Workshop Proceedings

Embodied Interaction: Theory and Practice in HCI

Workshop at CHI 2011,
May 8, Vancouver, Canada

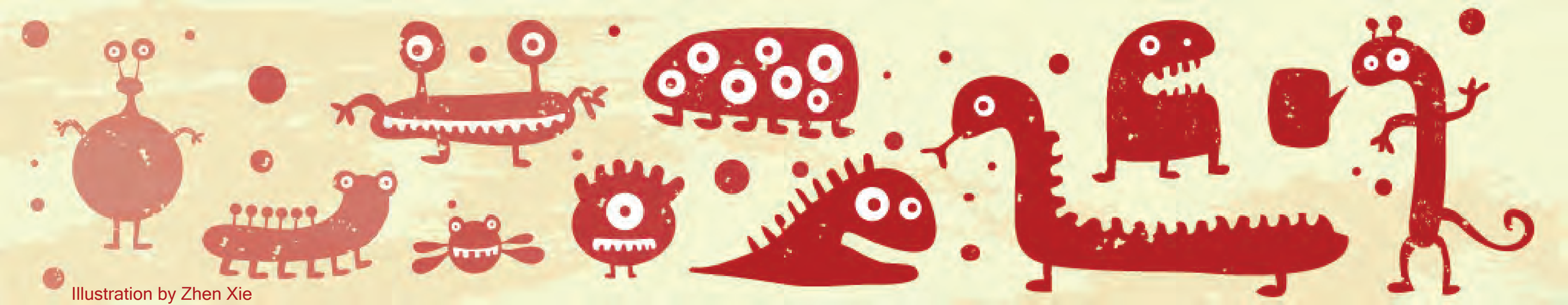
Illustration by Zhen Xie

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The 29th ACM International Conference on
Human Factors in Computing Systems

CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

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Abstract

For over ten years researchers in human-computer interaction (HCI) have explored an embodied perspective that seeks to describe and explain the fundamental role played by the physical body in how we experience, interact with and understand computation in the world we live in. Recently, such a perspective has been used to discuss human actions and interactions with a range of computational applications including tangibles, mobiles, wearables, tabletops and interactive environments. This workshop aims to enable participants to critically explore the different approaches to incorporating an embodied perspective in HCI research, and to develop a shared set of understandings and identification of differences, similarities and synergies between our research approaches.

More information: http://www.antle.iat.sfu.ca/chi2011_EmbodiedWorkshop

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Embodied Interaction: Theory and Practice in HCI

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For over ten years researchers in human-computer interaction (HCI) have explored an embodied perspective that seeks to describe and explain the fundamental role played by the physical body in how we experience, interact with and understand computation in the world we live in. Recently, such a perspective has been used to discuss human actions and interactions with a range of computational applications including tangibles, mobiles, wearables, tabletops and interactive environments. This workshop aims to enable participants to critically explore the different approaches to incorporating an embodied perspective in HCI research, and to develop a shared set of understandings and identification of differences, similarities and synergies between our research approaches.

Keywords

Embodied interaction, embodiment, tangible computing, social computing, physicality.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g. HCI): Miscellaneous. H.1.2 [User/Machine Systems]: Design

Introduction

In 2011 it will be 10 years since the publication of Where the Action Is, where Paul Dourish set out a theoretical foundation for HCI grounded in phenomenological theories of embodiment. His approach, termed embodied interaction, rejects the cognitivist models of the previous generation of HCI theory, embracing work in phenomenology and emphasizing practical social and physical action. The CHI community has shown an increasing interest and focus on embodiment as an alternative perspective on human computer interaction. This is reflected in a variety of design and research projects concerned specifically with bodily action, human experiences, and physicality, in the context of interaction with and through a world comprised of computationally mediated artifacts and environments [1-5, 9, 12, 14-16]. This workshop capitalizes on this growing body of work by bringing together a community of researchers who are currently creating interactive technologies to investigate and design for embodied human-computer interaction.

The workshop aims to address a series of challenges, which we see as essential to overcome in order for a discourse grounded on embodiment to become fully integrated into the HCI community. These challenges include the following:

What do we mean when we say "embodiment"?

The first goal of this workshop is to work towards a common understanding of the meanings of "embodiment" in the context of HCI. From a perspective of cognitive science, Rohrer describes a dozen different uses of the term embodiment in the literature [18]. The concept of embodiment also has several usages in the HCI literature. Ethnomethodological studies of activity and social action have emphasized the embodied nature of meaning making (e.g. [10, 11]). Mechanisms underlying intuitive meaning making in various settings, such as embodied metaphors, have been applied in interaction models (e.g. [1-4]). The concept of embodiment is also used in tangible user interfaces to describe how physical objects may be used simultaneously as input and output for computational processes (e.g. [9]) and in wearables research focused on how we experience our bodies in interaction (e.g. [19]). The term has also been used loosely to classify the extent that the user perceives computation is embodied within a particular physical form [8]. In all cases, the ideas of embodiment provide a fundamentally different perspective than a Cartesian or information processing perspective on interaction. What is needed is a shared understanding that includes how each can be used as a theoretical foundation that informs research and design practices.

Moving beyond description

Understanding an embodied perspective requires moving beyond descriptions of concepts. It requires explanations that are developed based on mechanisms that underlay an embodied approach to cognition. The mechanisms of embodiment reach from Von Uexkull's ticks to complex social systems [6]. In humans, these mechanisms operate a variety of scales from the neurological and the individual through to distributed social groups, each in dynamic interplay with the surrounding environment.

Important interpersonal and intrapersonal explanatory theories that have emerged to date in HCI include:

affordances [17]; dynamic couplings [7]; representational forms as resources [16]; embodied metaphors [1-4] and conceptual blends [13]. In this workshop we will identify and explore some key *explanatory concepts* from theories of embodied cognition through sharing of research and design in embodied HCI. A common language including both descriptive and explanatory theories is essential to create shared understandings across subfields of HCI and design.

Moving beyond interpretation

An embodied view on interaction provides us with an interpretive perspective that can be used to describe and explain the actions and interactions of users with a range of applications including mobile, tangible, wearable, tabletop and interactive environments, as well as more conventional laptop or PC based applications. However, to date, there has been more work that deconstructs existing systems than empirical research that generates guidelines that can inform the design of such systems [2]. While Dourish [7] provided some high level design principles based on embodied interaction, these principles require further exploration and empirical validation. In this workshop we will share and discuss different research prototypes that have been built to explore and generate guidelines for various aspects of embodied HCI.

Goals

The primary goals for the workshop are:

- To bring together a *community* of researchers and designers who are creating interactive technologies based on embodied interaction;
- To present and discuss design and research projects that have a *theoretical* foundation based on different perspectives on embodiment;
- To share and discuss concepts and prototypes that have been designed to explore embodied interaction in *empirical* work;
- To identify fundamental differences, similarities and synergies between different *design and research approaches* that have been employed to study embodied interaction in HCI.

Structure

Before the workshop potential participants submit one of: 4 page position paper, 2 page position paper + poster, or proposal for a demonstration, related to their own experiences with workshop issues, themes and goals. Authors are to include a working definition of how the term “embodiment” is used as a foundation for their own work. Participants are expected to read all other accepted submissions prior to the workshop.

At the workshop: The one day workshop is split into four sections. In the first section of the morning we will have CHI Madness style introductions. The second section of the workshop will be a keynote talk by Dr. David Kirsh (UCSD). After a group lunch, we will have the third section, which includes discursive break-out sessions in smaller groups. Topics will include: Perspectives on Embodied Interaction; Design and Evaluation for Embodied Interaction; and Future Research. The day will conclude with interactivity demonstrations that enable different kinds of embodied interaction. As we conclude the workshop, we will collectively summarizing the different perspectives and ideas we had during the day.

After the workshop: Workshop participants will be invited to submit longer versions of their work to a special issue of *ACM Transactions on Computer-Human Interaction* (ToCHI) (submitted) which will be edited by Drs. Antle, Marshall and van den Hoven and will include a guest editorial by Dr. Paul Dourish.

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About the organizers

Alissa N. Antle is an assistant professor of Interactive Arts and Technology at Simon Fraser University. Her research interests focus on embodied forms of interaction including tangibles and whole body interactive environments. Her recent work explores the application of embodied image schemata and conceptual metaphors in interaction design for tangibles and interactive environments, and investigates the role of complementary and epistemic actions in understanding how we “think with our hands” using tangible and multi-touch tabletops.

Paul Marshall is a research fellow at the University of Warwick, working on a project looking at participation in healthcare environment engineering. His research interests centre on the role of physical and spatial factors in mediating interactions with and around technology.

Elise van den Hoven is an assistant professor at Industrial Design, Eindhoven University of Technology. She has been working on embodied interaction by combining tangible interaction with a user-centered design research approach. Her work centers around everyday remembering and physicality.

Movement transcriptions of SECs in a componential model of emotions

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
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Abstract

In this paper, we present a work-in-progress exploratory study for determining movement cues characteristics of Stimulus Evaluation Checks (SECs) responses in Scherer's Component Process Model (CPM). This study integrates itself in our research on movement-based emotion recognition for augmenting ballet dance. The experimentation described in this article was designed in two parts. The first part produced a corpus of scenario-driven, acted affective sequences recorded both on video and using a motion capture system. The second part should lead to a set of movement cues characterizing some SEC responses in Scherer's CPM, to be integrated in an existing emotion recognition system, called eMotion.

Keywords

Affective Computing, Emotion Recognition, Component Process Model, Arts, Ballet Dance.

ACM Classification Keywords

J.4.4 [Computer Applications]: Social and behavioral sciences – *Psychology*

General Terms

Human Factors, Experimentation.

