Motor Memory in HCI

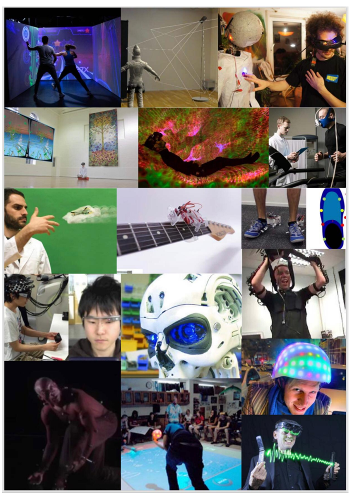

Figure 1: A collage of images from authors' previous related work.

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Abstract
There is mounting evidence acknowledging that embodiment is foundational to cognition. In HCI, this understanding has been incorporated in concepts like embodied interaction, bodily play, and natural user-interfaces. However, while embodied cognition suggests a strong connection between motor activity and memory, we find the design of technological systems that target this connection to be largely overlooked. Considering this, we are provided with an opportunity to extend human capabilities through augmenting motor memory. Augmentation of motor memory is now possible with the advent of new and emerging technologies including neuromodulation, electric stimulation, brain-computer interfaces, and adaptive intelligent systems. This workshop aims to explore the possibility of augmenting motor memory using these and other technologies. In doing so, we stand to benefit not only from new technologies and interactions, but also a means to further study cognition.

Author Keywords
Motor memory; embodied cognition; embodied interaction; intelligent systems; natural user-interfaces; brain-computer interfaces.

CCS Concepts
•Human-centered computing → Human computer interaction (HCI);

Figure 2: *Mind over Motor:* Testing a self-driving wheelchair with brain-computer interface (BCI) and biofeedback [30].

Figure 3: Self-driving wheelchair with "cyborg-motor-memory" for an electric motor [30]. A linear array of light sources on each spoke assists with biofeedback-based motor memory training.

Introduction

We are becoming increasingly aware of the role of embodiment in the way humans experience the world, with movement acknowledged as foundational to thought [66]. There is increasing evidence that memory is tied to the sensorimotor system rather than only to the sensory system [13], a dynamic that is referred to as "motor memory" [21, 61, 69]. We are now realizing that movement can help us think and learn new information faster by establishing embodied representations of reality [20, 38]. Additionally, the lack of movement where movement would be normal, e.g. after amputation, also evokes motor memory [44, 47]. For example, concepts of motor memory are embodied in the "Mind-over-Motor" project [30], a human-computer interface where there might not be any *human* motor movement at all (Fig. 2 and 3). Motor memory is also interpersonal – our own motor memory can shape how we perceive and remember others [25, 35]. Furthermore, sensorimotor information is coupled to form spatial memory necessary for navigation and exists as a key to creativity [64, 65]. This suggests that thought is internalized action, and re-externalizing thought through congruent actions further promotes thought [58]. When translated to the design of technological systems, this means that not only should we consider that we can learn and memorize motor activity (e.g. motor skills), but that we can also perform motor activity to learn and memorize new information (e.g. gesturing directions) [68].

This broader importance of embodiment has since inspired much HCI research, leading to the development of concepts such as embodied interaction [14], on-body interaction [19], bodily games and play [16, 32, 33, 37, 39, 40, 41, 42], tangible interactions and tangible cognition [67], "wearables" (wearable computing) [26], and natural user interfaces (NUIs) [9, 10, 17, 28, 52, 70]. While these concepts have productively brought forth a wealth of new design perspectives, systems and technologies [11], it is arguable that much psychological and cognitive theory has been left behind [63], resulting in approaches that laxly appraise anything that includes the physical body as sufficiently "embodied." Moreover, "cyborg" technologies like prosthetics, are often not appraised as "embodied" even when warranted (e.g. the brain-controlled wheelchair on Fig. 2 and 3). Thus we feel that the notion of "embodiment" is often laxly applied, in both over-broad and over-narrow senses.

Resultantly, we find that there is a limited number of works in HCI exploring deeper aspects of embodiment such as the relationship between motor activity and memory. Considered alongside new and emerging technologies, this presents an exciting opportunity for novel explorations. For example, neuromodulation can be used to prime the brain to better absorb motor memories [15, 46, 51, 55, 62] and electrical stimulation can produce motor activity without executive control from the brain [45, 53, 56]. Brain-computer interfaces allow us to directly access intentions of motor activity without necessitating bodily movement [12, 18, 31, 34, 30], and lastly, adaptive intelligent systems can iteratively and cyclically learn with humans through the sharing of motor and memory resources forming cyber-human, or humanistic intelligence (HI) [27, 29, 34, 54, 36].

As motor activity is foundational to human cognition, these technologies hold the potential to drastically influence how we experience the world. In this workshop, we explore the areas of embodied cognition and interactions, biomedical and "cyborg" technologies, wearable computing, natural user-interfaces (NUIs), and intelligent systems, towards new horizons of investigation and innovation.Thus' we stand to benefit not only from the genesis of new interaction technologies and application areas, but also a means to further study human cognition.

