Final Report

Poppy the Shy Wall: A material exploration of AI body detection in the context of Architecture-Centred Interaction Design

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Abstract

This paper delves into an individual project in interaction design, specifically focusing on the question of "How might one use body movement tracking AI to improve conventional sensor-based Architectural Interactivity?". Drawing from relevant literature, it examines the role of interaction design in contemporary architecture and establishes hypotheses regarding the integration of AI in architectural interactions. Departing from a conventional two-user framework proposed by previous research, the experiment explores the possibility of replacing the second user with an AI system capable of detecting and tracking body movement. By challenging established classifications, the understanding of guidelines for effective interaction in interactive architecture is expanded. The paper highlights the research potential between the dynamics of building usage and the interaction qualities of interactive artifacts. Additionally, it questions Oh et al.'s (2014) theory of collaborative systems by introducing an artifact that necessitates kinaesthetic empathy and social skills, leading to a collaborative style of interaction between a single user and AI, rather than between two users mediated by an artifact. The results demonstrate the potential of AI in enhancing interactivity within experimental architectural interactions, thus shedding light on new possibilities in the field of user experience.

Introduction

In the context of our current digitalization era, characterized by the widespread adoption of technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and 5G, the intersection of interaction design and architecture presents numerous opportunities. These advancements have enabled practical solutions for everyday challenges in home and public spaces, such as adaptive heating, lighting, and shading, leveraging various sensor technologies. While these advancements demonstrate their value in pragmatic terms, the focus of this project diverges, embracing a more exploratory approach.

This project delves into the realm of possibilities that arise from coupling body movement interaction with otherwise inert architectural elements. A fundamental challenge in linking interaction and architecture lies in the inherent static nature of buildings. As the industrial world rapidly evolves, technologies emerge and fade away at an accelerated pace. In stark contrast, buildings endure for the long term. Consequently, this project recognizes the need to move beyond simplistic 'one-loop' reactive systems that may initially captivate but quickly lose their novelty. Instead, it aspires to establish a collaborative relationship between a system and one or multiple users, fostering richer and enduring interactions. It will explore the question “How might one use body movement tracking AI to improve conventional Architectural Interactivity?”.

Context

This scholarly report delves into the field of interactive architecture, presenting a knowledge contribution within this domain. The project aims to unravel the intricate connections between interaction design, architecture, and interactive art, shedding light on the blurred boundaries that unite them. The specific objective is to investigate the integration of AI technology for body movement detection within interactive architectural experiences.

By going beyond the conventional applications of interaction in architecture, which often rely on rudimentary sensors or scheduling mechanisms, this exploration seeks to challenge existing practices and draw inspiration from the innovative landscape of interactive art. It aims to contribute to the ongoing discourse surrounding interactive architectural design, pushing the boundaries of what is currently understood and opening new concepts for exploration and innovation.

The project's context is rooted in the field of interactive architecture. It presents a comprehensive understanding of research and design endeavours, aligning them with the broader objectives and expectations of the discipline. The work aims to contribute to the advancing field of interactive architecture through the integration of AI technology and the exploration of new possibilities for engaging and immersive architectural experiences.

Methods

This paper’s aim is to explore the growing topic of interaction design in the context of architecture. Its pursuit lies in the exploration of new possibilities AI technology affords in the goal of creating deeper, more engaging interaction between a user and their built environment. Given the expanding nature of interactive architecture and AI technology respectively, the main overarching method of research this project is anchored in is material exploration through prototyping.

In order to achieve this, the experiment uses the design process “Double Diamond” format put forth by J. Pedersen (2022). The end goal of this project is material exploration to explore the boundaries of use of AI within the defined sector of interactive architecture. This specific design process is set up with a research, a definition, a development, and a delivery phase to of first gaining knowledge in interactive architecture to subsequently foster an informed ideation and implementation phase. The context of this research limits the ability to truly explore the material and tinker with it, as Pedersen (2022) suggested in the context of material exploration, but instead draws from experience designing with AI body detection and seek to grasp what it means to be designing interactive architecture. Additionally, Pedersen suggests a design process which incorporates experience/reflection as a fourth step, but in the frame of this experiment, since the goal is to explore the boundaries of interaction in architecture by integrating AI technology in an artistic form, the artefact isn’t necessarily prototyping for testing purposes, but rather evaluating a base concept by implementing it into a prototype which manifests itself as means to create a frame for discussion on the topic. Therefore, the ‘deliver’ format works better for the needs of this project.

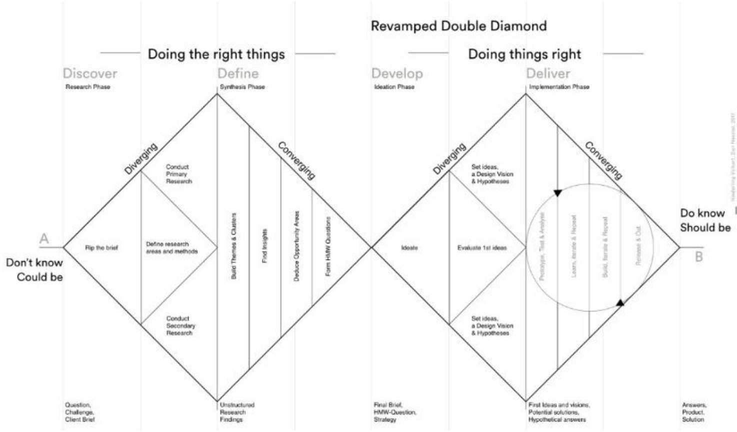

Figure 1: Enhanced Double Diamond Method from the course by J.Pedersen

The method begins with an extensive research phase, with an analysis of the current landscape of interactive architecture by reviewing relevant research papers and analysing projects that align with the essay's scope. It was necessary to assess the topic in order to gain a better understanding of the current state of the field.

Once a substantial body of information is gathered, the synthesis phase commences, where a comprehensive list of design characteristics pertinent to conceptual interaction in architecture is set up. This process enables a deeper comprehension of the state of interaction design within conceptual, exhibition-focused architecture and helps identify design opportunities based on the research material. Additionally, this stage involves delving into AI body detection within the context of interactive art to supplement the limited available literature on AI movement tracking specifically in architecture.