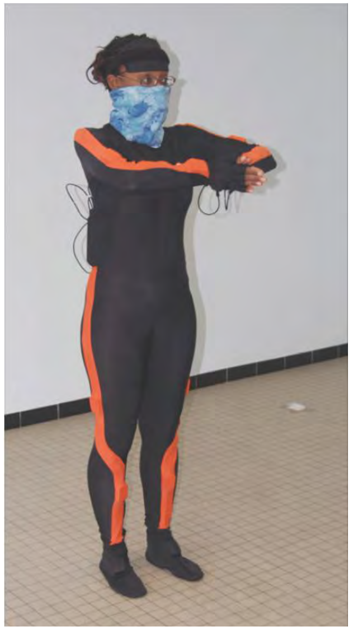
Introduction

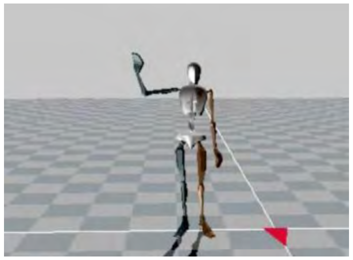
This article presents a work-in progress exploratory study that integrates in our current research on movement based emotion recognition, with an application on ballet dance. We consider emotion recognition to be an interaction: user's emotions trigger reactions from the machine. In our context, this interaction is embodied, as the dancer's emotional expression is performed using his body. Augmenting a live ballet show implies recognizing emotions from movements in real time (i.e. less than 2 seconds). Emotional cues extracted on periods lasting more than a few seconds hence cannot be used. In addition, we seek to be able to segment a dance into several emotional expressions. To fulfill those constraints, we consider Scherer's Componential Process Model (CPM). The CPM describes emotions as dynamic processes. In this model, an event (the stimulus) triggers a cognitive evaluation, decomposed in an ordered sequence of Stimulus Evaluation Checks (SECs). The subject assesses the *relevance* of the event, his *implication* within the situation, his *coping potential* with probable outcomes, and the *normative significance* of the intended reaction. Each SEC is decomposed into sub-SECs (13 in total). The overall evaluation triggers mental, physical and physiological changes that constitute an emotion. The CPM is fully explained in [3]. This model is more and more popular in the affective computing community, and is well adapted to emotion synthesis. Beginning with the experiment presented in this paper, we seek to adapt the CPM to emotion recognition, where discrete and continuous models are the norm [5], by identifying movement cues that translate sub-SECs responses. Being able to recognize at least some of the sub-SECs responses in the sequence would allow for a fine-grained depiction of the subject's cognitive evaluation of the situation. In HCI, the recognizable sub-SECs would provide as many parameters for the machine to react to. Moreover, at least the first SECs are evaluated quickly enough for our real-time context. Finally, monitoring the subject and recognizing the first sub-SECs responses (*relevance* of the event*)* would provide a starting signal for the system to analyze the expression, allowing segmentation of a dance into emotional expressions. In this paper we present an exploratory, bottom-up experiment to identify movement cues that translate sub-SECs responses. For broader contribution, the current experiment is generic and not focused on dance. The methodology is inspired from [4]. The contribution we present is the production of a hundred scenario-driven affective sequences. The originality of this work is that sequences are recorded both on video and using a motion capture device, allowing for precise analysis of the movements. Videos are taken on a clear background, with positioned markers, and the camera's position is known. As such, our corpus can be used for video-based emotion recognition, or for testing video-based body tracking techniques (using the motion capture coordinates as a reference). The second part of the experiment is a work-in progress, where this corpus will be analyzed in details by coders to identify movement cues that are characteristics of some SECs responses. On a longer term, identified cues will be integrated within our current movement-based, real-time emotion recognition system [1].

Gathering affective sequences

Experimental setup and process

In the first part of our experiment, we gather affective sequences recorded both on video and using a motion capture system. As SECs are heavily focused towards





Actor wearing the motion capture suit, and a screenshot of the 3D avatar used for monitoring and evaluations.

the triggering event, we use a scenario approach [2]. The ISEAR databank [6] features several thousand real-life situations where SECs responses are evaluated. We select 32 situations from this databank (with a precise enough depiction), following a roughly equal distribution of SECS response on 5 emotions (10 anger, 4 joy, 6 sadness, 6 disgust and 6 fear). Scenarios are elaborated to illustrate the selected situations. Each scenario is divided in a context and an acting part [2]. The actors consist in 18 subjects (10 men, 8 women, age ranging 18-41, average 23.6) who volunteered to participate for free in our experiment. 16 of them are engineer student and 2 are social science associate professors. To ensure a broader range of acting, we choose not to specifically use trained actors, although some of them (7, i.e. 40%) had a previous acting experience. A classroom is used for the recordings. For video processing purposes, a stage with a clear background is delimited with markers, keeping the actors into the camera's (a tripod-mounted JVC Everio) field of view. Stage dimensions and camera's position are taken. Actors are also recorded using an XSens MVN motion capture system, which gives the coordinates of the actors' bodies (divided in 23 segments) at a 60Hz rate. To record the data and monitor the recordings, we use MVNStudio, a proprietary application sold with the motion capture system. Each actor has to play 20 scenarios (4 from each emotion), among the 32 retained scenarios. Scenarios are chosen semi-randomly. Consequently, each is played an equal number of times. Scenarios are given 24 hours in advance to let actors get familiar and prepare acting. However, actors are instructed to avoid communicating about the experiment. Scenarios are re-read before each recording. Actors have to clap their hands in each sequence to help synchronizing video and motion capture recordings.

Analysis an Results

34 engineer students (age ranging 18-26, average 20.4, including 30% of women, independent from actors) are asked to watch all 360 sequences (18 actors x 20 scenarios). A video of the motion capture file is made for each sequence (see figure on the left). Videos are then randomly regrouped respecting equiprobability. Evaluators are asked to identify the emotion played in each motion capture video. We choose only the videos that are recognized with an accuracy of at least 70%. That process leads to keep 27.8% of the sequences. Evaluators are also instructed to rate the naturalness of the expression for each sequence (from 1 to 7) for further use. This first part of our experiment led to a corpus of 100 scenario-elicited affective movement sequences, shared among five emotions: anger (25), joy (7), disgust (18), fear (15) and sadness (35). Each sequence is recorded both on video and using a motion capture system. Available motion capture files are xml .mvnx file. Such files can be visualized using the free demo version of MVNStudio software[1] (files available on request). In addition, visual markers and camera's relative positions allow the use of body-tracking techniques on the videos, crossed with the motion capture data.

Encoding of the affective sequences

The second part of the experiment is a work-in progress. Its methodology is inspired from [4]. It will rely on the retained affective sequences from the first part. Coders will be selected and trained on Scherer's

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[1] Available on http://www.xsens.com/demo

CPM. Coders will then be asked to produce a few scenarios from ISEAR for evaluation of their understanding by an expert, in order to support the relevance of the results. We expect 40 coders divided in 4 groups of 10, each group coding 25 motion capture files. Proportion of emotions is preserved in each group. Coders will fill answer pages on a website. For a set of affective sequences, they will be asked to recognize the SECs responses when possible, and what part of the movement will have led them to their conclusion. For this study, we choose to use motion capture files only, due to the following reasons. First, motion capture files are rendered as an expressionless skeleton, eliminating the bias that an actor's eyes and eyebrows could bring. Second, the MVNStudio demo allows full interaction on visualization, including replays, moving the point of view, and slow motion (down to 1/8). Coders will be allowed to perform those operations to better identify SECs responses in the movement. We expect that the analysis of the answers will highlight recurrent movement cues leading to a same SEC interpretation.

Conclusion

We present in this paper a work-in-progress exploratory study to identify movement cues related to SECs responses in Sherer's CPM. The first part of this experiment produced a corpus of a hundred selected scenario-based affective sequences recorded both on video and on a humanly-readable open-format (XML) motion capture files. This corpus is available on request to the first author (7.2 Gb). Motion capture files (~500Mb) can be played using a free reader available online. Videos (6.7 Gb) have clear background and recorded positions of markers and cameras for potential video processing purposes. Selected motion capture files will now be analyzed by trained coders in order to identify SECs-related movement cues. On the longer term, those cues will be integrated in our emotion recognition application and will be used to dynamically recognize emotions.

Acknowledgements

We thank Frank Enos from Columbia University for his help and advice concerning the ISEAR databank and scenario-based emotion acting. We also thank all the participating students from ENSC Bordeaux.

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Investigating the Effects of Bimanual Multi-touch Interaction on Creativity

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

HCI research into multi-touch interaction typically focuses on technical innovation or basic task-performance metrics such as efficiency or accuracy. Recent findings from the cognitive sciences may provide a basis for investigating more complex aspects of human performance using multi-touch interfaces, such as creativity. This paper outlines a theoretical basis for investigating if multi-touch interaction improves divergent thinking.

Keywords

Bimanual, multi-touch, creativity, divergent thinking.

ACM Classification Keywords

H5.2. User Interfaces: Input devices and strategies, J.4 Social and behavioral sciences.

General Terms

Design, Human factors.

Introduction

Technical innovation in multi-touch displays has been a cause for great excitement in both academia and industry. Despite rapid increases in technical implementations and consumer adoption, there is limited understanding of the key differences between multi-touch and traditional mouse and keyboard interfaces beyond simple biomechanical differences. However, a small but significant body of HCI research has investigated how the body movements afforded by multi-touch displays (like gestural bimanual interaction) affect user cognition [11, 13]. This research is grounded in an embodied perspective on cognition [5, 16]. Our physical presence and movement in space structures our thinking in ways not immediately apparent from the Descartian mind-body view of cognition. Investigating the interplay between interface style, body movement and cognition may enable more effective designs to support thinking.

