Case Report

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Embedded Computation versus Embodied Interaction: Connected Objects for Connected Thinking

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Abstract: What will future creativity-based work in collaboration with ubiquitous, AI-driven systems be like? In this paper, we argue that following a 'tangible interaction' approach can be beneficial in this context. We describe six connected objects that illustrate how the quality of future creative work could be designed. The objects aim to shape embedded computation in ways that support embodied interaction. They include a place for sacrificing one's phone, an olfactory calendar, a reader/writer for cloud data in everyday objects, a concrete-based data logger, a slot machine for recombining old ideas into new ones, and a dimmer for artificial intelligence. We summarize the results of a critical reflection of the prototypes in an argument for designing interactions that foster collaborative creative processes between embodied humans in a world of embedded computation.

Keywords: Collaboration, creativity, design, embodied interaction, tangible user interfaces

1 A Speculative Scenario

It is the year 20XX – a potential, near future. Sally works at a creative agency. Together with her colleague, Thomas, she is working on a new campaign for a bike-sharing company.

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It is Monday morning, Sally arrives at the office. Recently, a new ambient artificial intelligence (AAI) system was installed in the office, designed to help her and her colleagues to creatively collaborate with each other. To log in to the system, Sally drops off her phone at the *Phone Sacrifice*. The system recognizes her phone, authenticates with the server and synchronizes her field notes and photos to the AAI's database. Sally had taken and tagged a series of inspirational photos on a weekend trip. These photos are automatically downloaded from her phone and projected to the office's interactive wall.

Thomas arrives, also dropping off his phone – he just finished reading some articles about worldwide bike sharing trends. He had marked some parts in the articles, which, once he drops off his phone, also appear on the office's interactive wall.

Sally and Thomas enjoy their 'distraction-free' time, discussing the results of their research and associating trends and pictures on the office's interactive wall. All of a sudden, Thomas smells something. 'I think we should move on to concept creation, or we might fall behind schedule...', he says – the office's *Scent Schedule* had started to vaporize marker ink, which created a 'sketching' atmosphere to guide the activities of the team, in accordance with the project schedule.

Sally remembers some inspirational photos of wooden furniture from another project that might fit right into the current discussion. As she really liked these photos back then, she gave them a special place: a small, wooden toy boat that her father had built with her when she was a child. It had always been her companion, and she kept it on her desk. She places the boat on the *Personal Data Objects* reader/writer device, which immediately loads the photos from the AAI's database, and projects them floatingly on the wall.

After lunch, Sally and Thomas decide to try the new *Slot Machine* that was installed in the office. Sally pulls the lever: 'Bike lock – for kids – based on voice' the system randomly combines a topic from their project with a target group and a technology. 'Interesting – a bike lock for kids that they can't lose the key to... I have to think about that!', she says. 'Well, there you go!' – Thomas just noticed that the 'Concrete Data' clock just had made a mark in its concrete disk. 'That only happens when the AAI thinks that a really good idea was just uttered!', Thomas excitedly explains. The system was installed as a motivational tool, marking important moments in the project by setting them in stone.

'You know what?', Sally looks over to Thomas, 'We're going to turn up the artificial intelligence now.' She walks up to the *Dimmable AI* control panel and sets the intelligence level of the system, which had been set to 'Assistant' until now, to 'Coworker'. 'Hello, Sally and Thomas.', the AAI joins their conversation. 'I think you're on to some interesting concepts here. Why don't we brainstorm together?'

2 Introduction

In its early years, HCI widely conceptualized users similar to computers, as 'information processors' [6]. This is reflected in system designs that focus on information interchange between the human and the computer, using text for input and output. Compared to today's systems, computers at that time were also considerably larger. Technological advancements, especially towards increasingly smaller computers, brought along the field of *embedded* computation, which enabled computers to be integrated into everyday objects. Today, this development is also observable in the 'internet of things' (IoT). At the same time, another concept of the human user developed in the HCI community: a concept of humans as bodily feeling and acting, as socially interwoven beings. A frequently used term for this new focus of HCI is *embodied* interaction. Combining embedded technology with embodied users appears to be a promising approach. Great research advancements in this area underline this potential.