The subsequent phase, ideation, focuses on the methodical process used to create a concept. It describes how an informed concept-generating brainstorm was carried through in order to generate initial potential ideas for the artefact’s physical form, and what are the qualities that drew me to choose this idea in particular. The next step is about defining the project’s influences through a “bodystorming” activity, where the application of the design boundaries relative to the desired user experience and relating the artefacts qualities to the design characteristics established.

The selected project's realisation constitutes the fourth stage of the process titled 'deliver.' This phase centres around the prototyping process as a means to interrogate the research material. Within this section is provided a justification for the design choices made in relation to the artifact, as well as insights into the coding and construction processes. This critical evaluation of design decisions enables a reassessment of the research findings, culminating in a comprehensive wrap-up and conclusion.

Design Process

Research

Interaction Design x Architecture

The intersection between Interaction Design and Architecture was the starting point for this individual design project. Although there are already innovative systems being integrated into new buildings, such as smart air ventilation systems and door security systems, the research on interactive architecture is arguably still in an explorative phase. Most available literature focuses on individual experiments rather than the globality of the subject.

One key resource used in this report is a paper by Mikael Wilberg (2020). Wilberg's definition of the intersection of interaction design and architecture provided a foundation for new hypotheses. He states that "Interaction design is increasingly about embedding interactive technologies in our built environment; architecture is increasingly about the use of interactive technologies to reimagine and dynamically repurpose our built environment" (Wilberg, 2020). Wilberg's paper is the initial trigger for this paper's research question.

Given the scarcity of academic literature about more meta, globally applicable principles/guidelines for designing in the context of interactive architecture, particularly in the context of using AI body movement detection as a user input medium, there is a significant prototyping opportunity to explore. While Wilberg briefly mentions AI technology in his paper, this paper's research process looked into the more developed field of interactive art to find research papers that could fuel this project and move away from typical solution-centred interaction in architecture. One must also acknowledge the work of Gordon Pask, an early proponent of cybernetics, who played a significant role in the study of interaction in architecture. His work and the concept of cybernetics have been referenced in various research papers on the subject.

Typologies of Architectural Interactions

A paper by Oh, Patrick and Cardoso LLach (2014) from Pennsylvania State University provided typologies of architectural interactions and their analysis of recorded attempts at such projects. Their work categorized architectural interactions into three types based on the characteristics of information flow between the artifact and its user(s). These categories are single loop systems, coupling systems, and collaborative systems. Understanding these classifications helps in identifying which type of project to focus on and what kind of interaction would be exciting and repeatable.

The first type, single loop systems, is characterized by one-directional data flow, where input parts dominate output parts. Researchers determined that "Namely, there is a clear distinction between the input and output, with the input parts dominating the output parts" (Ashby 1957, as cited in Oh et al., 2014, p.2). This form of interaction is reactive rather than interactive (Haque 2006, as cited in Oh et al., 2014, p.2) and may not provide the opportunity for creating exciting and repeatable interactions.

The second type, coupling systems, involves two-directional information flow, aiming at creating a symbiotic relationship between the user and the artifact. Real-time feedback from the artifact allows users to gain nuance and control in operating it. "The interacting agencies construct a common outcome through their mutual reconfiguration"(Oh et al., 2014). Haque (2007, as cited in Oh et al., 2014) formulates it this way "humans and devices and their shared environments coexist in a mutually constructive relationship" (p.3). This type of interaction is typically associated with early cybernetics.

The third type, collaborative systems, that Oh et al. (2014) suggested to take into account, relies on social interaction between at least two humans to function. The artifact serves as a catalyst for human-to-human interaction, enabling mutual input and feedback between the parties involved. However, it is arguable whether collaboration is essential for an interaction to change, as suggested by Chen et al. (2020) in their research on human-machine integration.

Design Considerations

A paper by researchers from Newcastle University, Northumbria University, and Georgia Institute of Technology titled "Interioractive: Smart Materials in the Hands of Designers and Architects for Designing Interactive Interiors" (Nabil et al., 2017) provided insights into design characteristics and considerations for interactive interiors. These considerations include discoverability and legibility, revelation and coherent dynamics, and spatio-temporality. These attributes help in situating the interactions that future prototypes may offer and can be used as evaluation criteria or constraints.

	Fully Discoverable	**Undiscoverable** *(Hidden Interaction)*
Fully Legible	Obvious and Consistent	Hidden and Playful
Not Legible *(Hidden Logic)*	Spatio-Temporal and Autonomous	Mysterious and Magical

Figure 2: Combinations between ranges of discoverability and legibility of an interactive interior space by Nabil et al.(2017)

Nabil et al. (2017) first consideration is discoverability and legibility, which they group together. Discoverability refers to how quickly users can uncover interactive elements within a space and how an interior unfolds as users start interacting with it. Legibility, on the other hand, focuses on establishing a clear connection between cause and effect in the interaction. The researchers argue for the strong relationship between discoverability (clarity of how to interact) and legibility (clarity of why it reacts). They have developed a diagram to illustrate the expected effects of interactions that are either discoverable or not, and legible or not. Lenz et al.'s (2013) work also touches on similar interaction attributes, such as apparent vs. covered for discoverability and direct vs. mediated for legibility.

The second consideration put forth by Nabil et al. (2017) is revelation and coherent dynamics. They emphasize the intriguing aspect of an interactive interior space that can conceal hidden appearances and personalities, gradually revealing them through user interaction. While the concept of revelation shares similarities with discoverability, it integrates an element of time, highlighting how the interior unfolds once it has been discovered. Coherent dynamics can be paralleled with Lenz et al.'s (2013) fluent vs. stepwise interaction attribute, combined with the fast vs. slow metric. Nabil et al.'s description of coherent dynamics values the gradual unveiling and real-time evolution of hidden elements within the interactive space.

The final consideration identified by Nabil et al. (2017) pertains to spatio-temporality. They assert that an actual immersive experience in architectural interactions incorporates the dimension of temporality as a key player in user spatial engagement. This principle is particularly intriguing as it doesn't have a direct equivalent in Lenz et al.'s (2013) table of interaction attributes. The researchers suggest that by designing interactive spaces that can change over time or possess autonomy, the environment can communicate self-expression through unfolding interactions. This concept leverages the human dynamics of building usage to create an evolving relationship between the project and its user. It also raises an intriguing hypothesis regarding the potential of AI to create environments that effectively communicate self-expression.

A noteworthy aspect of Nabil et al.'s (2017) analysis is their remark on scalability. Given the architectural context, scalability holds particular relevance as designs may need to accommodate large spaces or surfaces. This consideration should be kept in mind for future ideas, especially as the presentation of the artifact will require it to be compact and portable.