One area of HCI research that may benefit from this kind of embodied perspective is creativity support. A significant body of work in psychological research has been devoted to developing a clearer understanding of the influences and outcomes of human creativity. While human creativity is expressed through a wide variety of behaviors and contexts, specific creativity theories and measurable constructs have clarified the relationships between specific mental phenomena and creative output (see [4] for an overview). Some of the cognitive constructs that underlie the complex mental processes involved in creativity have been successfully operationalized to an extent that may prove useful for investigating how the input actions afforded by multi-touch interaction affect creative thought.

Theoretical Background

A common approach to understanding creative problem-solving processes is to investigate a mental strategy called *divergent thinking* [7]. Divergent thinking consists of mental operations that produce multiple novel solutions to a problem. Understanding and supporting divergent thinking has important implications in a wide range of areas, including childhood social development [18], workplace group dynamics [17], and entrepreneurship [1]. Within HCI, divergent thinking has been primarily examined within groupware contexts [8, 3] and in evaluating how information discovery may be supported by using image and text compositions as surrogates in representing information collections [12].

While many approaches to evaluating divergent thinking exist, one of the most common used in psychological research is the Alternate Uses Task (AUT) [2]. The AUT has been used to measure a person’s ability to generate alternate uses for everyday objects. Existing research shows that scores from the AUT often correlate to creativity in the “real world” [15, 10]. The AUT has also successfully been used to explore the underlying mental and neurological processes that influence divergent thinking [4, 6, 14]. One specific neurological process that has been examined *inter-hemispheric interaction* (IHI).

IHI occurs when signals pass back and forth between the right and left brain hemispheres through the connecting brain tissue of the corpus callosum. Certain behaviors and mental operations require information to be shared between both brain hemispheres, which increases inter-hemispheric activity. It has been shown that exercises that increase IHI correspondingly increase divergent thinking performance during subsequent AUT trials for some people [14]. For example, [14] describes the increased creative output of strong-handed (i.e. not ambidextrous) participants after performing bilateral eye movements (BEM) for 30 seconds. BEM is the movement of both eyes back and forth horizontally. This suggests that other bilateral movements, such as the bimanual hand motion used while interacting with large multi-touch displays, may enhance creative thinking as well.

To better understand the effects of multi-touch interaction on creativity, we propose measuring users' divergent thinking performance with a computerized version of the AUT with three interface styles: unimanual mouse-driven, unimanual multi-touch, and bimanual multi-touch. This enables us to identify differences in divergent thinking performance between bimanual and unimanual interaction and between direct (touch) and indirect (mouse) interaction styles.

Traditional Alternate Uses Task (AUT)

The AUT is traditionally administered via paper and pencil. Participants are asked to generate novel uses for a set of 15 everyday objects and are given one minute per object to write down their alternate uses. Scoring a participant's responses involves evaluating their alternate uses along five dimensions:

- *Appropriateness*: the number of valid responses;
- *Detail:* the amount of elaboration provided in the response;
- *Fluency*: the total number of uses per object, regardless of appropriateness;
- *Originality:* the number of unique responses, compared all responses given by all participants. This is usual binned into responses that are provided by less than 5% of the participants, responses provided by less than 10%, etc;
- *Categorical Distinctiveness* or *flexibility*: the number of object categories used in a set of responses.

Multiple raters independently rate the responses, and inter-rater scores are checked for inter-reliability (e.g. Cronbach's α). [14] found statistically significant increases in the originality and flexibility subscales for the strong-handed BEM group in their research.

Computerized Alternate Uses Task (AUT)

To facilitate the investigation of the effects of the style of interface on divergent thinking using the AUT, we have created a computerized version of the test. The application displays the name of an object, as well as a 3D model of that object that can be rotated and resized. Each interface style maps the rotate and resize functions uniquely to match the affordances of each interaction technique. For example, resizing is implemented with the scroll wheel using the mouse and with single handed or dual handed pinching using the multi-touch interfaces.

The AUT application has been initially design for use with a 3M M2256PW 22" capacitive multi-touch screen using the PyMT framework [9]. Because the PyMT framework can handle many different multi-touch hardware configurations, the software can be easily reconfigured for different display sizes or multi-touch sensing technologies.

The AUT application differs from the traditional test in three significant ways. First, participants are shown a 3D representation of the object along with the name and normal use of the object. Second, participants are encouraged to manipulate the 3D representation of the object while they generate new uses for it. Third, participants are asked to speak aloud their new uses, rather than writing them down (research has found no differences between verbal and written AUT performance [6]).

Summary

This paper outlines a unique approach to investigating the effects of multi-touch interaction on divergent thinking. Recent psychological and neuroscience research suggests that the mental process of divergent thinking is enhanced by bilateral body movements. Such movements are a key difference between bimanual multi-touch interfaces and unimanual multi-touch and mouse interfaces. We contribute the theory and a research instrument design that can be used to investigate this notion.

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Embodied Behavior Processing in ECAs by Perception-Action Integration

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Abstract

Perception and generation of verbal and nonverbal behavior is one of the main foundations of human social interaction. We model these abilities for embodied conversational agents (ECAs) on the basis of perception-action links as in humans. With a focus on gesture processing, we propose a computational model which enables ECAs to interact with humans in an embodied manner and supports many aspects of social interaction. The model performance is briefly illustrated on the basis of an interaction scene.

Keywords

Perception-action Links, Gestures, Cognitive Model, Social Embodiment

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

ACM Classification Keywords

I.2.10 Vision and Scene Understanding - Motion [Cognitive Model, Interactive System]

Introduction

An increasing number of findings and theoretical considerations in Cognitive Science suggest that human interaction and intersubjectivity is grounded in embodied processes. According to this view, perceiving and generating behavior are not separate processes but are both grounded in the perceiver's own motor repertoire (cf. *mirror neurons*). Moreover, such couplings between perception and action can be considered as a basis for creating common ground, mutual coordination, and *social resonance* [3]. Some of these processes apply also to the interaction of humans with artificial anthropomorphic agents [4]. The development of embodied conversational agents (ECAs), however, has so far neglected embodied processing of social behavior. Although coupling of perception and action has been touched upon by work on computational models of mirror neurons and in particular imitation learning [5], these approaches do not focus on social behavior, which requires fast and concurrent processing based on motor resonances during observation. In this paper we propose a computational model for the processing of communicative hand gestures in ECAs when interacting with humans. In general, this model has to account for a num ber of behaviorally and neurobiologically suggested require ments: (1) Hierarchical structure: Perception-action links [1 are assumed to be effective at various levels of a hierarch cal sensorimotor system, from kinematic features to moto commands to goals and intentions [2]. (2) Motor resonance Motor representations are shared between processes of per ception and generation, and this accounts for motor reso nances and covert imitation during embodied perception [7 (3) Top-down and bottom-up processing: The levels of th action representation hierarchy in the model must be able t interact bidirectionally with each other [8] during both per ception and generation. (4) Fast and incremental processing With incoming stimuli, resonances and activation of sensor motor structures must arise in a fast, robust, concurrent and incremental manner. (5) Imitation learning: The integration of perception and generation abilities must support the social learning of behaviors. (6) Interpersonal coordination: Perception-action links provide a likely basis for the fast and often non-conscious interpersonal coordinations (e.g., alignment, mimicry, interactional synchrony) that lead to rapport and social resonance [3] between interactants.

In the remainder of this paper, we describe our computational model and show how these requirements are met.

The Computational Model

Our computational model provides an ECA with motor knowledge that is shared between – and interacts with – perception and generation processes (see Figure 1). On the one hand, the perception module receives wrists' spatial positions of a human interlocutor at each time step, preprocesses them, and tries to recognize or learn gestures based on the shared motor knowledge. On the other hand, the generation module employs the represented motor knowledge to control the wrists movements of the ECA for gesture generation.

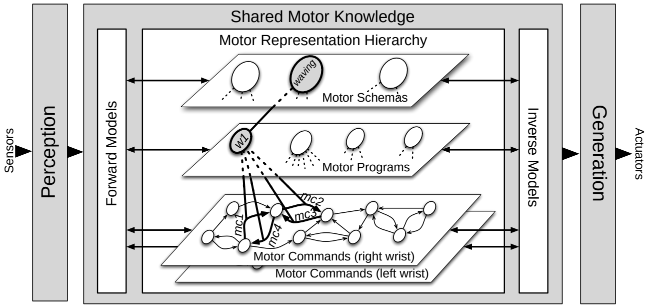

Figure 1: Overall model for embodied gesture perception and generation, integrated via shared motor knowledge. An example representation of a "waving" gesture is highlighted through bold lines and nodes.

Shared Motor Knowledge

The shared motor knowledge module consists of a pair of generic forward and inverse models and a hierarchical motor representation. At the lowest level, *motor commands* (in short, MC) represent spatiotemporal features of simple movement segments, arranged in a graph-like structure for each wrist (cf. *motor primitives*). At the next level, *motor programs* (MP) represent particular performances of a gesture as sequence(s) of motor commands. At the highest level, *motor schemas* (MS) cluster different performances of a gesture (i.e. MPs) and separate between invariant and variant features such as handedness or sub-movement repetition.

When the ECA observes a hand movement, all these represented motor components (MCs, MPs and MSs) serve as recognition hypotheses. At each time step, forward models evaluate those hypotheses against the observed movements, which results in a recognition confidence for each motor component. If the agent is not confident enough about observing any of the known motor component at one level, the perception process switches to inverse models that extend or adjust the motor knowledge to the newly observed movement. The same motor repertoire is, in turn, also used to perform gestures through a generation process in which probabilistic activation flows top-down to the level of executable MCs. That is, the ECA perceives hand movements in an embodied manner as he recognizes a movement by continuously comparing it with a motor repertoire that represents how the agent itself would perform that gesture.