Unfortunately, other recent research might indicate that embedded computation can also be at odds with embodied interaction: for example, our attention can be overly drawn to our mobile phones [36]. The psychologically addictive potential of networked devices is being demonstrated in various fields of research [22]. Computers have become parts of people's everyday interactions, but not always in a positive way: they can interrupt social activities, they can undermine relationships, and they can prevent conversation – rather than enabling it [42].

Despite being seamlessly embedded from a human-*computer* interaction perspective, such systems could have a profound, and sometimes negative, impact on our human-*human* interactions. It appears that solely embedding the *technology* is not enough: the interaction might need to be *embedded into social practice*, too. Here, great potential could be found in *tangibility*. This is especially relevant for areas of interaction that do require the collaboration of humans with humans, as well as of humans with computers. This is, for example, the case in computer-supported creative processes. As van Dijk et al. note, such processes should be conceptualized as a practice of embodied cognition [50], in which the role of the computer needs to be carefully designed. Unfortunately, only few design research projects follow this approach. In this paper, we describe the results from a critical design research project that assesses this issue, aiming to design representational embodiments of digital data in ways that suit the experiential embodiment of the human user [18].

The design process was structured as follows. In an *initial research* phase, existing projects in human-computer collaboration, especially in the context of creativity, were reviewed. In the following *potential identification phase*, unused potentials were identified and, in the following *concept development phase*, concretized. They were unified in a *consolidation phase*. Based upon these final concepts, the resulting prototypes were designed in the final *product design phase*. The project was conducted at the University of Wuppertal, where the Interface Lab is being established in the Industrial Design department.

3 Related Work

Several research projects investigate our future everyday interactions with interactive systems. In this section, we provide an overview over activities that inspired our work and thus lay its foundation.

3.1 Distraction Management

Unplanned use of smartphones has been subject of various research activities, indicating that it can lead to a loss of experience of time [32] and that interruptions may have severe effects on productivity [38], human relationships [48] and happiness [39, 31]. Decreases in cognitive capacity have been suggested to result from the mere presence of a smartphone [52]. HCI research in this area has investigated how to detect points in time at which users are likely to be less disturbed by a notification [35, 43], as well as how to design for less distractive interactions with mobile devices [9, 8, 1].

3.2 Olfactory Actuation

Olfaction has been considered to be a promising approach to ambiently display information [53], which has led to research on influencing dreams through olfactory actuation [4], making museum experiences richer [28], and to augment audiovisual content in storytelling [26]. HCI research in this area has yielded olfactory displays based on inkjet printing [46], synchronized olfactory actuation to the user's inhalation [37] and even simulating smells via electric stimulation of olfactory receptor cells [14].

3.3 Token-Based Data Handling

Associating data with tangible objects is one of the prime principles of the 'tangible interaction' research community. It goes back to Bishop's Marble Answering Machine [3] and Ishii's and Ullmer's principles of Tangible Bits [21]. Later endeavours of applying token-based interaction to creative tasks have included interaction principles through tracked objects for making music [25], digital content handling [27], explorative learning [34] and architectural planning [49].

3.4 Data Ephemerality

The permanence and ephemerality of digital information has been the subject of various HCI research projects. Research in this area has reflected the impossibility of erasing data [54] and also brought forward the approach of 'slow computing' [5]. Likewise, the ephemerality of digital information has been investigated, through interaction principles based on soap bubbles [47, 10] and even projecting on people's breath [2] in cold environments. Even though stone-based 'data recording' has been cultural practice from the onset of human civilization, it has been used in HCI only rarely (e. g. in [51]).