Integrating AI

Another relevant paper on AI integration in interactive art, "Methodological Approach to Create Interactive Art in Artificial Intelligence" by W. Chen, M. Shidujaman, J. Jin, and S.U. Ahmed (2020), explores the potential of human-machine integration in creating interactive art. This research provides insights into the methodology and process of incorporating AI technologies into the creation of interactive artworks, which can be valuable in the context of interactive architecture.

"With the rapid development of AI technology, machines will become more and more intelligent, and human-machine integration is imperative. The so-called integration is that human and machines are interwoven with each other. On the one hand, AI media, as an extension of human senses, limbs and thinking, has expanded human physical fitness and intelligence, and can help people perform large-scale calculations, inferences and judgments, completing tasks impossible for the human brain; on the other hand, human have also helped AI gain perception and cognition."(Chen et al., 2020, p. 28).

The researchers clearly acknowledge the evolution of AI and its potential in terms of increasingly being interwoven with human interaction. This raises a paradox concerning collaborative systems: If the second human necessary to a collaborative system (Oh et al., 2014) were to be replaced by 'sentient' AI (Chen et al., 2020), could one still consider it a collaborative interactive system?

Case Studies

Additionally, this research phase delved into various case studies of interactive architectural installations and projects that demonstrate the integration of technology and user interaction. These case studies offer inspiration and insights into the design possibilities and challenges associated with interactive architecture.

One notable example is "The Cloud" by Carlo Ratti Associati, a project that transformed an ordinary public space into an interactive environment. The installation consisted of a canopy of responsive umbrellas that opened and closed based on weather conditions and the presence of people. This project exemplifies the potential of interactive architecture to engage users and create dynamic and adaptive environments.

Another interesting case study is "Senselab at the Nanyang Technological University" by M. Kaltenbrunner, D. Thiel, and J. Bongard. This project explored the integration of sensors and responsive materials to create interactive and immersive architectural spaces. The Senselab demonstrated the possibilities of using technology to enhance the sensory experience of architecture and create engaging interactive environments.

This paper's research phase also explored the realms of interactive art, particularly Daniel Rozin's Wooden Mirror among all his fascinating work. Rozin's Wooden Mirror shares similarities with this paper's research in terms of ideas, although approaches differ. His innovative method involves creating flat surfaces, such as floors or walls, using ultrasonic sensors to generate real-time pixel art. Each pixel is a tiltable square surface that can reflect or darken, resulting in a binary feedback system. Rozin's approach of manipulating light and utilizing individual surfaces to create dynamic visual effects is both inspiring and relevant to the exploration of interactive architecture. His work serves as a notable reference in the field and provides valuable insights into the use of technology to create engaging and visually captivating interactive installations.

Synthesis

Considering all the research and case studies, several relevant design considerations have been identified for this design project. These considerations include:

- Challenge classical Architectural Interaction: Staying away from pragmatic, solution-based design and focusing on the experimental aspect instead (Wilberg, 2020). The design will consider the contextual relevance of the architectural space, taking cues from Oh et al. (2014). This involves understanding the purpose and specific requirements of the environment to ensure that the interactive elements seamlessly integrate and enhance the overall experience and functionality of the space.
- Create a Collaborative Interaction with AI: The project aims to explore the integration of AI technologies, drawing inspiration from Chen et al. (2020) and Fogtmann et al. (2008) to challenge Oh et al.'s (2014) classification of collaborative systems. By leveraging AI algorithms, such as body movement detection, the design seeks to enable collaborative interactions between users and the AI controlled architectural environment. This integration of AI aims to engage the user in a bodily interaction and foster kinaesthetic empathy towards the space.
- Interaction Design Principles: The project will incorporate interaction design principles inspired by Nabil et al. (2017) and Lenz et al. (2013) to ensure discoverability, legibility, revelation, and coherent dynamics in user interactions.
- Scalability and adaptability: Building upon the insights of Nabil et al. (2017), the design will take into account scalability and adaptability. This consideration is crucial for accommodating different architectural contexts and user scenarios, ensuring flexibility and future expansion possibilities. The design should remain adaptable to evolving user needs and technological advancements.

Ideation

Brainstorming

In aims to generate ideas for new concepts concerning the artefact, a sketch-based brainstorm has been carried out. This brainstorm consists of five one-minute sketches using the research guidelines as a reference. The concept should focus on interaction design within conceptual architecture, specifically integrating AI body detection in a more engaging manner compared to traditional systems and sensors used in interaction design in architecture. The goal is to integrate the technology directly into architectural elements like walls, floors, or facades, rather than creating standalone artifacts that lean more towards interactive art. Considering the limited time, resources, and financing available for this individual design project, as well as constraints linked to the exhibition where the artefact is presented, feasibility and scalability are also key considerations. Additionally, the aim is to omit screens and picture projections as output and instead create a tangible artefact for the presentation and exhibition where the concept will be evaluated.

With that in mind, the brainstorming session bore five different concepts relative to three different ideas. After careful consideration of the attributes of the five concepts, it has been deliberated in favour of *The Wall with a Personality*, and here's why: from a standpoint of Oh et al.'s (2014) classification, the Shy Wall has enough room left on the behaviour programming side to create an interaction which ends up playing with the ambiguity of collaborative systems by bringing AI into the equation to replace the second user in the collaboration. If one were to give the AI emotions and moods, as well as a way to communicate those back to the user, then the opportunity to challenge Oh et al.'s (2014) established classification would be worthwhile.

Looking into Nabil et al.'s (2017) considerations, from a perspective of discoverability and legibility, what stood out positively about the project is that it has the potential of throwing a curveball to the user. One might think that the wall is inanimate, but it's hiding. From a standpoint of revelation and coherent dynamics, the fact that it leaves clearance to be creative in the programming aspect is a positive aspect. From a standpoint of spatio-temporality, it allows for flexibility because the personality of the AI is variable at wish, so this project qualities will depend on whether the integration of a 'sentient' AI (Chen et al., 2020) is executed in a clever way.

On the scalability, this is the project which would work best, because it can be scaled down without much loss, whereas the others would conceptually still work, but be small elements of a potentially bigger system. For presentation purposes, having a tangible artifact is also preferrable. The Shy Wall just seems technically more feasible for cheaper cost because of the easy access of the necessary building materials.

Bodystorming: What kind of personality does the artefact need?