Embodied Motor Resonances

The previously described perception process is realized in a probabilistic Bayesian framework. Following the Bayesian inference (see Figure 2), forward models resonate each motor component probabilistically w.r.t. the current observation. In order to make this embodied perception process robust, fast and incremental, we take three methodological steps: First, the motor resonance of each component ($m \in \{mc, mp, ms\}$) at each time step T is defined as its average activation over time: $P_T(m) := \frac{1}{T}\sum_{t=t_1}^{T} P_t(m)$. This step makes motor resonances incremental and robust against sensory noise. Second, at each time step t, the a priori of each motor component as a hypothesis is set to the previous a posteriori at time $t-1$, which supports incremental processing. Third, motor resonances are updated at each time step by two processes: (1) bottom-up belief propagation computes the a posteriori at each level given wrists observations and the a posteriori of the associated components at lower levels; (2) top-down belief guidance updates these

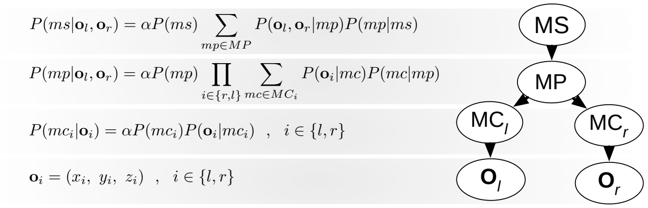

Figure 2: Probabilistic dependencies of motor resonances at different levels, given observations of left and right wrists ($\mathbf{o}_l$ and $\mathbf{o}_r$); α indicates the Bayesian normalizing constant.

Perception-Action Integration

To support the mutual effects between perception and generation processes, we define a *neural activation* for each motor component which is updated *and* used by both processes at each time step. On the one hand, the perception process sets the activations equal to the corresponding recognition probabilities. The generation process activates all generating motor components and the activations of all not-updated

components decrease. On the other hand, these neural activations are considered as prior probabilities while recognizing or generating gestures. In this way, we create perception-action links which account for different social capabilities and characteristics. For instance, this coupling enables direct, simultaneous imitation when the agent is set to perform motor resonances overtly. Furthermore, alignment and behavior coordination becomes possible because the ECA automatically tends to perform gestures which have been observed
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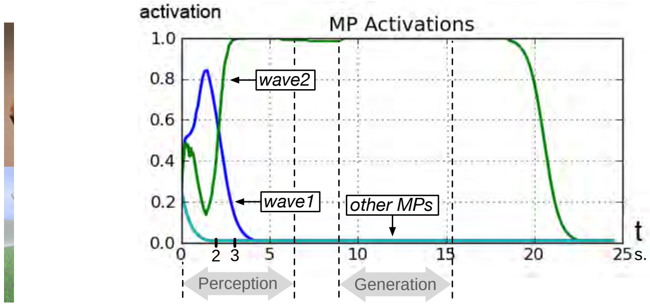

Figure 3: *Left*: Human user interacting with an ECA. *Right*: Evolving motor activations at the motor program level while, first, observing a known "waving" gesture ($wave2$), and then performing it in return (see [6] for more detailed results).

Conclusion

We have argued that embodied interactive agents like ECAs should be based more on principles of embodied cognitive processing to support many aspects of social interaction, from microscopic effects of behavior coordination to macroscopic abilities of imitation learning. We have presented a model that assumes a common sensorimotor structure and provides an embodied account of how to perceive, recognize, learn and generate hand gestures at the motor level. In this context, extending this model to higher representational levels that capture referential, communicative, and social intentions will be an important step for future work.

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On the Problem of Modeling Context for Embodied Interaction

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

Researchers have been investigating context-aware systems for various decades. Fields of research such as Ubiquitous Computing, Situated Computing or Embodied Interaction are strongly coupled to this basic thought of situating applications or objects in specific contexts. However, a context only considers the present and neglects the high dynamics of the situation, including the past and the future, it is embedded in. We argue that this leads to a fundamental context-modeling problem. Moreover, we propose a new model for describing highly dynamic environments with situations, contexts and circumstances. We show that a situation has a Gestalt and outline the importance of analyzing situations for future research challenges.

Keywords

Embodied interaction, context, situated computing, theoretical modeling

ACM Classification Keywords

H.1.m. Models and Principles: Miscellaneous.

General Terms

Theory

Introduction

In recent research, terms like context, context-sensitivity or context–adaptation have characterized a change in computer science. Namely, behavior of applications should depend on the environment and particularly the context in which they are deployed. Fields of research like Ubiquitous Computing or Ambient Intelligence are strongly coupled to this basic thought. Also research conducted under the umbrella term *Embodied Interaction*[1] is based upon that very same presumption: objects are embodied within a specific context. However, most research typically focuses on detecting context elements (like temperature, geographical location or time), which are to describe the context. And the term context itself remains rather vague and fuzzy. In other words, if a set of features was set and recognized, those features would describe the context. We feel that this leads to a fundamental misunderstanding in modeling context.

In the present paper, we first identify the aforementioned, fundamental modeling problem. Based upon this, we then elaborate on the distinction between situation, context and circumstance. A more fine-grained and thorough distinction allows us to gain a deeper understanding of research challenges, which will conclude our paper.

Context Modeling

Context is typically modeled under the assumption that it is defined by various pieces of information [2]. Consequently, context awareness is the “property of computer programs to have *information* about circumstances under which they operate” [4]. “Information characterizing the *situation*” [5], as a modeling assumption, can be seen analogously to the real world: humans sense information through their senses. Using these pieces of information, humans assess the situation and form a mental model. Analogously, computer models are set up by describing a context utilizing sensor data (see Figure 1).

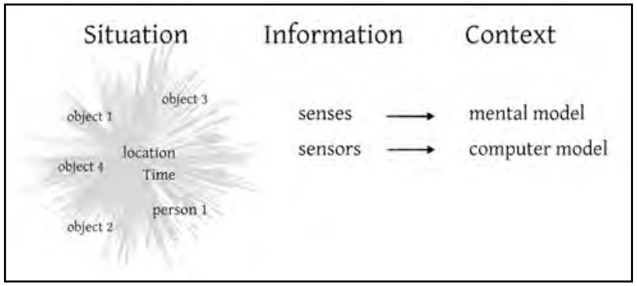

Figure 1. Context Modeling

However, a situation is a much more complex structure and only a set of features (i.e. information) does not suffice to define it. This observation is also motivated by the context definition in textual sciences: “For natural (and informal) languages, the word context denotes the parts of a discourse that surround a word or passage and can throw light on its meaning.” [4]. In this case, the context actually contributes to the meaning of the information or even, what the information is. Hence, information determines context on the one hand, but information is interpreted according to the context in which it is articulated on the other hand. Both arguments are valid, but circular. They therefore appear as an error.

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[1] We here refer to the definitin of Paul Dourish [1], „Embodied phenomena are those that by their very nature occur in *real* time and *real* space“.

However, there is more to it: this circle in the argumentation is particular important in textual sciences, the so-called hermeneutic circle. As an example: the meaning of a paragraph can only be determined with an overall understanding. But an overall text understanding cannot exist without considering the meaning of each paragraph. Moreover, this circular dependency is not to be resolved, it is an interplay of moments: a preconception leads to an understanding of individual moments (e.g. the understanding of a particular paragraph), which in turn has an impact on the overall understanding, which moreover influences the understanding of particular moments. Situations in highly dynamic environments should be modeled on this very level of complexity. For this purpose, we define a situation as a composition of contexts and circumstances in the following section.

Situation, Context and Circumstance

In the following, we define a situation with respect to four aspects: a situation (1) has a *Gestalt*, (2) is comprised of circumstances and (3) is nested.

(1) Situations have a Gestalt

That objects can have a certain Gestalt is a well-known fact and has been discovered by Psychology and Philosophy in the early 20th century. Gestalt here means that the whole is not the sum of its parts. Moreover, the Gestalt determines the parts/elements and their meanings [8,9]. Consider for instance a melody: every tone can be transposed, but the melody remains the same. In contrast, when every tone remains the same but is played figuratively, the melody changes. Hence, the melody attributes a certain (musical) value to each tone. Here, the Gestalt determines its meaning. The relationship between context and information can be expressed in a structurally similar way. Hence, situations share the attributes of a Gestalt: they are very much like musical tones not the sum of its parts [3,6]. Moreover, Gestalts can convey different internal structures. Consider for instance an orchestra. Soloists are basically musicians in the orchestra. Only by setting themselves apart from the rest, e.g. by raising their voice or playing a unique melody, they become soloists. Situations as Gestalts can have the same attributes: elements can emerge or take a back seat. Differences in their Gestalt are differences in their internal structure.

(2) Situations are comprised of circumstances

Situations can have a Gestalt structure such that they require a certain object to be present (e.g. a soloist). But these objects manifest themselves in terms of circumstances. Circumstances are the results of assertions (e.g. an object is present in a room).