3.5 Human-Computer Separation of Labor

The principles of separating work between humans and computers is another active field of HCI research [23]. For example, unwanted help by a computer has been shown to be a trigger for user frustration [13]. Acceptance issues are especially visible in human-robot interaction [12, 15, 44], but in the 'IoT' age, these issues are likely to become increasingly widespread. In creative work, AI-based systems have also been demonstrated to be potentially valuable collaborators, in activity fields ranging from music composition [19] to graphic design [24].

3.6 Collaboration with Artificial Intelligence

New ways of collaborating with AI-based systems are currently being explored by HCI researchers. This research investigates, for example, how humans and AI-based systems can collaborate more effectively [33]. Other research investigates how the data and work processes taught to an AI may remain the property of the worker who taught it [45], making him or her the AI's 'owner'. Acceptance studies of social robots [17] have shown that humans can have a 'theory of mind' on autonomous systems [16] and perceive robots to be more human if they bear resemblances of themselves [11]. Nonetheless, user acceptance of autonomous systems like AI-based systems and social robotics remains a main issue for products and services in this field, especially when people feel to be subliminally spied upon and potentially out-smarted by an ambiently present computer.

The topics presented in this section are under current research in the field of HCI. Unfortunately, few research projects span more than two of these fields, even though these fields are likely to converge into people's future everyday lives altogether. To remedy this issue, we present a design research project in which we developed connected objects that investigate how embodied thinking can be supported by embedded technology.

4 Connected Objects for Connected Thinking

The goal of this critical design research project was to create prototypes of connected objects. These are set in the 'Interface Lab', a fictional, future workplace in which designers creatively collaborate with computers. Each object thereby investigates a 'tangibility-driven' approach to the previously outlined topics of distraction management, olfactory actuation, token-based data handling, data ephemerality, human-computer separation of labor and collaboration with artificial intelligence. The objects are designed to foster collaborative human creativity, helping people to connect with each other as embodied beings. The overall goal of the project is to spark a discussion about how future collaboration with AI-based systems in creative workplaces could be shaped.

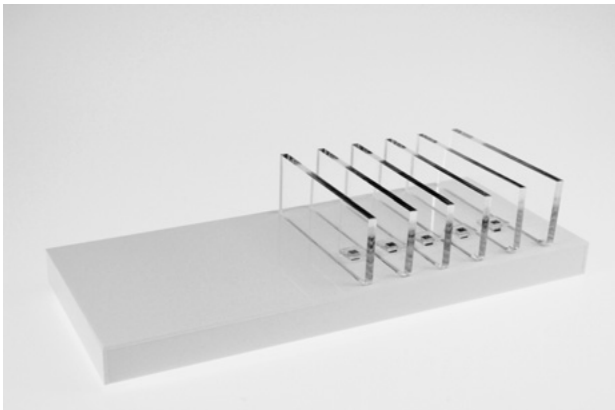

Figure 1: The Phone Sacrifice: a sacrificial place for mobile phones.

Figure 2: The Scent Schedule: a calendar that changes its smell based on the currently scheduled project phase.

4.1 Embodied Presence: Phone Sacrifice

The Phone Sacrifice (Figure 1) serves as a login ritual for the Interface Lab. It is inspired by the rituals performed, for example, when entering a church (taking off one's hat) or a kung-fu dojo (taking off one's shoes): it encourages users to drop off their phone when entering the room. Each phone is recognized, once dropped in: dropping one's phone uploads inspirational notes and photos collected on the go into the Interface Lab's ambient idea management system.

Conceptually, the prototype is based on the assumption that embodied beings have only a limited amount of attention, and that removing attention attractors is beneficial for their presence in a situation.

4.2 Embodied Ambience: Scent Schedule

The Scent Schedule is an ambient calendar that can change its smell (Figure 2). Depending on which project phase the Interface Lab is currently scheduled to be in, it diffuses a typical smell from this phase: the smell of books (research phase), sticky notes (brainstorming phase), marker ink (sketching phase), technology (prototyping phase), and woodworking (exhibition phase). Thus people working in the Interface Lab can check whether they are working on schedule by comparing what they are currently doing to what the room smells like.