A bodystorming with five candidates has been organised with the purpose of assigning a personality to the concept. The candidates represent the largest group of stakeholders, the general users of a building. The individuals have been selected among my surroundings but did not have any prior knowledge of the experiment which is critical to the test. Being familiar with the organizer of the experiment allowed the participants to feel at ease in participating in the experiment.

The experiment is set up as follows: A test subject is put in front of a laptop with Jens Pedersen's body detection code running. The subject can see the camera feedback on the screen in front of them. To distract the test subject, colourful dots were placed on random body parts on the camera feed. Next to the screen is a small 3,5V lightbulb, which is controlled with two batteries and a wire, unknown to the testers. The testers are led to believe that the lightbulb is linked to the AI programme, and if the body language matches, the light goes on. The subject is confronted with a choice between three cards, each with a different behaviour written on it: *Confident*, *Shy*, and *Upset*. These were chosen for their commonly understandable body language cues.

The user pulls a card and must act in front of the screen to provoke the light to turn on. This test is set up in order to observe the change in body language in the user, as well as a categorisation of different types of behaviour that were linked to their respective prompts. Once the individual experiments were done, each candidate was asked to reflect on the three experiences they took part in.

The subsequent results of the experiment showed that overall, the test users had rather similar ways of behaving to the same prompt. For instance, *Confidence* provoked the test subjects make broader arm movements, speak louder, place their hands on their hips, and similar gestures. In essence, these cues drive the user to make themselves bigger, louder and stronger in appearance. The reaction to *confidence*, shared similarities to the reactions to the *Upset* reactions, focusing purely on the body language.

The *Upset* experiment was more diverse, because while three testers became loud and gesticulated even more drastically and faster than in the *Confident* test, the two other subjects gave the artefact the silent treatment, one staring straight at the screen, the other turning away and ignoring the screen. It was more challenging to get a globally applicable *Upset* body language, because people have diverse ways of expressing their anger, some have their eyebrows raised when they're upset, the others have them arched down in the middle.

The *Shy* experiment appeared to draw the most focus from the test subject. The users began whispering, and two subjects reduced their silhouette by covering up their eyes with their hands, while two crossed their arms low, and one crossed their arms to the shoulders. Eye contact was reduced for four of the candidates, while one of them kept eye contact but with a low, sideways chin. The candidates all moved slower in the *Shy* experiment compared to the two other behaviours. One of the subjects noted that "the difference between the two other behaviours is that when shy, the space is less crowded with different bodily expressions, but instead with minimal body language it is possible to express that state of mind.

Overall, the *Shy* experiment accounted for the most recognisable, easily applicable body language cues, considering the necessities of this paper and the exhibition that's ahead. Instead of expecting a lot of gesticulation from the user, the minimalistic approach appears to be the more easily applicable in or context.

Concept

Challenging conventional Interactive Architecture

The concept for the artefact revolves around giving a personality to a wall. The goal of this concept lies in a desire to challenge the static nature of architectural elements, particularly walls, which contrast with the dynamic nature of interaction design. While movable partition walls exist in the building sector, they lack animation. The idea is to give the wall a personality and the ability to communicate and express certain types of behaviours in reaction to the users input. From an AI perspective, this interaction would be more engaging and profound, going beyond simple responses to gestures or human presence. The goal is to leverage AI to create a novel user experience that sets itself apart from conventional sensors in current application in buildings.

The concept for the tangible artefact draws inspiration from an art exhibition at Tate Modern that seen many years ago. An artist presented, among others, a roughly DIN A3-sized picture that was cut in vertical strips of one centimetre each, as if it went through a paper shredder. The strips were then rearranged in a manner where each second strip was removed and put in a second frame. Once rearranged, it produced two perfectly legible pictures out of one, each containing only half the original information.

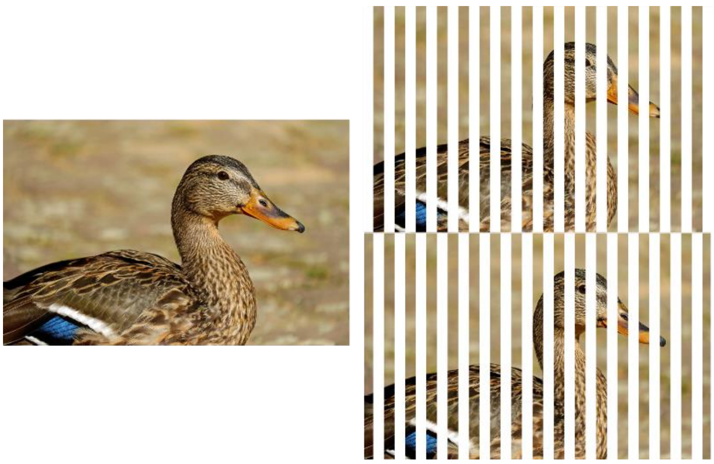

Figure 3: Approximate reproduction of art seen at Tate modern, as it was impossible to find back this artist all these years later.

The chosen sketch that emerged from the brainstorm shows a system, two different images are collaged vertically side by side on a wall or partition element. A comb-like frame covers either one or the other picture, giving the possibility for exploring the aspects of discoverability and revelation suggested by Nabil et al. (2017). Additional iterations of the sketch led to the concept of adding a

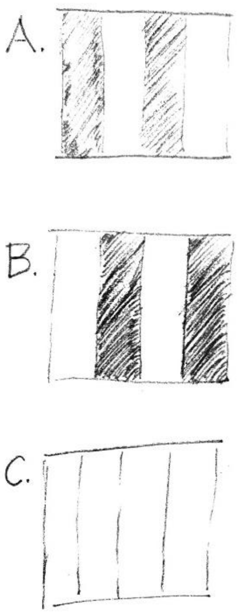

Figure 4: Three modes of display

second comb frame that either aligns itself with the first comb or doesn't, in which case it hides both pictures. This would allow for a third state for the artefact, which would help break away from the binary feel of the original concept.

Poppy the Shy Wall's main focus on the digital side is to explore sensing capabilities by using AI body detection to expand the possibilities in terms of Architectural Interactivity. As previously stated, the current state of sensor interactivity in the domain of architecture is limited to technical solutions for everyday home or public space problems, such as adaptive heating, lighting, and shading (Wiberg, 2020). While these solutions make sense for everyday use, they also have their limits in terms of pragmatism. The opportunities AI body detection opens up in that context are what this prototype aims to challenge. Instead of just sensing, it has to engage the user by affording a system that expects body language to serve as a medium of communication between the user and the artifact. The shy personality of the wall provokes the user into a conversation through their body language and output behavior, respectively. This aligns with the idea of kinesthetic empathy mentioned in Fogtmann et al. (2008).