(3) Situations are nested

In contrast to contexts, situations can be nested. Typically one argues that situations are defined by the present, the “here and now”. However, the present is influenced by both past and future [7]. Consider for instance being on a shopping tour, while being aware of the fact that you have to take a test the next morning. This might lead you to procrastinating and shopping a little longer to avoid coming home and having to anticipate the tomorrow. In this example, the “now”, the present, is influenced by a future event. Basically, this particular future event constitutes your “now”. Existing approaches in computer science do not consider these emerging Gestalt boundaries. They assume a static “here and now” by e.g. evaluating GPS data, the current time and therefore define a context,

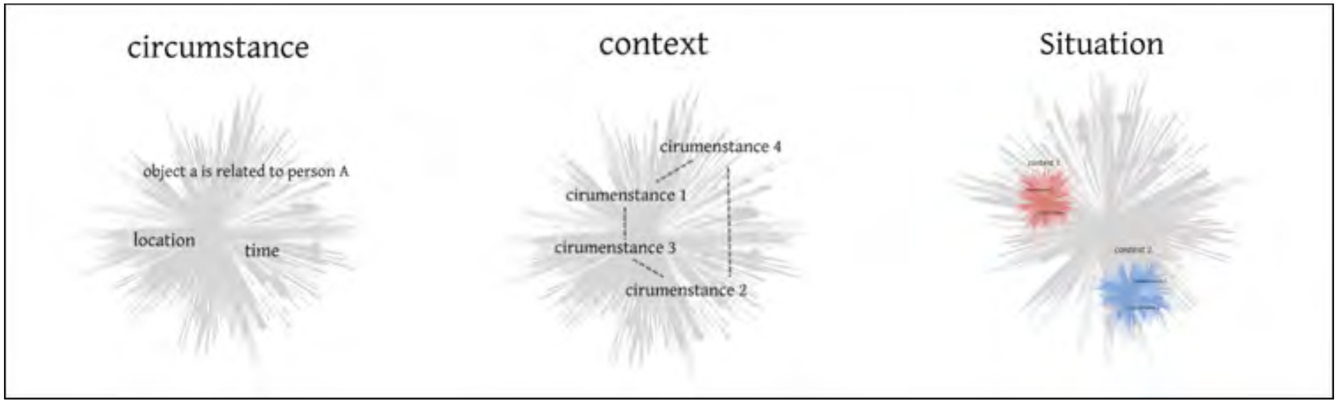

Figure 2. Situations as compositions of contexts and circumstances

comprising various circumstances in relation to a specific situation. A context cannot be nested.

Conclusion

Situations are highly dynamic. Their boundaries are not known a-priori (see Figure 2). They are nested and can span various contexts. Contexts on the contrary are not temporally nested. They are bound to the direct, spatial proximity. Circumstances are the elements of contexts (e.g. the spatial location of an object). These three terms lead to different research challenges. Existing research has mostly focused on the analysis of circumstances, less on context and only little on situations. Particularly for a field such as embodied interaction, the analysis of a situation plays an important role, since the embodiment takes plays in a situation. Computers are embodied in situations and therefore not only dependent on the “here and now”, but also on the past and the future.

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On the Information Potential of Embodied Interaction

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Abstract

The standard model views HCI as two-way information exchange between the human and the computer. Within this model, user's environment has no other role than a source of noise that degrades performance. Understood like this, being "embodied" can only have a detrimental effect, and there is increasing empirical evidence supporting this implication. I have been lately examining the question if "embodiment" could also have positive effects on performance. I argue that a special case of embodiment where the user leverages her capacities of perceiving and acting upon the proximate environment can boost performance.

Keywords

Embodied interaction, human-computer interaction, information theory, user performance

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces – *interaction styles, e.g., commands, menus, forms, direct manipulation.*

General Terms

Human factors

CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

table 1. Negative effects of walking when compared to sitting or standing

- 19 to 23 sec in task completion time in text entry
- 18 to 13 wpm in text entry with a speech+tap UI
- 20 to 15 wpm with a mini-Qwerty
- 19% decrease in menu selection times
- 459 to 603 msec target selection time
- 17 to 30% error rate in target selection with stylus
- 20% audio target selection with gestures
- 26 to 30 sec reading time
- 27 to 23 chrs/sec reading speed.

All references in [1].

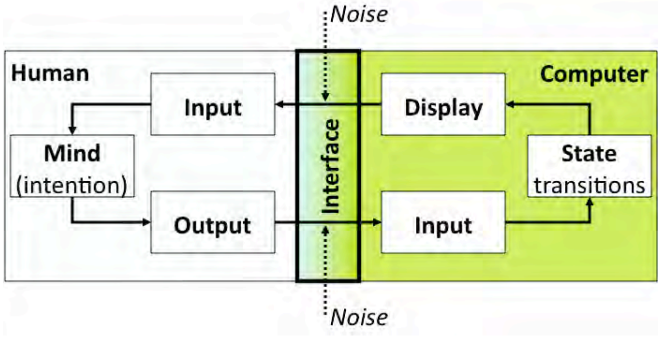

figure 1. Environment is a source of noise in the traditional analysis of human-computer interaction [7].

Introduction

It has become fashionable to talk about contextuality and embodiment as if they were good things. It should be considered troubling that controlled studies where users walk in or otherwise engage with a real environment indicate that the effect of environment on performance is negative. The environment is a source of “perceptual noise”, such as tremble, loud auditory noise, abrupt perceptual events, and bright lighting. The environment also distracts users by “making” them to multitask. This divides their capacities away from processing the interface. Numerous studies show that walking, the defining task of mobility, when compared to standing or sitting, dramatically decreases performance (Table 1). Other common secondary tasks, such as waiting for a bus, drinking coffee, pushing carts, and holding cigarette boxes also decrease performance [2][3].

Could this be otherwise? In particular, could embodiment actually improve performance? As always in science, the answer is that *it depends*. The answer is “no,” if HCI is presumed to be two-way information-exchange (Figure 1). In this traditional model of HCI [7], there is no role for the environment except as a source of noise and, therefore, the effect can only be negative.

In the rest of the paper, I outline a couple of ideas on conditions where the answer may be “yes.” This involves analyzing “embodied interaction” as human-*environment*-computer interaction, i.e. involving environment as part of the interaction loop.

Embodied interaction

To address the question if embodied interaction bears information potential, I have worked to recast embodied interaction in terms of the traditional information-theoretical analysis.

I cannot present the full argument here due to limited space, but Figure 2 presents a schematic where the two-way analysis of Figure 1 has been extended to include Environment. The figure proposes four basic positions in which the environment can be in relation to human and computer as part of information exchange. One-way arrow means feedforward/feedback. Two-way arrows mean that both actors are in an interactive feedforward–feedback loop.

Within this three-way interaction model, I give the following (narrow) definition:

Embodied interaction refers to using the perceivable, actionable, and memorable structure of the proximate environment as a “shortcut” to digital information.

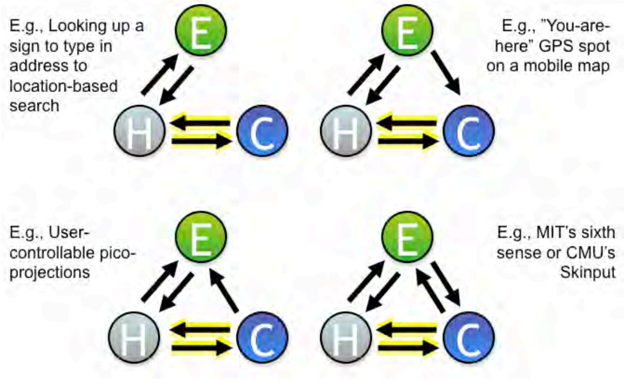

figure 2. Four modes of Human-*Environment*-Computer interaction. The signal between the human and the computer can be boosted by using perceptual-cognitive capacities related to the proximate environment and supported by interactive technologies.

Examples
Let us work through a concrete case. Imagine you are standing on a parking lot of a grocery store. If you are interested in getting information about the store, there are multiple ways you can do it. The present-day method is to pick up your mobile device, launch the browser, point at the search field, type in the store's name (and/or address), and tap a promising-looking result item to view the page. I have asked my colleagues to do this task and it takes more than 60 seconds to carry out.

Alternative, you could use embodiment as follows:

- Point at the store and flex your index finger (click), thereby using your perceptual capacities in locating the store and your motor capacities in identifying it for the computer.

- Turn your upper body to face the store and say "I want information on that store over there," using your perceptual-motor capacities to align your body with the environment in way that the verbal expression "*that* over there" is understandable to the computer.

- Looking through your AR glasses, turn your gaze to the direction of the store and say "yes" when the store is highlighted in the HMD.

These three scenarios highlight that embodied interaction could boost information exchange rates in specific conditions. Using the means in the three scenarios, doing the task would take something in the order of 2-5 seconds to complete.

Another example: the large perceptual field of an embodied user can be levaraged in augmented reality (AR) pointing. In a laboratory study of AR "magic lens" pointing conducted [5], it was shown that having targets available in an A0 size visual background—as opposed to dynamic peephole pointing where they are only visible through the display and visual background is used to localize the viewfinder—increases information throughput from 1.9 bits/s to 3.2 bits/s. In a follow-up study [6], it was shown that real 3-D targets (buildings) at varying z-distances can be selected with a rate of 5.2 bits/s. A caveat to this comparison is that in the previous study the viewfinder was slower and the subject pool somewhat different.

It may occur curious that I have included the GPS dot as an example of *embodied* interaction in Figure 2. The default way of thinking about GPS is that it is an example of context-awareness, the computer sensing the

GPS location to update its content for the user. However, for the user, this information is meaningful exactly because it is his/her present location, which helps him/her understanding the relationship between the perceivable environment and the mobile content better. The crux of the improved information potential here is that this adaptation changes the demand from spatial inference to that of recognition. The similarity to Kirsh and Maglio's notion of epistemic vs. pragmatic action is apparent. Generally, speaking, implementing interactions that leverage this aspect of embodiment requires that the computer is not only aware of its own position in the environment (context-awareness) but also *the user's position in relation to the environment.*

Possible domains for information potentials

As the final point I speculate about where we could discover strategies of embodied interaction. I have been intrigued by the theory of action–neurological systems in 3-D spatial tasks [4]. These distinct systems involve: 1) grasping space, 2) near–distant action space, 3) far-distant action space, and the 4) visual background. From this model, we could derive four different "embodiment spheres" that, on the one hand, are associated with unique neural-perceptual-motor resources. On the other hand, embodied interaction using these unique capacities can take place with *minimal* distraction to simultaneous activities on the other spheres.

