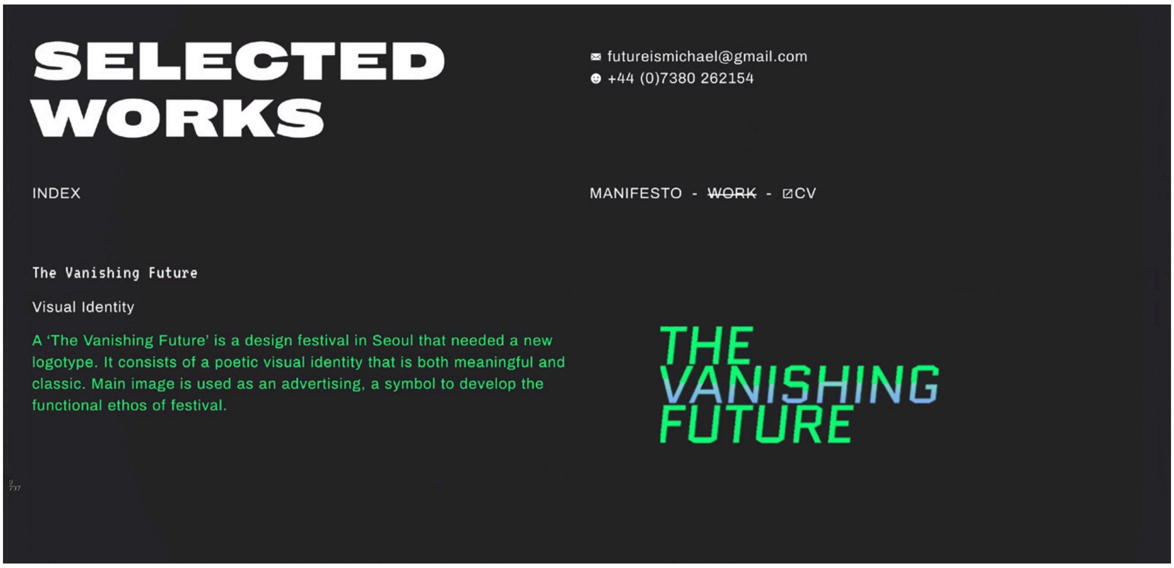

Fig. 1. Michael Barnes *Work* (Source: https://barnes.persona.co/)

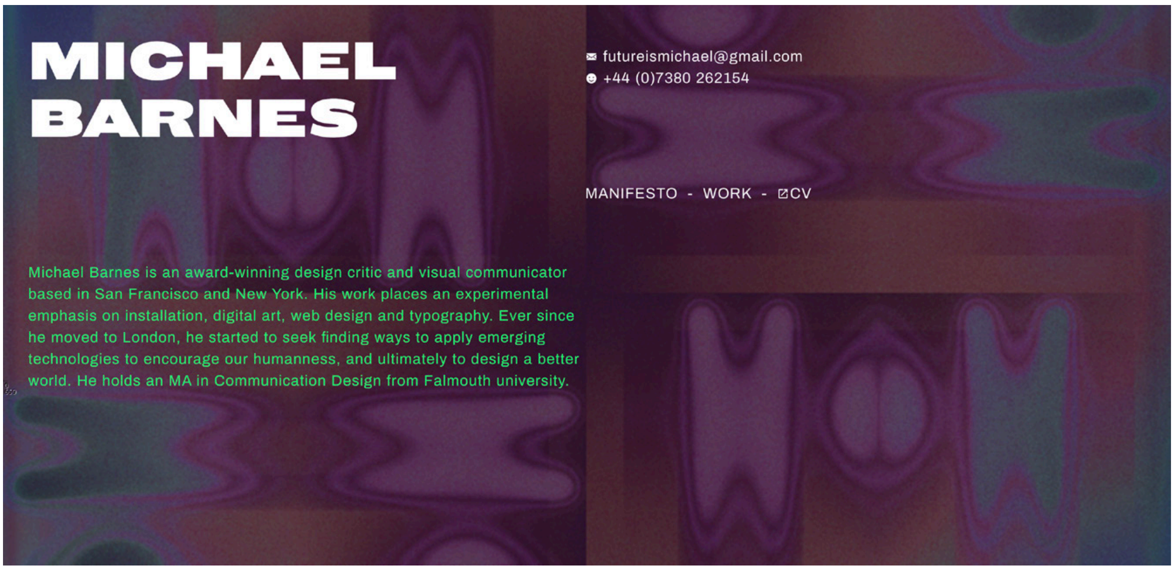

Fig. 2. Michael Barnes *Biography* (Source: https://barnes.persona.co/)

Fig. 1). According to his biography, Barnes' is "an award-winning design critic and visual communicator based in San Francisco and New York" (See Fig. 2).