Topics of Interest

The topics of interest for the workshop include theories, technologies, and applications related to motor memory in HCI. We encourage contributions which do not neatly fit in existing categories.

Theory

- Using motor memory in the design of intelligent "enactive systems" [23] to support declarative memory
- Drawing from cross-disciplinary literature including cognitive neuroscience, psychology, phenomenology, and somaesthetics
- Theoretical understandings to direct the design of intelligent systems for augmenting motor memory

Technology

We are interested in contributions related to how technologies like BCI, EMG, EMS, haptics, robotics, machine learning, artificial intelligence and human modeling can be leveraged for physically interfacing with motor memory for HCI applications.

Applications

- Augmenting motor memory to design towards the extension of human capabilities and learning
- Augmenting motor memory in games including bodily games and serious games
- Designing for health and biomedical applications including rehabilitation and prosthetics
- Novel UX mechanisms for interacting with motor memory
- Designing towards humanistic and cyber-human intelligence [27, 36]

Goals of the Workshop

The most important goal of the workshop is: (1) to serve as an enduring community and networking platform for researchers who are investigating the intersections of technology, memory, and motor activity.

Other workshop goals are: (2) to identify and articulate relevant theoretical constructs and create resources for future research, (3) understand synergies at the intersections of emerging technologies and current knowledge; and (4) nurture the growth of a cross-disciplinary research community around these topics and develop plans for subsequent activities (e.g. workshops and Dagstuhl Seminars[1]).

Topics of interest for the workshop are given on the sidebar.

Organizers

Rakesh Patibanda is a PhD candidate at the Exertion Games Lab, Monash University. His research mainly focuses at the intersection of body, technology and play [49, 50, 48]. His PhD focuses on how we can use muscle memory as a design resource for intelligent and "enactive" systems [23].

Nathan Semertzidis is a PhD candidate at the Exertion Games Lab, Monash University. With a background in psychology and neuroscience, he is currently exploring how Brain-Computer Interfacing can be applied to foster integration between natural and artificial intelligences as "Cyborg Intelligence" [60, 59].

Michaela Scary is an Exertion Games Lab member at Monash University who recently completed an honours degree at the University of Melbourne and is interested in cognitive psychology, computer science, mathematics, biology, physics and philosophy. She also experiments with technology and game design to understand the brain and consciousness.

[1] Dagstuhl Seminars are academic events for open discussions of results and ideas, hosted at Schloss Dagstuhl in Saarland, Germany.

Joseph La Delfa is a PhD candidate at the Exertion Games Lab, Monash University. Joseph aims to design human-drone interactions that improve somatic awareness by leveraging co-movement, materiality and narrative [22, 24].

Josh Andres from IBM Research Australia and Exertion Games Lab, Monash University, has co-led various workshops as well as the first Summer School on inbodied interaction [4, 57, 2].His work focuses on investigating intelligent-like systems as human partners to inform the design of systems that support human potential [43, 1, 3].

Mehmet Aydın Baytaş is MSCA Research Fellow at Qualisys AB. His research has covered embodied interaction [11], motion capture [5, 7], gestural interface design [8, 10, 71], gestures in live music [6], and human-robot co-movement [22, 24].

Anna Lisa Martin-Niedecken is a Senior Researcher at the Subject Area Game Design, Zurich University of the Arts. Anna's research mainly focuses on movement-based exergames [32, 33]. In 2018 she founded the Startup and ZHdK-SpinOff, Sphery Ltd.

Paul Strohmeier is a postdoc at the HCI group of Saarland University. He is interested in human perception and computer sensing. He applies methods from psychophysics to deepen his understanding of human perception, especially in relation to action.

Bruno Fruchard is a postdoc at the HCI group of Saarland University. His research focuses on gestural interaction and command selection. He previously explored mechanisms for supporting memorization.

Sang-won Leigh is an Assistant Professor of the School of Industrial Design at Georgia Institute of Technology. His research focuses on augmenting humans and their creativity, through forming symbiotic and tactile relationship between humans and computers.

Elisa D. Mekler is assistant professor in HCI at Aalto University. Her research concerns meaningful and emotionally fulfilling interactions with technology, and the development of conceptual and methodological tools to evaluate these.

Suranga Nanayakkara is an Associate Professor at the Auckland Bioengineering Institute, the University of Auckland. In 2011, he founded the Augmented Human Lab to explore creating 'enabling' human-computer interfaces as natural extensions of our body, mind and behaviour.

Josef Wiemeyer is a Professor for Sport Science with special emphasis on Movement, Training and Computer Science at Technische Universität Darmstadt, Germany. Since 1996 he teaches and researches at TU Darmstadt and his work focuses on designing and evaluation Serious Games (health and exergames).

Nadia Berthouze is Professor in Affective Computing and Interaction. Her main area of expertise is the study of body posture/movement as a modality for recognising, modulating and measuring human affective states in HCI.

Thanassis Rikakis is professor of Bioengineering and professor of Performing Arts at Virginia Tech. His research spans systems design, engineering and arts with a special focus on interactive neurorehabilitation, experiential media, adaptive learning and cyber-human intelligence.