The above examples touch on performance with objects and places in the proximal, perceptually available environment. There are also strategies of embodied interaction that utilize *the remembered* environment. Most of the places we visit are places we have been before, and we therefore know something about their spatial structures. Classic theories of spatial cognition argue that there is we have two kinds of spatial knowledge: survey knowledge (topology) and route knowledge. Survey knowledge could be used for example by providing the user with an opportunity to indicate the *direction* of a building by some means and *distance* by other means. For example, index finger could show the direction and extension of the arm could be mapped to distance.

Acknowledgements

This work was funded by the Emil Aaltonen Foundation.

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Understanding Movement in Technology Interactions

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

This paper presents one way to approach the understanding of movement for technology interaction by considering human movement and experience from four different perspectives: movement as object for investigation, movement as subjective experience, movement as a form of knowing, and movement as a social construct. These different perspectives can be used to analyze movements when designing as well as an analytical tool to classify methods for designing of and with movement. From these perspectives a nascent framework extending the concept of user experience is suggested.

Keywords

Body, Embodiment, Experience, Interaction design, Movement, Theory, User experience

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Body, Embodiment, Experience, Interaction design, Movement, Theory, User experience

Introduction

Movements of the human body are involved in all our interactions with technology, and these movements have kinaesthetic and proprioceptive aspects to them. We use our kinaesthetic sense to know that our hand is moving the mouse or that our leg is kicking a ball using Nintendo Wii™ [7], even though we are not looking at our hand or leg as we move them. We also use our proprioceptive sense to know the position of the hand and the leg in relation to the technology and muscular effort involved in the these interactions.

With the overall aim of designing better interaction experiences from the point of view of our kinaesthetic and proprioceptive senses, the research presented in this paper takes a phenomenological approach to studying and designing technology interaction. An embodied perspective is necessary as it makes explicit the body's fundamental role in perception, including the movement experience of our interactions with technology. To this end this paper presents four different approaches towards understanding human movement and experience in interaction design:

- Movement as object for investigation;
- Movement as subjective experience;
- Movement as a form of knowing; and
- Movement as a social construct.

Together, these four approaches provide a way of describing and analyzing movement and movement experience when designing, as well as ways to classify methods that involve the design of and with movement.

Related research include work by Antle et al., Hornecker, Loke, Larssen, Schiphorst and Svanæs, who have explored theoretical aspects of movement and movement experience in interaction design [1, 2, 4, 5, 8, 9]. Antle et al., Hornecker, Klooster, Loke, Moen and Schiphorst have also taken their own, or other designer-researchers theoretical explorations and actualized designs for and with movement, to show how design practice might change and how design emerging from the use of movement focused methods might be different from other methods [1, 2, 3, 5, 8].

We first describe the four different approaches and what they can offer interaction design. We then suggest how these considerations can extend the concept of user experience to include kinaesthetic and proprioceptive aspects of interaction experiences.

The Four Approaches

Movement as Object for Investigation

Movement studied as an *object* for investigation describes movement from a 3rd person viewpoint (e.g. the arm moved), as means to some end (e.g. pressing a button on a mouse), or as an object for others or oneself (e.g. pulling my mobile phone out of my pocket, I become conscious of being observed). This approach is used in much sensing by technology. Technology is often good at capturing movement, but not always as good at interpreting what movement means. Movement as an object for investigation considers movement from the perspectives of both technology and human observers. This approach is concerned with how the movements look or are experienced from a third-person point of view.

Movement as Subjective Experience

Understanding movement and experience as *subjective* experience is concerned with experience from a first-person perspective. The body subject studied in phenomenology refers to the basic, intuitive experience of bodily existence as being-in-the world. An example of this would be the experience of effortlessly walking, running, swimming, paddling or biking. Your movements feel smooth as you move and you do not have to focus on them. Studying movement as subjective experience, provides insights about how to access and address kinaesthetic and proprioceptive experiences in technology design and use.

Movement as a Form of Knowing

When observing a person skilled at what they are doing, it is easy to recognise their skill regardless of the observer's familiarity with the activity. The ease, fluency and confidence, or alternatively the jerkiness and insecurity, of the performance would reveal whether a person is skilled in the activity. Movement as a *form of knowing*, provides insights into the role of the kinaesthetic and proprioception experiences in doing and performing, and the relationship between knowing and doing in the performance of bodily skill. Movement as knowing and understanding can be used to describe movement both from the point of view of the person moving as well as an observer.

Movement as a Social Construct

Mastering different forms of movement in different settings is part of the skills we can learn and acquire as we mature. We know how to move and behave in certain settings; this is deeply ingrained in us as knowing how to move at all. Movements as a *social construct* means considering how social and cultural contexts we are a part of impact on our movements and movement experiences. For example, you are walking along and you become aware of being watched, or you see yourself reflected in a window and become conscious of your movements. You become aware and even self-conscious of your movements. You might appraise your clothes and your posture based on social norms for a particular look, movement or movement style in a setting. Movement as social construct determines, for example, what we wear, what movements we do, as well as when and how we do them, the way we hold our mobile phones in different settings and in different countries. It also determines the movements we might be willing to perform in relation to technology in different settings and in different contexts. This approach enables us to address the communicative role of movements involved in interaction with technology.

The Possibilities of Different Approaches

These approaches disclose and highlight different aspects of movement that are of relevance when considering interactions with technology. Considerations about the kinds of understandings of human movement and experience, that can provide useful approaches for interaction design, are issues of both methodological and epistemological significance. In order to inform the study and design of technology, that relies on movements of the body for interaction, we need these different approaches. They offer opportunities for reflection and allow us to study movement with appropriate analytical rigor, utilizing perspectives that incorporate both the experiences of being a mover and experiences of observing other moving bodies.

A Framework Extending the Concept of User Experience

An explicit focus on human movement and experience in technology interactions allows us to include kinaesthetic and proprioceptive aspects of technology experiences. With these considerations in mind, we suggest that the concept of user experience could be extended. From HCI, we already know that a successful interaction *gets the job done*, I effect the interaction I intended, (clicking CTRL+P to Print or swinging my leg to kick a ball with Wii®). Though, as pointed out by Djajadiningrat et al. [2], some interactions are not driven by ease of use, but *enjoyment of use*. From movement as social construct, we also know that an interaction needs to *look good/right*. People are concerned with how they appear to their surroundings (e.g. elegant, dumb or awkward) while carrying out an activity with (or without) technology, and there are certain movements people are willing/unwilling to perform in certain settings. Finally, an interaction needs to *feel right* to the kinaesthetic and proprioceptive senses – movement as subjective experience. This is not necessarily visible to the eye of an observer, but to the mover's internal senses telling them how an interaction feels. Adding these considerations to those already existing for user experience of movement-enabled interaction, a nascent framework could consist of the following considerations: *to get an interaction done; enjoy an interaction; to look good/right* while carrying out an interaction; and for the interaction to *feel right* at the kinaesthetic and proprioceptive level.

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Design for interface consistency or embodied facilitation?

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

This paper explores how tangible interaction, despite the development of specific frameworks and classifications for system modeling and description, still relies on the body of knowledge from the graphical user interface (GUI) paradigm to guide the design and development of its interfaces. In particular, this paper focuses on this issue in the domain of tabletop computing. Its goal is to explore the tradeoff between insights derived from applying an existing body of knowledge to a new area (e.g. GUI design to tabletops) and those derived from new domain-specific design guidelines and methodologies. It proposes an evaluation that compares two different interfaces for a collaborative tangible system: one built with recourse to the GUI guideline of *consistency*; the other rooted on a theory of *embodied cognition*. The results of this evaluation should be a valuable resource for researchers trying to develop specific methodologies and guidelines for the tangible interaction paradigm.

Keywords

Tangible interaction, embodied cognition, interface consistency, design guidelines.

ACM Classification Keywords

H5.2. HCI: User Interfaces.

Introduction

As the field of tangible interaction matures, frameworks and classifications have been introduced to aid developers in the creation of rich interactive systems (e.g. the TAC paradigm [5]). Such frameworks provide a common ground on which to compare different tangible systems. They typically focus on manipulable tokens and how they can be used to interact with an application. However, in the specific case of systems based on tabletop surfaces (e.g. [3]), most visual interfaces are still built with reference to methods and guidelines derived from GUIs. This is most likely due to the fact that typically these systems rely heavily on multi-touch input and pen-based interaction [6].

This paper questions the suitability of applying design guidelines created for GUIs to the development process of tabletop tangible systems. It also proposes the theories of *embodied cognition* as foundational material for guidelines that aid the design of rich tangible interaction, with a particular focus on how humans off-load cognition onto their surrounding environment. The rest of this paper is organized as follows: (1) a brief introduction to an important design guideline – *interface consistency* – and its implications for tangible interaction; (2) a short introduction to one of the aspects of *embodied cognition* – how users manage cognitive load by using their surroundings; (3) the description of a tabletop tangible application for collaborative routine creation that was developed for evaluation purposes; and (4) a plan description for user studies so as to determine how group performance is affected if a guideline like *consistency* is overshadowed by design decisions rooted in the body of work related to *embodied cognition*.