Despite the unremarkable design work and the uncomfortable syntax, the website seems to all intents and purposes authentic. That is, the portfolio appears typical of the countless online design portfolios that are (arguably) largely indistinguishable from one another [10].

However, 'Michael Barnes', his name, biography, manifesto, and projects are entirely fictitious. 'He' has been computationally generated using a combination of tools (Python coding, Markov Chain sequencing, image generators, etc.) and data scraped from existing graphic design texts and websites.

Thus, 'Barnes' represents but one randomized version of a potentially exponential number of designers and portfolios that could have been algorithmically generated. He could have, for example, been just as easily characterized as:

… a curious interaction designer and UI/UX designer based in Barcelona and Bangkok…

Or:

… a meticulous design strategist and visual communicator based in London and Sydney…

Certainly, this kind of parafictional deceit in cultural production is nothing new; Nat Tate (created by William Boyd) and The Yes Men (Jacques Servin and Igor Vamos) spring to mind. In each case, the characters draw on and mimic existing dialects – cultural, aesthetic, and textual – as a means of gaining entry to, and legitimacy within, a specific sphere [11]. However, unlike The Yes Men (et al) who intentionally 'dupe' the viewer, 'Michael Barnes' offers up 'his' own duplicity for scrutiny. Namely, the last section of the website, the *curriculum vitae*, reveals the project as a fictional endeavor, and makes publicly available the various code and tools used in the creation of the character and his portfolio.

3. An Adversarial Approach

While not overtly political, Kwon's project can be seen as a form of adversarial design – a type of critical making which seeks to provoke debate through the speculative modelling of possible scenarios and socio-political configurations [12]. Specifically, once 'Barnes' is revealed as an algorithmically generated figure, the existing relationship between AI technology and design, and perhaps more importantly, its shared future, are visibly problematized for the viewer. By doing so, rather than simply exploring the *potential applications* of AI technology and design, *Michael Barnes* demands consideration of its implications as well.

One area highlighted by *Michael Barnes* is the ease with which it achieves, at least in part, a kind of semiotic invisibility. It appears authentic. Thus, the website exposes the generic globalized reality of design and portfolio websites in which imitation has become a tool of legitimization. This, in turn, raises further questions around the *current* impact of AI technology in the field of design. Firstly, given that the featured work ('best of', 'most viewed' etc.) on graphic design showcase sites (for example, Behance and Dribbble), and the practice of locating stock images and templates, is search engine driven, to what degree are computers already agents of (rather than simply aids to) design practice? And looking forward, if design software is increasingly left to make decisions computationally, what will these be based on? Aggregates of taste? Engagement levels? Sponsorship? And, in turn, whose views will these privilege?

As such, the project recognizes that advancements in graphic design AI are not value-free, but rather, embedded within a broader data environment, which will ultimately prioritize particular social, political and economic forces.

Another area underscored by the project are shifting notions of originality within our current hyper-networked culture. Specifically, while Michael Barnes' portfolio is comprised entirely of pre-existing data, it *is* original in the sense that it is one-of-a-kind. In turn, this begs the question: who is the author of the website? The algorithm? Kwon? The 'original' authors of the now-unrecognizable data sources? And, additionally, who owns the intellectual property rights to the work?

While theorization around shared cultural production and ownership recognizes contemporary appropriative cultural practices and the use of existing data as 'material' for production (such as sampling by deejays), the discourse is still predicated on human-agency and intentionality, which does little to clarify ongoing debates around AI and algorithmic authorship [13-14].

4. Contestation vs Consensus

Michael Barnes is by no means a 'polished' form of AI; the design and various textual elements are largely inexpert; and the final outcome relied on the assembly of its individual parts by Kwon. However, the intention of the project is not to predict the future, nor to attempt to compete with rapid technological advancements in the field of computer science. Rather it seeks, playfully, to provoke debate and speculate 'what if?'. By suggesting a possible world, where a new 'designer' complete with personal backstory, ethos and portfolio can be generated at the click of a button, ad infinitum, the project encourages a recognition of the tensions which lie at the heart of the convergence of AI and graphic design.