The prototype is based on CPU fans, which can be controlled by a timer, and thus pre-programmed according to a project's schedule. The smells are created by chopped book pages, glue, ink, 'new car' smell trees and sawdust.

Conceptually, it is based on the assumption that embodied beings have an implicit feeling for the situation, which is strongly influenced by the olfactory sense.

Figure 3: Personal Data Objects: a reader/writer for cloud data in everyday objects.

4.3 Embodied Ownership: Personal Data Objects

Personal Data Objects is a reader/writer for cloud data in everyday objects (Figure 3). It is based on the observation that in the age of cloud computing, data is sometimes considered to be lacking a concrete place. Placing an object on the device's platform will create the illusion of 'pulling' the currently displayed file on the nearby screen 'into' the object. Technically, a reference to the file is stored in a database, where it is associated with the object.

Technically, the device is based on a kitchen scale, measuring the object's precise weight – similarly to Konomi et al.'s Passage prototype [27]. When the same object is placed on the device's platform again, the associated file is read from the database, and shown on the screen as 'popping out' of the object.

Figure 4: Concrete Data: a stone-based data logger.

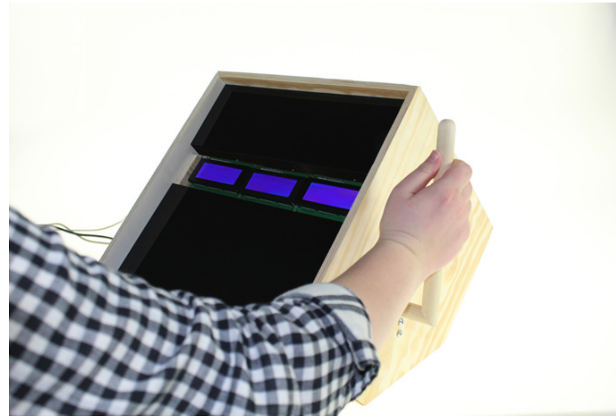

Figure 5: Slot Machine: an undesirable future of human-AI collaboration.

This device is based on the assumption that embodied beings have a need for feeling ownership, which spans across physical objects and digital data – and that this need should be satisfied also for intangible assets, like cloud data.

4.4 Embodied Materiality: Concrete Data

This device is a data storage unit, based on setting data in stone (Figure 4). In the Interface Lab, it is used to keep a log book of creative moments. It symbolizes that deleting information may not always be possible. Also, it is a device that would listen to all conversations in the lab, thus raising privacy concerns.

Technically, it is based on a concrete disc, in which a stepper motor drives an axis with a servo-driven chisel. A magnet on the concrete disc's back side increases the pressure exerted by the chisel.

Conceptually, this object is based on the assumption that embodied beings have a need for physical manifestations of abstract data.

4.5 Embodied Activity: Slot Machine

The Slot Machine (Figure 5) is an idea generator. When its lever is pulled, it recombines three ideas from the Interface Lab's database into a new idea that isn't in the system yet. For the designer, this means that creative activity can be reduced to pulling a lever. Thus, this object is a critique of outsourcing too much of creative work to an artificial intelligence.

Software-wise, the device is based on a hidden Markov chain algorithm. Hardware-wise, it consists of three LCD displays, which are connected to an Arduino. The Arduino is connected to the Interface Lab's idea repository.

Conceptually, it is based on the assumption that embodied beings have a need for diverse, purposeful activities – more than just pulling a lever to generate ideas.

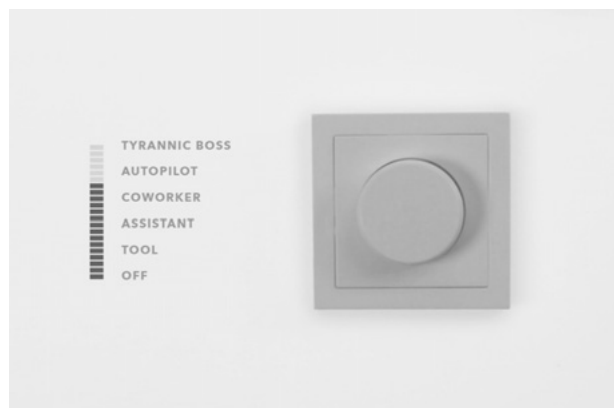

Figure 6: Dimmable AI: a computational assistant with adjustable 'brightness'.