Kai Kunze works on technology to understand ourselves better. He is an Associate Professor at the Keio Graduate School of Media Design, Keio University, Japan. He has a general love for science, hacking, making and playing with tech.

Aisling Kelliher is an Associate Professor at Virginia Tech, where she also has a joint appointment in the Institute for Creativity, Arts, and Technology and the School of Visual Art. She co-leads the Interactive Neurorehabilitation Lab at VT with Dr. Thanassis Rikakis.

Kevin Warwick is a British engineer and Deputy Vice-Chancellor at Coventry University in the United Kingdom. He is known for his studies on direct interfaces between computer systems and the human nervous system and has also done research concerning robotics.

Elise van den Hoven is Professor of Human-Computer Interaction at University of Technology Sydney and Eindhoven University of Technology, and is Honorary Professor at University of Dundee. Elise's research interests span different disciplines, including interaction design, human-computer interaction and cognitive psychology, which all come together in the research program she leads called Materialising Memories.

Florian 'Floyd' Mueller directs the Exertion Games Lab at Monash University and will bring to the workshop experience in designing systems for the motor systems that are particularly engaging, having developed theory on how interactive design can support motor movement through games thinking.

Steve Mann is often referred to as "the father of wearable computing," in recognition of his invention of the first

Tentative Workshop Timeline

- Opening
- Session 1
- Activity 1
- *Lunch break*
- Session 2
- Activity 2
- *Coffee break*
- Activity 3
- Results of the design probes session
- Discussion of future directions
- Closing
- *Evening: workshop dinner*

general-purpose wearable computer, as well as many more techniques that seem to have come from the future.

Website

The workshop web page contains more details, call for papers, link to the submission system, and accepted submissions: www.motorhci.com

Workshop Structure

The workshop will take place over one full day. Activities are planned to comprise workshop presentations by participants, context creation and future thinking activity sessions, out-of-the-classroom group exercises, and discussions. The estimated number of workshop participants is 35. A tentative timeline for workshop activities is given on the sidebar.

Prospective participants will apply to join the workshop by responding to an online form.[2] This information will help us understand the thinking, prior research, future plans, insights, and/or interests of potential participants as it pertains to motor memory in HCI. Responses will be reviewed by the workshop organizers, and selected for inclusion based on quality, novelty, and potential to engender discussion, while aiming for a balance of different perspectives.

Group activities will consist of a exercises done in groups of 7-10 people. Activity 1 will involve creating a context and a shared understanding around motor memory in HCI among the workshop group. Building upon this shared understanding, activity 2 will comprise two parts. First, groups brainstorm on three novel scenarios or ideas that focus on motor movement and memory for 20 minutes. Second, they create a 300-word write-up on each idea in 40 minutes. The third activity is also group-based, where each team swaps the generated novel ideas from activity 2 with the team on their left. Once swapped, each team goes through the three new scenarios/ideas, chooses one and picks a prototyping technique of their choice to expand on it for 90 minutes and create the following: (1) artifacts such as drawings and flowcharts to show how future technology could assist in the contexts and activities in question, (2) artifacts to showcase how futuristic technology could augment motor movements and memory. Concepts should integrate a technology element that resonates with the definitions discussed around motor memory. Presentations about the concepts will be created (e.g. as a slideshow, video, or enactment), shared, and discussed. The organizers will provide an assortment of prototyping materials including post-it notes and props.

[2] tiny.cc/jwpihz

Post-Workshop Plans

Following the workshop, we aim to conduct a hands-on design workshop on motor memory and HCI at Schloss Dagstuhl in 2020. We aim to submit an article to a relevant academic venue (e.g. ACM Interactions, TOCHI Journal) co-authored by the participants. We also plan to organize a journal special issue where our participants will be encouraged to publish. To sustain communications, we aim to use an online platform (e.g. Slack) which will be open for all those interested, and relevant details will be published on the workshop website. Finally, we will work towards conducting a second edition of the workshop at CHI 2021.

Call for Participation

The workshop *Motor Memory in HCI* focuses on how memory is tied to the sensorimotor system and embodied experiences of performing actions, a dynamic we refer to here as “motor memory.” Body movement can help us think and learn new information faster by establishing embodied representations of reality. This dynamic is also interpersonal – our own motor memory can shape how we perceive and remember others. When translated to the design of technological systems, this means that not only should we consider that we can learn and memorize motor activity (e.g. motor skills), but that we can also perform motor activity to learn and memorize new information (e.g. gesturing directions).

The workshop aims to shape our understanding of how and in what circumstances movements assist memory. Once understood, it probes the groups to think of how futuristic sensorimotor systems can be designed to augment motor memory.

To apply to the workshop, submit your responses to the questions in this google form: http://tiny.cc/jwpihz. The submission deadline is February 11th, 2020. The responses will be reviewed by the workshop organizers. Accepted authors will be notified by February 28th, 2020 and the list of participants will be posted on the workshop website. Upon acceptance, all accepted participants must register for both the workshop and for at least one day of the conference. You can contact us on hello@motorhci.com if you have any questions.

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