In turn, *Michael Barnes* seeks a response from design educators and practitioners, a community whose voice is more often than not lost in the scientized race for AI. This provocation is, perhaps, most succinctly encapsulated in the darkly comic automated email response should you try to get in touch with 'him':

Hello! Thank you for your email.

BAD NEWS: I'm away from the office until Artificial General Intelligence becomes a reality.

GOOD NEWS: Me being away means that your job is safe from automation – for now.

Until then, Cheers!
Michael

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AI-Stylist: An AI-based Framework for Clothing Aesthetic Understanding

Abstract

Current studies in computer science on clothing aesthetic evaluation are difficult to be practically applied as fashion is a subjective field affected by various factors, like cultural background, or physical information (e.g. skin color). On the other hand, computer is good at processing logical tasks with clear definition and evaluation index. In this work, we propose a framework which divides the aesthetic evaluation task into three levels, namely apparel harmony, personal compatibility, and personality expression, to reduce its complexity such that computer has great potential to evaluate the clothing aesthetic practically. Each level is clearly defined, and the technic solutions is proposed correspondingly. Initial work with examples is presented to demonstrate the potential of the proposed framework.

Keywords

Ai-Stylist, Clothing Aesthetic Evaluation, Understanding, Fashion

1. Introduction

The cross-domain between fashion and Artificial Intelligence (AI) has received increasingly attention recently. In the field of computer science, fashion related tasks can be roughly divided into three progressive parts [1]: fine-grained attributes recognition for fashion lovers [2-4], clothing aesthetic evaluation for stylists [5-7], and design auto-generation for designers [8-10]. With the assistance of AI, huge amount of personal information can be recorded and processed simultaneously. It can be expected that customized advices of outfit matching or personal styling service can be easily accessible by the public. However, the challenge is to what extent an intelligent model can behave like a human stylist with professional styling knowledge.

Fashion is an extremely subjective topic and highly diversified among different individuals. Current evaluation studies also suffer from this subjective factor and thus cannot achieve good performance in real application. In this work, we attempt to abstract the subjective aesthetic evaluation and divide this complicated process into a series of small work with clear task definition. We propose a computer based clothing aesthetic evaluation consisting of three progressive levels, namely apparel harmony, personal compatibility, and personality expression with technic solutions. An initial work is described to elaborate the whole idea of the proposed framework which is like an AI-stylist.

2. Methodology

In the proposed framework, the three levels are

Apparel harmony: Are all fashion items of an outfit well matched?
Personal compatibility: Is an outfit matching with an individual's physical information e.g. hairstyle, body figure, etc.;
Personality expression: Is the total look well expressing an individual's attitude or emotion?

In computer science, compatibility of fashion items (including apparel, shoes, and bags, etc.) of an outfit is considered under a matching principle at apparel harmony level. The requirement of an AI model at this level is to assess the visual balance of an outfit (Good, Normal, or Bad) and the model is also capable of providing a reasonable explanation for its judgement. On the first level, physical information including body figure, skin tone, and hair style etc. will be taken into consideration. Then, at the second level, i.e. personal compatibility level, the AI model is required to know how to create an outfit for an individual. Finally, at the highest level, i.e. personality expression level, the AI model is expected to be able to understand an individual's personality and recommend suitable items accordingly.

To achieve the objectives stated above, the proposed evaluation model consists of three phases. Specifically, the first phase is attribute recognition which provides basic fashion knowledge (V-neck, velvet, and dotted etc.) to the model. The second phase is rule learning which teaches the model about the basic rules of mix and match. The final phase is auto introspection to further refine its performance as a stylist. The details of the proposed framework are shown in Figure 1:

(1) Phase 1 – clothing attribute recognition and concept learning
Attributes are treated as components of an apparel item. High accuracy of fine-grained attribute recognition is the foundation for clothing aesthetic understanding. Although previous networks reported in the literature have achieved promising performance, there is still a lot of room for improvement from the fashion perspective. There are two main tasks in this phase: 1. Fine-grained attribute recognition, especially the accuracy of multi-label recognition; 2. Attribute feature presentation to connect the visual feature with fashion semantic.