4.6 Embodied Control: Dimmable AI

The last object (Figure 6) is a dimmer for an AI's 'brightness'. Depending on its setting, it regulates the niveau of the Interface Lab's ambient AI assistant. It can be set to different levels, ranging from 'off', 'tool', 'assistant', 'coworker', 'autopilot' and 'tyrannic boss'. Depending on the level, the relationship between the user and the AI changes.

Technically, it consists of an off-the-shelf dimmer, connected via an Arduino to the Interface Lab's server. In a 'scripted story' demo, it controls the ambient projection, displaying different activity levels of the system – from an empty screen to an uncontrollable, seemingly chaotic, self-organizing network.

Conceptually, it is based on the assumption that embodied beings seek to negotiate their relationships with others, and that they have needs for different relationships in different situations.

5 Discussion

These objects materialize our vision for what interactions with AI-driven, ubiquitous systems should feel like, and what they shouldn't feel like.

In line with Turkle [48], the *Phone Sacrifice* prototype manifests the argument that computers must not come in between relationships. Interactions with the digital world can be beneficial for creative processes: they can help users to discover inspiration, they can externalize our memory, and they can help users to quickly sketch out interactive ideas, using digitally-enhanced prototyping tools. However, these interactions can also get in between what is paramount in creativity: human-human interaction. We therefore claim that interaction design for creative processes should let conversation between people take center stage, and encourage leaving technology out as much as possible.

In line with Ishii [20], the *Scent Schedule* prototype manifests the argument that computers should remain in the periphery of perception, and not take center stage. There is a thin line between how much a computer should be present in a creative space, and how much it should disappear. We believe that it should be up to the user to either focus on the computer, or to ignore it. Therefore, we believe that using atmospheric cues, like olfaction, might be a promising approach to an 'easy to ignore' approach to computation that leaves more space for creativity.

Inspired by Bishop [3], the *Personal Data Objects* prototype manifests the argument that the most natural way to handle digital data is by handling physical objects. The development of 'cloud computing' can be interpreted as a counter-movement to tangible interaction: files stored in the cloud have, from a user's point of view, lost their tangibility and their place. To foster intuitive handling of data in times of growing computational complexity, especially in creative processes, permanent data-in-object (pseudo-)containment should be recultivated through interaction design.

In line with Lanier [29, 30], the *Concrete Data* prototype manifests the argument that privacy and reversibility need to be at the core of interaction design. Growing concerns about data protection and privacy need to be addressed from an interaction design perspective, in order to enable a trustful relationship between the user and the system, and to prevent 'chilling effects' [41] when people express and develop their ideas.

In line with Churchill [7], the *Slot Machine* prototype manifests the argument that interaction design should aim for engagement, rather than consumption. The psychological importance of intrinsically motivated work, which one perceives as fulfilling and purpose-giving, has been the objective of many sociological and psychological studies. Current developments in automation demand that the separation of work between humans and machines are designed to be purpose-giving for the human user, especially in the case of creative tasks.

In line with Paulos [40], the *Dimmable AI* prototype manifests the argument that interaction design should leave the control over the system in the user's hands. AI has the potential to fundamentally change the way we perceive computers. At the same time, it is bound to change our relationship to them. This relationship needs to be carefully designed. This prototype argues that interaction design should put humans in control about the nature of this relationship.

6 Conclusion

We presented the results of a design research project, aimed at sparking a discussion on how humans and AI-based systems may collaborate in future creative processes. We described six connected objects which were designed following a 'tangible interaction' approach. Lastly, we summarized our arguments for designing embedded computation in support of embodied interaction.

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