Following the findings of the bodystorming session, the storyboard base for the wall's personality loosely mimics a 7-year-old cat named Poppy. Poppy is distrustful of head-on approaches and feels uneasy with eye contact. One must to slowly approach her leading with the index finger and let her do the last 10cm to give one's hand a head bump of trust. The project gets its name from here.

From a technical standpoint, an Arduino Micro can be used to enable the manifestation of output through stepper motors, servos, etc. While the implementation details are not the primary focus at this stage, the feasibility of coding three display modes (A, B, and C, figure 7) is promising. This concept offers flexibility in terms of input, which needs further exploration.

Meaningful AI Integration

In the context of Poppy, the integration of AI technologies would aim to create a subtle and nuanced interaction experience. By leveraging AI algorithms, particularly in the analysis of body language and gestures, Poppy would be able to interpret and respond to users' movements in a sophisticated and refined manner. One of the main advantages of using AI in comparison to ultrasound sensors, for example, lies in its ease of use and flexibility. It greatly facilitates the design of increasingly complex inputs and output behaviours as well as the potential for reinventing an artefact's behaviour regularly of dynamically.

The AI algorithms would be designed to capture and interpret the user's body language, allowing users to communicate with Poppy through their physical gestures and movements. Rather than relying on explicit and overt interactions, the installation would respond to the delicate cues and signals conveyed through body language.

For example, a user's hand movements or body positioning could evoke a specific response from Poppy, such as a slight adjustment in the positioning of its elements or a subtle change in lighting. These responses would be designed to convey a sense of understanding and connection between the user and the installation, creating a more immersive and intimate experience.

The finesse of the AI-enabled interaction would lie in its ability to interpret and respond to the nuances of users' body language, adding depth and subtlety to the communication between the user and Poppy. It would enable users to express themselves and engage with the installation in a non-verbal and intuitive manner, fostering a unique and personal connection.

By incorporating AI in this way, Poppy would provide an opportunity for users to explore a new mode of interaction that goes beyond traditional input methods. It would allow them to engage with the installation in a more intimate and expressive way, adding finesse to the overall experience and enabling a deeper level of communication through body language.

The interfaceless nature of Poppy becomes a central aspect of the design, encouraging users to focus on the perception their own bodies, where the devices output is aimed at becoming a validation. As a user approaches to and interact with Poppy, they become active participants in the creation of the experience. Subtle nuances in gestures, movements, body language, and proximity to the installation trigger responses that further engage their senses and deepen their connection to the artwork.

Poppy's interactivity is not limited to traditional modes of engagement such as touch or gesture recognition. It seeks to create an immersive experience where users perceive and respond to the installation in unexpected ways. The non-tangible nature of the behavioural aspect of the installation opens up for possibilities for incorporating technologies that enable users to interact through body language, subtle movements, or even their emotional states, adding layers of nuance and depth to the interaction.

Through this embodied interactivity, Poppy aims to create a novel experience for users, blurring the boundaries between the physical and the digital, the self and the installation. By engaging users in a unique manner in conjunction with AI, Poppy becomes a catalyst for introspection and a deeper understanding of one's own presence within a space.

In summary, Poppy's design revolves around the concept of unexpected interactivity and the embodied nature of the installation. It challenges traditional notions of interaction by inviting users to passively engage with the artwork, figure out that their actions have consequences on the artefact, and then perceive their own bodies in relation to it, and explore the boundaries between themselves and the installation.

Design Attributes

Poppy's design aims to provide an unexpectedly interactive experience for users. At first glance, it may appear as a peculiar wall, intriguing visitors and piquing their curiosity. The initial lack of explanation as to how to interact doesn't invite users to actively engage with the installation. Instead remains hidden and may only manifest itself when the environment is quiet, creating a sense of revelation and mystery when the user finds out there's more to this wall than expected.

The focus is on creating interactions that are intriguing, mysterious, and subtly revealed to users. While the principles of discoverability and legibility still apply, they would manifest in a different way. Instead of immediate clarity, the design would emphasize creating an aura of curiosity and intrigue, prompting users to explore and engage further.

Discoverability, in this context, would involve designing subtle cues and hints that invite users to interact with Poppy without explicitly revealing the outcome. The installation might feature elements that subtly respond to users' presence or gestures, encouraging them to discover more about the hidden possibilities and interactions within the space.

Legibility, on the other hand, would revolve around creating interactions that have a sense of purpose and coherence, even if their exact outcomes are not immediately apparent. Users should feel that their actions have an impact on Poppy, even if the full extent of the interaction remains mysterious. The cause and effect relationship might be more nuanced, requiring users to observe and interpret the subtle responses they receive.

Revelation would play a crucial role in the design of the prototype. The interactions could gradually unveil hidden elements or trigger unexpected transformations, building intrigue and a sense of discovery as users engage with the installation. The revelation might occur over time, as users spend more time interacting with the space and uncovering its secrets.

Ultimately, the goal of incorporating these adjusted interaction design principles is to create a captivating and enigmatic user experience with Poppy. The interactions should pique users' curiosity, provide a sense of agency, and offer a glimpse into the hidden possibilities of the installation.

Scalability and adaptability

Scalability and adaptability are crucial considerations in the design of Poppy. The installation is conceptualized to accommodate different architectural contexts and user scenarios, ensuring flexibility and the potential for future expansion. By considering these aspects, the goal for Poppy is to remain adaptable to evolving user needs and technological advancements.

The design of Poppy allows for scalability, meaning that it can be adapted to different sizes and proportions within architectural spaces. Whether installed in a small intimate gallery or a large open exhibition hall, Poppy's design can be adjusted to suit the specific spatial requirements. This scalability ensures that the installation can be experienced and appreciated regardless of the architectural context, maximizing its potential impact.

Furthermore, Poppy is designed with adaptability in mind. As user needs and expectations evolve over time, the installation can be modified and expanded to accommodate these changes. The design framework of Poppy allows for the integration of new technologies, functionalities, and interactive elements, ensuring that it remains relevant and engaging in the face of technological advancements.