(2) Phase 2 – experts embedded and reinforcement learning
Based on the recognized clothing attributes, the reasoning network based on the recognized attribute is proposed. In this phase, the core task is to find the relation among attributes of apparel items of an outfit.

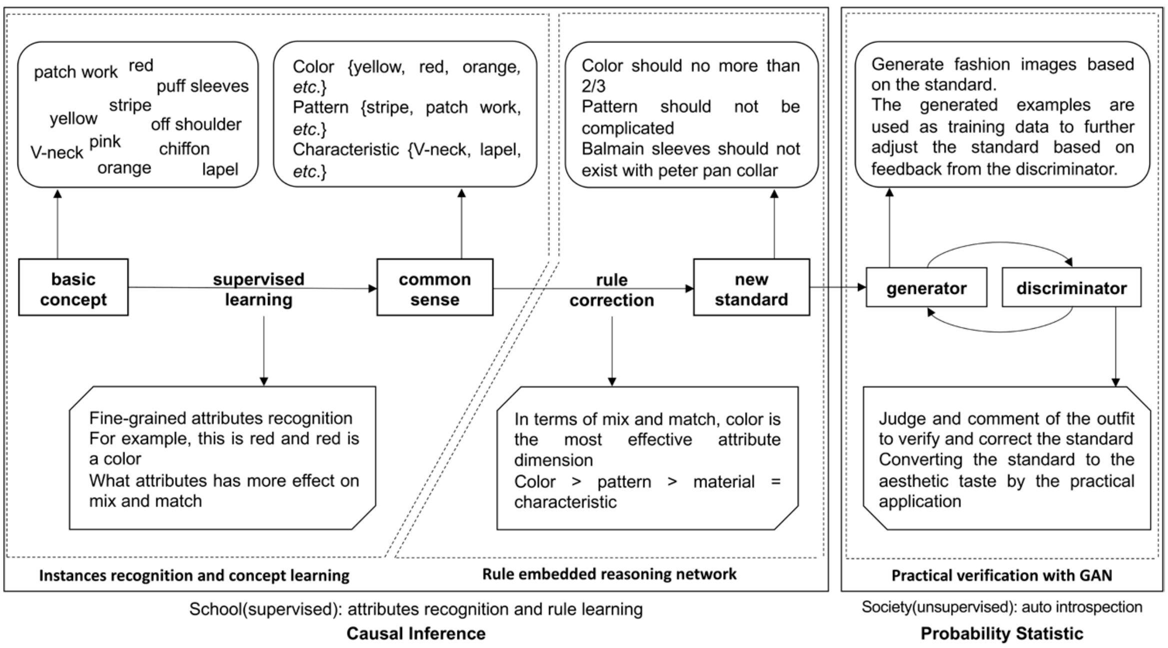

Fig. 1. Proposed framework of the AI-based clothing aesthetic evaluation

Current approaches are mainly focusing on finding a compatibility space and suitable metric to measure the distance between attributes. We propose a novel method with symbolic reasoning to formulate this problem.

(3) Phase 3 – practical verification with Generative Adversarial Nets
As shown in Figure 1, both attribute recognition parts and rules learning parts are under supervised learning or semi-supervised learning which requires training data. (It is noted that the rule defined here is a kind of principle for guidance only and thus is not the same as the rules in the previous expert system.) To fine-tune the performance of evaluation model and generate more data for training, a GAN-based model can be developed to realize the auto introspections.

3. Initial Experiment

To demonstrate the potential of proposed framework, we present some experimental results of the initial work on clothing aesthetic evaluation at the apparel harmony level (first level of the framework) for the reference. Different from the scenario like Amazon echo look (which is limited to make a comparison on two outfits), the proposed framework should provide absolute evaluation/assessment on one outfit rather than comparing two outfits in most real-life situation, e.g. someone always asks how is my outfit today? As