Related work

Interface consistency

Striving for consistency is an important part of any process regarding the design of interaction or interface. It is Shneiderman's first *Golden Rule of Dialogue Design* [7], and has been the focus of diverse research over the last three decades. A user interface can be consistent: with external features in the real world [2]; with other familiar interface designs; and with itself. One of the key characteristics of tangible interaction is its existence in the real world, normally leading to an interaction that is consistent with the users' real-world knowledge and skills [4]. Additionally, recent work from Ullmer *et al.* [1] has focused on how to develop tangible elements that are valid across different interactive systems. In contrast, this paper explores an interactive tangible tabletop application how can be consistent with itself if critical parts of the interface, such a token representing a tool, can be moved and dropped in diverse locations (even out of the systems' sensing capabilities). It also discusses whether spatial consistency should be enforced, and what the most effective way to achieve this is.

Embodied Cognition

Embodied Cognition is a perspective in cognitive science that grants the body a central role in how the mind operates, and it is clear that many advantages conveyed by tangible interaction can be explained through these theories [8]. In regards to systems based on interactive tabletops, one interesting theory is of how humans exploit the surrounding environment to reduce the cognitive workload required to complete or understand a task. Users can make use of the interface (and surrounding areas) to hold or manipulate information for them, and they then harvest that information on a need-to-know basis only [8]. If users are in control of how they organize the interface (to some extent), will it increase or decrease group performance in collaborative tasks?

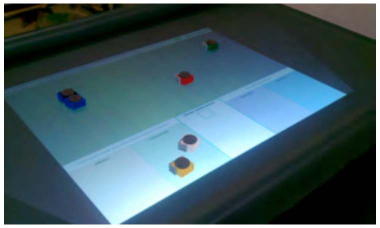
Figure 1. The version of the Eco Planner tangible system that was developed using the GUI design guideline of *interface consistency*.

Eco Planner

Eco Planner is a tangible system that tackles the issue of energy consumption at home, as it allows users to create, manage and analyze their daily routines through tangible objects that serve as physical representations of their activities. It is composed by a set of tokens and an interactive tabletop interface. Each token physically represents an activity (e.g. watching TV, doing the laundry), and users can collaboratively create their household's routine by laying the tokens on the tabletop. The 2D space of the tabletop represents a day of the week (from 7am to 11pm), so tokens placed closer to the left will represent activities to be completed in the morning, while tokens placed closer to the right will represent activities to be performed at night. Likewise, tokens that are vertically aligned on the tabletop represent concurrent activities. Additionally, small objects (pyfos) representing 30 minutes can be aggregated in front of the tokens. These are not recognized by the system, and serve only to help users create a more complete and understandable routine. Also, by placing a token on a specific area of the interface, users can commit to different options for an activity (e.g. with the laundry token, users can choose to commit to always do the laundry with a full tank). Users are also able to choose between ecological or financial motivational cues, changing how the system interprets their routine and the recommendations it offers. Furthermore, due to the physicality and visibility of the tangible elements, Eco Planner aims to facilitate understanding and coordination of activities between users in a household.

Evaluation Plan

In order to determine if design guidelines derived from the theories of *embodied cognition* might be particularly valid and useful as aids in the development of tangible systems, two different versions of Eco Planner were developed. The purpose of this decision is to perform a sort of A/B testing against a version of the interface built with resource to a classic guideline – *consistency*. The first interface contains key areas in the interface where users can drop the activity tokens when not in use. These areas are color coded, each representing an area of a house (e.g. living room, kitchen). The goal of this interface is to provide users with a coherent and consistent drop/pick up point for tokens. The second version of Eco Planner does not provide users with such areas in the interface, allowing them to freely explore both the interaction space and the space around the tabletop as drop/pick up points for tokens. This version of the interface will provide insights into how allowing users to organize a physical interface can impact their performance.

Several metrics will be used in order to compare group performance between the two versions of Eco Planner:

- Time it takes a user to find a desired token, and reach it.
- Occurrence of verbal requests between users.
- Moving of tokens from the interaction space to the periphery of the system (and vice-versa).
- Occurrence of interaction between users when dropping/picking up a token.

- Repositioning of users around the system's surface.
- Variations in these values after a period of learning.

Conclusion

This paper argues that if the field of tangible interaction is to continue to develop, it will need to adopt specific design methodologies and guidelines that reflect its unique features and constraints. Although frameworks such as the TAC paradigm [5] are useful for developers when describing and documenting their systems, many interface decisions are still rooted in knowledge created for GUIs – this is particularly common in graphically rich tangible tabletop applications. This paper considered theories of *embodied cognition* as source for guidelines that might be better matched to the development of tangible interaction. In particular, it focused on how users might take advantage of the interaction space and surrounding area to better understand and complete tasks.

This paper also presented a tangible system for users to collaboratively manage their daily routines. Two different interfaces were developed for this system: one rooted in *consistency*, an important design guideline for GUIs; and the other based on a particular theory in *embodied cognition*. The goal is to study differences in group performance when: (a) users are offered a coherent location to drop tokens when not in use; and (b) users are free to explore the space around them to rest such tokens. This paper ends by proposing how such an evaluation should be conducted.

It is clear that concrete methodologies and unique guidelines are required for tangible interaction to fully take advantage of its users bodies and environment. This paper argues that the theories of *embodied cognition* are a suitable starting point for generating this knowledge. Evaluations such as the one proposed here will help researchers to learn how to apply GUI knowhow to tangible systems, and also to generate dedicated new guidelines for tangible interaction.

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Gestural Interaction for Simulation Training

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Abstract

In this paper, we evaluate the potential use of commodity video game hardware as an gestural interaction tool for simulation training. We consider two possible applications: (i) in providing a simple and device free gestural interface for users who lack gaming skill in the domain of emergency response training, and (ii) to incorporate physical exertion into simulation training. An initial evaluation found that users can quickly adopt the gestural interface and use it to navigate through a 3D virtual environment.

Keywords

Training, Simulation, Microsoft Kinect, Gaming Literacy, Gesture Interaction, Physical Exertion

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation: User interfaces – Evaluation/ methodology

Introduction

Both driving and flying simulators are widely used in their respective fields, and combine virtual environments (VEs) with real interaction devices (e.g., the driving seat of a car or cockpit of an aircraft) [1]. Implicit in the training is familiarity with the interface and interaction devices themselves (e.g., the steering wheel or gear stick). Other examples of simulated training that takes place in a VE include military [7], fire safety [5], medical triage [2] and crisis management training [3]. All of which use a mouse & keyboard interface. Unlike a driving simulator, trainees have to learn how to use the interface, but gain no benefit when applying this skill in the real world. Also, mouse & keyboard interaction is much easier for those that play games, and are practiced in navigating in 3D VEs. There are opportunities to combine realistic interfaces with realistic VEs. Examples include the CyberWalk, Omni-Directional Treadmill [4]), and gesture based gaming [6]. They are, however, both cumbersome and expensive.

We can, however, turn our attention towards video games technologies. The way in which we interact with video games changed dramatically with the introduction of the Nintendo Wii in 2006. Suddenly, gamers could interact using physical gestures rather than simply pushing buttons on a game controller. More recently, Microsoft has joined this revolution with the introduction of Kinect; a motion sensing device that allows gamers to interact hands free, and using their whole body (see Figure 1). The Kinect can provide a low cost opportunity for creating a simple free-handed interface, and incorporating monitored physical exertion into training systems. The proceeding section describes the technologies used in this research, followed by a two potential applications. The paper concludes with a description of an initial evaluation aimed to identify whether gestural interaction, using the Microsoft Kinect, can be used to navigate 3D spaces.

Figure 1: The Microsoft Kinect device and the virtual world used in the initial evaluation.

Kinect, OpenNI and Unity3D

The Microsoft Kinect provides full body motion sensing for less than $200. It uses infra-red to measure distances of objects and generates a 3D view of the world. By feeding this data into OpenNI (http://www.openni.org/), an open source framework for natural interface devices, a joint recognition algorithm allows torso, limbs and head to be tracked in 3D. The coordinates of each of the joints can be detected and converted into a series of gestures (e.g., detecting running or walking by tracking the position of the knees over time). This enables us to create a library of unique gestures specifically aimed at virtual training.

Unity3D (http://unity3d.com/) is a game development environment enabling the creation of rich virtual environments. It is free for non-commercial use, and is highly configurable through the use of scripts and plugins. This gives us the ability to connect to OpenNI though a DLL, and capture the real time gestures recorded by Kinect. By using a script we can modify the behaviour of the system based on the gestural input. The combination of Kinect, OpenNI and Unity3D provides a low-cost environment for researching gestural interaction in VEs.

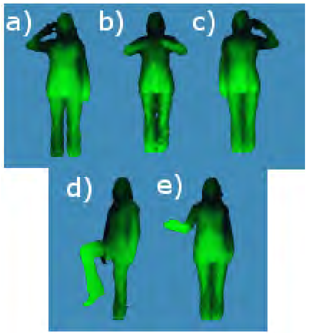

Figure 2: Five gestures captured by the Kinect: a) right hand to right ear, b) both hands on chest, c) left hand to left ear, d) running on the spot to move forwards, e) using left hand to navigate (forwards, backward, left and right).

3D Navigation and Triage

In simulations where trainees navigate through a virtual world, those who are experienced gamers can be expected to perform better. Using Kinect, we aim to develop a library of gestures to help those who do not have this gaming skill by providing a simple and intuitive interface. In the context of triage training for emergency services, where the state of an unconscious body needs to be rapidly identified, we have developed the following five gestures:

1) Check breathing - User place their right hand to their ear, representing the cupping of ones ear when listening intently (see Figure 2a). 2) Check pulse - Placing both hands on the heart (see Figure 2b). 3) Use radio/phone - User places their left hand to their ear (see Figure 2c). 4) Navigate - Using only the left arm, it can be brought up to move forward, and moved from side to side to turn (see Figure 2e). 5) Interact with on-screen content - Using their right hand to control a cursor, and relying on a dwell to initiate a click. The aim is that the gestures represent real and natural actions, making it easy for trainees to remember the interactions and getting them more engaged with the training than simply using a mouse & keyboard.