Additionally, Poppy's adaptability considers the changing user scenarios and experiences. The installation can be tailored to different user demographics, ensuring inclusivity and accessibility. Whether it is experienced by individuals, groups, or diverse communities, Poppy can be designed to accommodate various modes of engagement and participation.

This design ensures that its applicability extends beyond the initial implementation. The design allows for the integration of new features, behaviours, and growing relevance of AI technology, enabling the installation to evolve alongside the changing landscape of architectural interaction. For the needs of this project, it is naturally beneficial to focus on one type of scenario as a proof of concept.

Implementation

Coding shyness traits

By basing the code on the existing body detection AI code from Jens Pedersen in the Interactivity course it creates a solid foundation to start building towards the objectives. The objectives are the following: give three shyness attributes to the code, which include disliking eye contact, jerky movements, and the prospect of being touched by someone. In parallel, it is necessary to set up the Arduino code and the servos for the artifact. Finally, NodeJS is used to assemble the two sides of code.

The opportunities AI body detection open to us in that context are what is being reached for in this prototype. Instead of just sensing, the prototype strives to engage the user in an attempt to create a system that expects body language to serve as a medium of communication between the user and the artefact. The shy personality the wall has provokes the user into a conversation through their body language and the output behaviour respectively. It corroborates with the idea of kinesthetic empathy by Fogtmann et al. (2008).

Detect head-on eye contact

Using the 3D detection code, the axes x, y, and z originate from the hips of a person in the camera frame. One of the impactful features of this AI is its ability to estimate the rough locations of hidden body parts. This can be used to detect eye contact by estimating the position of each ear, even if behind a turned head. The idea is that when facing the camera, the ears are inevitably located farther from the center of the Y-axis of the body. If the position of either or both ears in relation to the eye of the same side of the head is no longer true, that means the person is not facing the camera head-on anymore, which is what we're looking for in our Shy Wall's personality. Therefore, if [R or L Ear Position X] < [R or L Eye Position X], it indicates that the user is not facing the camera head-on, and the Wall trusts them. The use of "sliding windows" helps make the readings less jittery by taking the last x amount of read values and providing a constantly updated average. This allows for adjusting the duration of eye contact and the sensitivity of the response to avoid false alerts caused by jittery body detection readings rather than jittery users.

Detect jerky movements and set up a threshold

The body detection AI code includes a pre-existing body parts speed detection sketch, which allows tracking of the estimated speed of different body parts present in the frame. To detect jerky movements, the average speed of the shoulders and wrists are measured. The shoulder tracking captures general body movement and rotation, while the wrist tracking represents the perceived dangers of jittery arm movements. This implementation enhances the interaction using the 3D tracking capabilities of the AI body detection code. The code tracks the average speed of the shoulders and wrists to detect jerky movements, as these represent the perceived dangers of fast and jittery arm movements. By quantifying the speed of body parts, the system can discern what constitutes a threatening jerky movement and adjust the response accordingly.

Detect the final approach and revelation

The code requires the user to slowly lift one hand and approach the frame. If the user holds the position without violating the other criteria for a set amount of time (twelve seconds), the code considers the user trustworthy, and the secret picture is revealed. The implementation includes timers and conditions to ensure a combination of trust conditions is met simultaneously. The hidden aspect of the artefact is meant to create an experience which would potentially take weeks for a user to figure out. It would be a well-guarded secret that only few would discover. This way, after a few weeks of repeated use of a space, a user would "have the privilege" of finally seeing Poppy reveal itself, while all the others in that building haven't.

Execution

For the execution of the final design, the prototype's scale was determined to be DIN A2 prints, which is large enough to showcase the interaction but still portable and convenient for printing. The mechanism of the prototype involves two racks of laser-cut vertical lines that slide over each other using servo motors. The racks cover or overlap each other's gaps, revealing or concealing the underlying image. The mechanical logic ensures that the existence of the second drawing is not revealed while the device slides around the racks, maintaining a sense of revelation and coherent dynamics.

Figure 5: Sketchup initial design

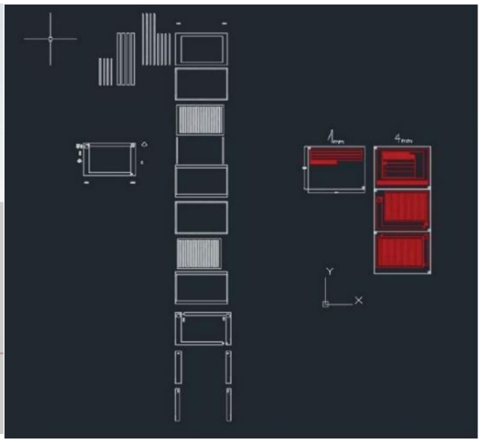

Figure 6: 2D CAD for the laser cutter

Poppy's meant to be ambiguous in its function and behaviour by tricking the user into thinking it is a *reactive, single loop system* (Oh et al., 2014), or one might even mistake it for a *conversional system* because of its seemingly two-directional information flow between the artefact and a user, but instead it is an attempt to provoke a discussion around the idea that given the role the AI has in this project, it's closer to a *collaborative system* where one of the two minimum humans Oh et al.(2014) identified as necessary for that type of interaction is replaced with a machine with "emotions".

An aspect of the prototype which is meant reinforce the feeling of personal relationship with a user is the way the racks make it that the users are required to stand right in front of the picture. If one were to stand at an angle, the depth of the gaps through which they're supposed to see the picture would not allow them to see anything. This is also good on a more pragmatical point because it forces the user in front of the artefact, thus in frame for the movement camera.

Figure 7: Final Prototype

From the front, all mechanism is hidden, there are no apparent screws and all the elements the user isn't supposed to see are hidden on the backside of the frame, which blurs the discoverability aspect Nabil et al. (2014) put forth in their list of consideration, which is desirable given that this artefact is aiming at feeling ambiguous to the user.

Visualisation of final prototype including Video Demonstration

https://berch730.wixsite.com/journal-christophe/post/studio-ii-poppy-the-shy-wall-gif

Design Evaluation

In the design evaluation workshop, three architects interacted with the project. At that time, the team of three was preparing a candidature for the Venice Biennale of Architecture. Given the context of this experiment, they were fitting candidates due to their interest in the research. They were selected because they represent a main stakeholder for this project, i.e., those who might be interested in designing with this technology, instead of being its consumer. (Note: The interviews were conducted in French and translated to English.)