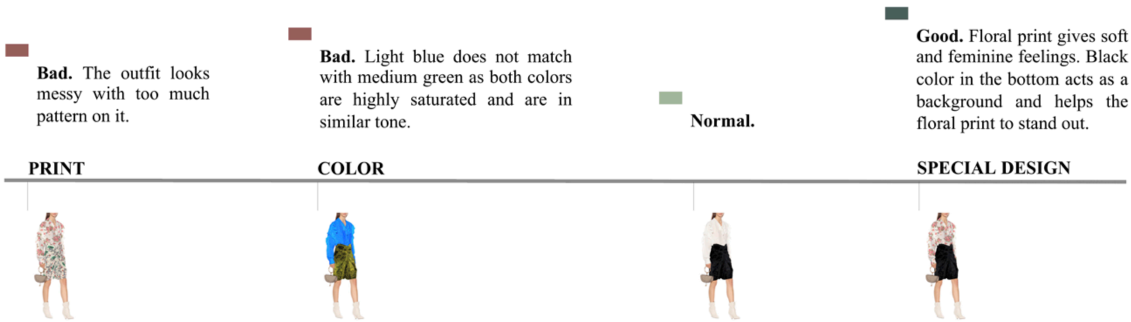

Fig. 2. Three ranks of outfit aesthetic ranking

Fig. 3. Randomly selected samples in Dataset

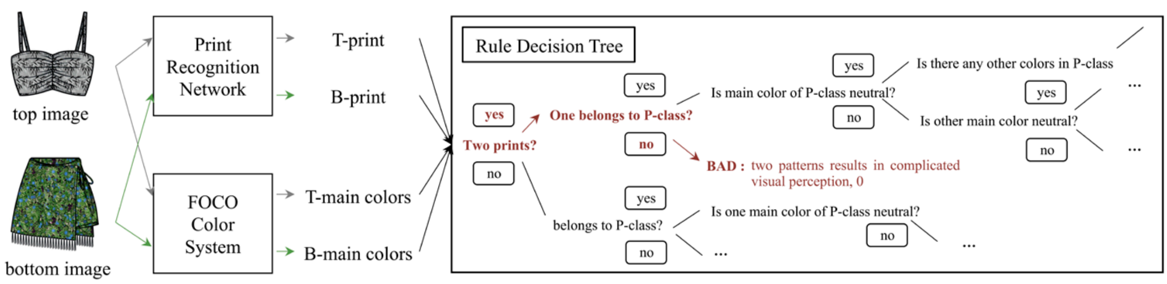

Fig. 4. Rule expert for fashion evaluation

shown in Figure 2, three ranks are defined based on fashion and styling knowledge to evaluate an outfit. The dataset built for training is based on these three defined ranks. We collected the image source from Polyvore firstly. Then, the collected outfits were annotated with the three-evaluation ranks (Good, Normal, Bad) and its corresponding reasons. We show the samples of the proposed dataset in Figure 3.

Next, we implemented a rule expert as a decision tree program. The learning system contains two components: a recognition network and a rule expert (The structure of the rule expert is shown in Figure 4). The recognition network fits into a traditional 3-class classification task. The evaluation loss is to train the network supervised by the labels. To let the network generate a reason why the outfits is rated as Good, Normal or Bad, we transform the knowledge of providing a reason from the rule expert to the network by multi-task learning. Finally, evaluating/grading an outfit with absolute judgement in terms of reasonable explanation can be generated. Sample results and compared approaches can be seen in Figure 5.

4. Conclusion

Recently, more and more researchers from computer science society put their efforts on applying AI technologies to fashion related tasks. However, fashion and styling are a very subjective topic and thus conventional computational techniques cannot be directly and practically applied to evaluate the clothing aesthetic. In this paper, we propose a framework at three progressive levels, including apparel harmony, personal compatibility, and personality expression to address this issue. Initial experimental results at the harmony level are presented to demonstrate the potential of the proposed framework. The proposed framework serves as a foundation and guidelines for the future development of related aesthetic evaluation techniques and systems which can be practically applied.

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Fig. 5. Examples of the initial result

Top	Bottom	Rule	Net	Net Eval Branch	Net Reason Branch	Reason Given by Rule	Reason Given by Net Reason Branch
		NORMAL	NORAML	NORMAL	NORMAL	prints in the top and the bottom are all belongs to P-class, at least one of their main color is netural	prints in the top and the bottom are all belongs to P-class, at least one of their main color is neutral.
		BAD	NORMAL	NORMAL	BAD	two patterns results in complicated visual perception	main colors are different and the print design color visual perception complicated
		GOOD	GOOD	GOOD	GOOD	color is well matched, design of floral make the whole outfit feels active	color is well matched, design of other cat make the whole outfit feels active
		NORMAL	NORMAL	NORMAL	NORMAL	do not make any mistake but the print dotted is regular	do not make any mistake but the other print is regular
		BAD	NORMAL	BAD	BAD	color matching is wrong	color matching is wrong
		BAD	NORMAL	NORMAL	NORMAL	color matching is wrong	patterns in the top and the bottom are all belongs to P-class, at least one of their main color is neutral