Before explaining the project, they were asked three initial questions. After a brief explanation of the project, the architects interacted further with the object. They were subsequently asked two more questions. The tests were carried out with each candidate separately to avoid cross-contamination of ideas.

The architects' initial responses varied, with interpretations ranging from a picture frame to a drying rack. Regarding the artifact's behaviour, they noted seeing movement but were unaware of the no eye-contact rule until it was discovered by one of the participants. After being informed, the users went through a second round of trials and provided feedback. Their approaches changed, with participants moving slower and more carefully. While some architects felt that collaboration was lacking due to the hidden aspect, others identified cause and effect between themselves and the artifact, although they couldn't describe the mechanism of the interaction. Finally, after the questions were done, the correct sequence of interactions was revealed to the candidates. They all were able to make it work with some directions.

Overall, the implementation and design of Poppy the Shy Wall aimed to create an interactive architectural element that challenges traditional notions of interactivity and explores the potential of AI in sensing and responding to human body movements. The combination of body language, hidden interactions, and mysterious revelations created too much confusion for users. An ideal process would've involved more prolonged participation, as the evaluation team didn't spend enough time with the artefact to engage with it meaningfully and the object is designed to stay potentially hidden indefinitely to some users given their general demeanour. In a way, that proves that the temporal quality of our artefact worked as intended, as no one managed to reveal the picture by themselves in the short time they tested the design.

Following this round of individual questions, a discussion around a table with the architects has been organised. The first prompt for discussion was directed at the current status of interactive media in Architecture. The essence of this talk revolved around the fact that Architecture is traditionally bound to pragmatic goals and that consequently the use of interactivity rarely goes beyond simple solutions to simple problems. On the other hand, the architects noted that projects with, for example, dynamic facades exist, but that they were not necessarily interactive in the sense that they didn't require user involvement in order to work. They also noted that technology-driven interactive architecture is an emerging topic in experimental architecture and exhibitions. According to the experts, the use of Augmented Reality (AR) and Virtual Reality (VR) has become increasingly common in architecture offices when presenting a project to a customer, although they have never used it themselves.

Next, the architects were asked to describe their experience with the artefact. They all agreed that it was challenging to initially understand how to interact without any prompt, but that it made sense now that they are aware of the spatio-temporal intention of the design. The team explained that the most interesting part of the experience was the introspective aspect of it, because it made the user focus on their own perception of their position in relation to their surroundings as means of interacting with the object, which conceptually bears some significance in terms of architecture, the art of creating human-scaled spaces. The team agreed that while the prototype itself had its limitations in terms of pragmatical use, it did raise a discussion about finer possibilities to engage the user of a space. They acknowledged that the use of body language to engage with technology is off-putting at first, but that the fact that it was possible to recognise body language cues with a simple laptop is impressive. Nevertheless, they added that for conceptual purposes, like an exhibition, the idea of using a user's own body as means of communication with its space was effective. Another critique underlined was that the artefact does not drastically impact the environment spatially. Given that the artefact is a surface modifier rather than a modifier of space removes some of the architectural identity of it.

Results and Discussion

The results of this research shed light on the question of "How might one use body movement tracking AI to improve conventional sensor-based Architectural Interactivity?" through material exploration. The final prototype not only addresses questions regarding the role of AI in the context of architectural interactions but also provides valuable insights into user dynamics and the potential for spatio-temporal interactions to enhance architectural interactions.

One key aspect that was explored is the possibility of collaborative systems (Oh et al., 2014) being one-user-only, replacing the second collaborator with AI, as proposed by Chen et al. (2020). This AI system reacts to body language and relies on kinesthetic empathy (Fogtmann et al., 2008). Although the principles used in the AI system remain rather simple at present, they represent a modest step toward the hypothesis concerning the relevance of AI in the context of social systems in architectural interaction. A debate remains as to whether the introduction of AI in the manner this paper did, within the artifact, compensates for the absence of a second user in a collaborative project or if AI-mediated projects require a new category of its own. An attempt to approach the collaborative aspect with nuance, asserting that with AI, it is increasingly easy to create an interactive collaboration between a computer and a user. In doing so, this paper explored a project that treads on the edge of the categorization established by Oh et al. (2014) in their research. While most functions displayed by this artefact could theoretically be recreated with other sensors like ultrasonic sensors Rozin used, the advantage body detection AI provides lies in the ease of use and flexibility it offers, even for novice programmers.

Moreover, this paper established a connection between user dynamics in buildings and the potential for spatio-temporal interactions to be enhanced through the use of AI, as demonstrated by Nabil et al. (2017). Leveraging this opportunity, I have created an artifact designed to gradually build a relationship between itself and the user.

While the interaction with the artifact aligns with the findings and hypotheses of the research process, it is important to note that the artifact may lack some depth once its hidden face is uncovered. However, during tests with our three architect candidates, the experiment revealed that the artifact was not straightforward to decipher. The fact that it requires time and effort for the final, hidden interaction to occur adds a certain level of intrigue and repeatability to the experience. If the interaction were too easy to figure out, it would diminish its impact. Furthermore, considering the limited timeframe for presenting this artifact, it adequately fulfils the requirements of this project. The goal was to create a discussion about the potential uses of AI in architecture, and this project managed to spark some ideas and solidify the understanding of the main points of interest relative to the project's goals.

During the presentation at the end of the course, the project received positive feedback, and the jury appreciated the concept. However, it is worth noting that one of the jury professors had coincidentally worked on a project with a similar end result, albeit focused on interactive art rather than architecture specifically. The feedback received from the jury has already been taken into account in the paper.

In addition to these findings and reflections, it is important to discuss the limitations encountered during the research process. These may include technical constraints, potential biases, or areas that require further investigation to fully understand the implications of integrating AI into architectural interactions. By acknowledging these limitations, we can provide a more comprehensive understanding of the scope and potential challenges of the research.

In summary, this research has provided valuable insights into the role of AI in architectural interactions, user dynamics in buildings, and the potential for spatio-temporal interactions to be enhanced through AI. While acknowledging the limitations, the findings contribute to the ongoing discussion and understanding of the implications of integrating AI into architectural interactions. The results highlight the potential for collaborative systems with AI as a substitute for human collaborators, while also emphasizing the importance of nuanced approaches to maintain the collaborative aspect. Additionally, the findings demonstrate the possibilities of leveraging AI to enhance spatio-temporal interactions in architectural settings, opening up new avenues for user engagement and experience.

The limitations encountered during the research process should be acknowledged to provide a balanced perspective. Technical constraints, such as the simplicity of the AI integrated in the code used for the prototype, could be addressed in future iterations to give more sophisticated behaviour to the artefact. Furthermore, potential biases, such as the selection of architect candidates or the limited scope of the artifact, should be taken into account when interpreting the results.

To fully comprehend the implications of integrating AI into architectural interactions, further investigation is needed. Future research could explore the long-term effects of AI-mediated projects on user experiences and collaboration dynamics. It would also be valuable to examine the ethical considerations associated with AI in architectural contexts, ensuring that the integration of AI aligns with principles of inclusivity, fairness, and transparency.

Considering the broader implications, the findings of this research have practical implications for architectural design. AI can serve as a powerful tool for architects and designers, facilitating the exploration of innovative design solutions, assisting in the generation of spatial configurations, and enabling interactive experiences for users.

In conclusion, this research has provided valuable insights into the role of AI in architectural interactions, user dynamics, and spatio-temporal enhancements. By addressing the limitations, discussing the implications, and considering future directions, this study contributes to the advancement of the field, paving the way for further exploration and refinement of AI integration in architectural design and human-computer interactions.

Integrating AI into architectural interactions holds immense potential to revolutionize the field, offering new possibilities for collaboration, user engagement, and design innovation. However, it is crucial to approach this integration thoughtfully, taking into account the nuanced nature of collaborative processes and considering the ethical implications and user experiences. By fostering a harmonious relationship between AI and human creativity, architects can unlock new horizons in design and create environments that are responsive, interactive, and deeply enriching for users. This research serves as a steppingstone in this exciting journey, providing valuable insights and opening doors to further exploration and development in the realm of AI-driven architectural interactions.

Conclusion

In conclusion, this project contributes to the field of interaction design by exploring the application of AI body tracking in the context of interactive architecture. By addressing a gap in the existing literature, this paper establishes connections between interaction design, interactive architecture, and interactive art, highlighting the mutually enhancing potential between building usage dynamics and the spatio-temporal qualities of interactive artifacts. This analysis allowed for classification and better grasping of the important design considerations that are beneficial to architectural interactivity, addressing the question of "How might one use body movement tracking AI to improve conventional sensor-based Architectural Interactivity?" by recognising that improvements to conventional architectural interactivity can be achieved through the design of systems relying on collaboration and mutual engagement between several entities.

One of the contributions this project is conceptually relying on is its challenging of Oh et al.'s theory of collaborative systems. By creating an artifact that requires kinesthetic empathy and social skills as means of interacting, we have attempted to redefine collaboration in the context of architectural interactivity. The collaborative style of interaction between a single user and AI, mediated by the artifact, demonstrates the transformative potential of AI in enabling novel forms of engagement and collaboration with users of a building.

From a user experience standpoint, this project showcases the possibilities offered by AI in experimental interactions within architecture. By pushing the boundaries sensor-based architectural interactivity, this project has demonstrated the potential of AI to facilitate enhance interactivity and redefine people's interactions with their built environments, because beyond giving new options and unmatched flexibility compared to already-in-use sensor-based systems, the integration of AI showcased a significant advantage in terms of ease-of-use and accessibility. Specifically, the project showcased the possibility of tracking subtle body language cues without becoming excessively complicated to code. This experimental exploration lays a modest foundation for the development of intelligent systems accessible to anyone to positively impact real-world applications and reimagine daily environments in beneficial ways. By creating a discussion around unconventional uses of technology to further user engagement in architectural spaces, this paper attempted to break the conventional expectations concerning the integration of interactive elements in the realm of architecture.

However, it is important to acknowledge the limitations and areas for further investigation. Future research should focus on refining AI algorithms, addressing ethical considerations, and conducting comprehensive user studies to evaluate the long-term effects of AI-mediated architectural interactions. By addressing these challenges, we can advance the field and guide the development of intelligent systems that are sensitive to user needs and contribute to the creation of more inclusive and human-centric architectural experiences.

In summary, this project represents a contribution to the research in the exploration of AI in architectural interactions. It contributes to the knowledge base of interaction design by bridging disciplines, challenging existing theories, and showcasing the transformative potential of AI. Through continued research and development, we can harness the power of AI to create intelligent systems that redefine user experiences, foster collaboration, and shape the future of architecture in meaningful and beneficial ways.

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MEDIA SOURCES

Figure 1. Pedersen, J. (2022). *Enhanced Double Diamond,* from the Interaction Design: Studio II VT-22

Figure 2. Nabil, S., Kirk, D. S., Plötz, T., Trueman, J., Chatting, D., Dereshev, D., & Olivier, P. (2017). *Interioractive*. 379–390. https://doi.org/10.1145/3064663.3064745

Figure 3. *Brown White and Blue Duck,* free stock photo https://www.pexels.com/photo/brown-white-and-blue-duck-209035/

Figure 4-7. All the Images used are my own.

APPENDIX

Evaluation Workshop

The three initial questions for architects were, Q1: *What do you think it is?* Q2: *Can you define what it does?*Q3: *How would you describe its behaviour in terms of interaction between yourself and the artefact?* In turn, I informed the participants of the intention of the artefact and how it is supposed to work, but without giving them too much information. They only were informed of the no eye-contact rule and told that "the wall has the personality of a shy cat, so try to use body language in order to gain its confidence, after which it will reveal you a secret". After that short explanation, I let them interact with the object some more. Finally, I asked the participants to describe Q4: *Can you describe how different your approach is to before I explained you the project?* Q5: *What does the word collaboration evoke to you in in respect to this artefact?*

To the first question(Q1), Candidate 1 (C1) and C3 said 'A picture frame', C2 'A drying rack'.

To the second question(Q2), all three said they 'I saw something move when I went in front, since then nothing', but when C3 turned their head to me to reply to the question, the device moved again, so C3 discovered the no eye-contact rule.

To the third(Q3), C2 said they thought the artefact was an automatic blinds system, C1 didn't know, described it as 'mysterious', and C3 noted his discovery with the no-look policy but nothing more.

After being informed, the users passed a second round of trials with questioning.

For Q4, C1 noted that they were 'finally seeing it now'. C3 tried to turn around and move further from frame to make it work but it didn't. C3 more relevantly noted that they were moving slower and in a 'more careful way'.

For Q5, C1 and C2 remarked the lack of collaboration mainly because they got thrown off by the secretive aspect, C3 deduced that it had to do with the collaboration between the artefact and himself.