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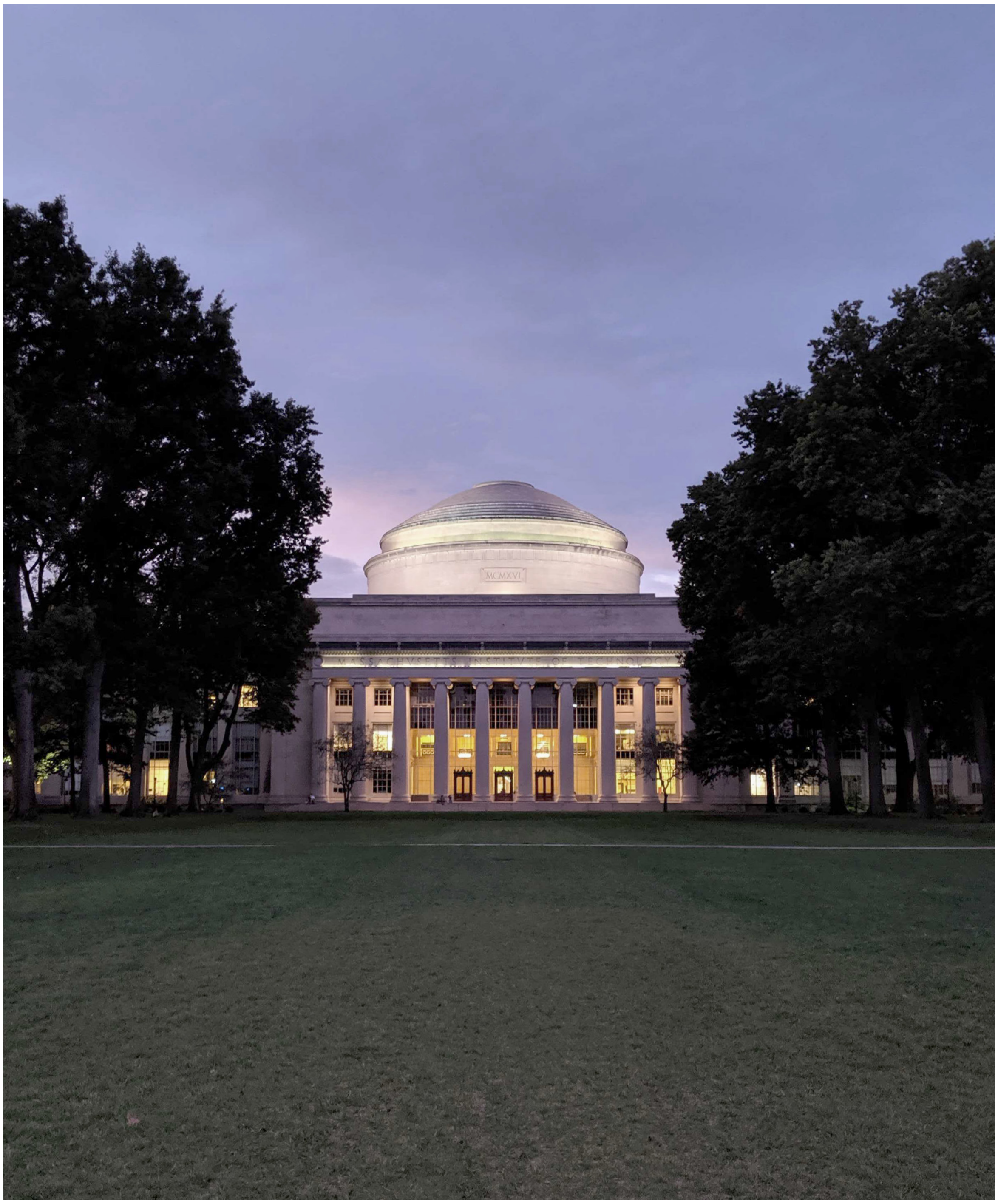

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