Exertion Training

Emergency services such as fire fighters physically exert themselves when tacking a fire or rescuing the injured. Training systems that use a mouse & keyboard interface do not incorporate this exertion into the training. We believe that adding a physical factor into simulated training will reflect some of the real physical endurances faced by emergency service staff, adding to the realism of training. As a starting point for this, we have developed a movement gesture that moves users forward in a VE as they walk or run on the spot (see Figure 2d). When combined with the gestures above, users will need to run to an unconscious body before they perform triage. We hypothesise that the exertion will make the decision making process more difficult, and therefore increase the realism of the training.

Initial Evaluation

We performed a pilot study to compare gestural interaction with mouse and keyboard for interacting with a virtual world. The task involved navigating through a series of corridors (see Figure 1). Six participants, five of which played video games regularly, each proceeded along three virtual paths (all of the same length) using three different methods of interaction: (i) mouse & keyboard, (ii) using only the left arm to both walk forward and turn, and (iii) using both arms to turn combined with walking on the spot to move forward. Each participant was given a short training period, then their time to reach the destination was recorded, along with a brief questionnaire. The interface order was counterbalanced, and the following observations were made.

All six participants were able to complete the task with all three interfaces, confirming the possibility that the Kinect device can provide an interface for using gestural interaction in 3D VEs. One participant commented that the gesture interfaces were fun to use. Further evaluation is required to see whether this is a short term novelty or has the opportunity to further engage people in training. This was, however, supported by another participant who said that with both the gestural interfaces he felt more immersed in the VE.

As expected from the short time they had spent with the Kinect device, all six participants performed the task quickest with the mouse & keyboard. Future experiments would benefit from a much longer training period. Five of the six participants performed the gestural task they did first slower than the second (whether it was arm only or walking+arms), suggesting that throughout the experiment they were still benefiting from experience.

Participants found the mouse and keyboard the easiest to use, but also found the single hand interface easier than the physical walking interface. It was observed that, for the walking interface, the software responded differently to each participant based on the way they ran on the spot, from this we can further improve the walking and running algorithms to work with a wider variety of people.

Conclusion

We have shown how gestural interaction can provide an interface for training simulations in VEs. There are two avenues of further work: further evaluation of the gestural interaction for navigation and triage, specifically with non-gamers, and a more detailed investigation of physical exertion, including its benefit, if any, on training for emergency service training.

Acknowledgements

The research for this study was carried out under the CRISIS project, funded by the European Commission's FP7 Framework Programme for Security Research, Grant Agreement Number FP7-24247.

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Kinesthetic Creativity in Participatory Design: A Phenomenological Perspective

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

In this paper we analyze kinesthetic creativity in participatory design from the perspective of Merleau-Ponty's phenomenology of the body. We report from a participatory design workshop where physiotherapists improvised Nintendo Wii games for physical rehabilitation through enactment. We found Merleau-Ponty's concept of *the lived body* to be of value in the analysis.

Keywords

Merleau-Ponty, phenomenology, embodied interaction, participatory design, kinesthetic creativity.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Human Factors, Design.

Introduction

There is a long tradition in participatory and user-centred design for using enactment to give users and designers a shared understanding of the context-of-use

Figure 1. Nintendo Wii controllers.

Figure 2. Nintendo Wii in use.

for future products [2,4]. Enactment has successfully been combined with in-situ technology improvisation, allowing users and designers to explore ideas for future technology and its use [7]. With sensor-based technologies, the user's body becomes an important element of the use situation. (See figures 1, 2, 3 and 4). Involving the users in the design process for such technologies requires methods and techniques that allow the users to explore, experience, and improvise full-body interaction.

The cognitivist tradition in Human-Computer Interaction has proved useful in analyzing important aspects of user's interaction with the computer, e.g. mental models, attention, cognitive load, and Fitts´ law. This tradition treats the interaction as a cognitive process, focusing on the user's mental representation of the GUI. There is little room for the human body in these theories, other than as an object among other objects in the external reality. With sensor-based technologies that allow for full-body interaction, such as Nintendo Wii™, Playstation Move™ and Xbox Kinect™, a cognitivist approach to interaction will result in a number of important blind spots, in particular related to the bodily aspects of the user experience.

In 1986, Winograd and Flores used the phenomenology of Heidegger to argue against the AI approach to systems design [8]. At the same time, within the participatory design tradition, Ehn used the phenomenology of Heidegger to argue for a tool-based approach to systems design [4]. Svanæs found the phenomenology of Maurice Merleau-Ponty useful in explaining the holistic nature of interactive user experience [6]. Merleau-Ponty was found to be particularly useful for understanding the bodily aspects of the user experience. This was also pointed out by Dourish in his work on *Embodied Interaction* [3].

Embodied Interaction

As a number of interpretations exist for *embodiment*, we find it is necessary to positioning ourselves. We do this by comparing with Dourish's use of the term in [3]. Dourish defines *Embodied Interaction* as: "the creation, manipulation, and sharing of meaning through engaged interaction with artifacts" (p.126). For him, embodiment is an approach to understanding human-artifact interaction that appreciates its contextual, situated and social nature. His perspective is inspired by the phenomenology of Husserl, Heidegger, Schütz, and Merleau-Ponty. Although Dourish recognizes that Merleau-Ponty has a strong focus on the human body, there is little focus on the body as such in [3].

From a philosophical perspective, Dourish's *embodiment* is close to Heidegger's concepts of Being-in-the-world (*In-der-Welt-sein*) and Being-with (*Mitsein*). In the present analysis we are closer to Merleau-Ponty in focusing on the role of the body in perception, cognition and communication. As he puts it: "The body is our general medium for having a world" [5, p.146]. It is through our bodies that we are in the world. Meaningful interactions with the world require a body. If I had suffered from total color blindness, I would not have been able to *understand* and *experience* color. Color would have been an abstract concept to me, of which I could have spoken, but with no way of linking it to my personal experience.

From this perspective, Embodied Interaction means taking seriously the fact that all experiences of interaction with man-made artifacts are bodily, and

Figure 3. Nintendo Wii balance board.

Figure 4. Wii Fit slalom.

that the resulting "user experiences" are meaningful at a very basic corporeal level.

A central concept to Merleau-Ponty was that of *the lived body*. The lived body (*le corps propre)* is my body as experienced by myself as me, which is different from seeing my body in the mirror as an object among other objects in the world. Through empathy, we relate to other people not only as objects in the world, but also as other lived bodies. This is the dual nature of our own body and of our relation to other people.

Participatory Design of Full-Body Interaction

As part of a Nordic project on the use of sensor-based technology in physical rehabilitation [1], we performed a participatory design workshop with physiotherapists to explore the potentials for Nintendo Wii technology. The aim of the workshop was to gain insights into the challenges and opportunities for this technology through role-play and improvisation exercises with physiotherapists.

The workshop was conducted as a three-hour session, with five physiotherapists, two facilitators (the authors) and one technician. Prior to the workshop, the participants had tested out some existing Nintendo Wii sports and exercise games to get acquainted with the technology. The session followed the format of role-play participatory design workshops described in [7], where the role of the facilitators is to support the participants and create an environment that fosters creativity, but not to take active part in the creative processes or contribute with design ideas.

Halfway though the workshop we split the participants into two groups, with one facilitator in each group. We asked the groups to come up with an idea for a Wii game for physical rehabilitation. An important part of the ideation process was to let the physiotherapists act out typical use situations. We let the participants use inactive Nintendo Wii controllers as props and blank whiteboards to simulate game displays.

One of the groups had selected kids with cerebral palsy (CP) as their user group. CP patients often do their physical exercises sitting, and the participants focused on exercises to improve the flexibility and mobility of the arms. Figure 5 shows one of the physiotherapists taking the role of patient and acting out a "rotation" exercise with one Wii game controller in each hand.

Figure 5. Participant acting out a use situation.

The facilitator asked the participants to imagine a game for this movement. A number of ideas emerged while they were enacting the movement, and they selected a game with a small ball falling through a circular maze being controlled by the user (Figure 6).

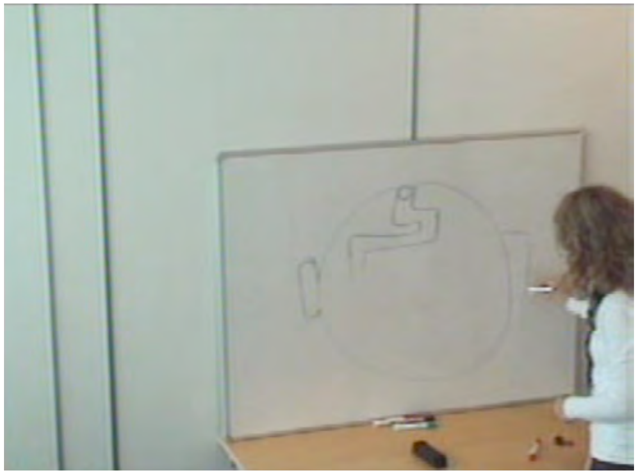

Figure 6. Workshop participant sketching the game interface.

Reflections on the Role of the Body

We observed that the physiotherapists easily took the role of the patient user, and improvised innovative Wii games through full-body enactment. They made active use of their bodies to illustrate their points and to try out ideas. Many of the design ideas emerged as part of acting out exercises, and corporeality was important in all aspects of the ideation process.

We are confident that similar insights and design ideas would not have emerged if we had not allowed the workshop participants to use their bodies to act out future use scenarios and explore the kinesthetic dimension of the interaction. In a similar manner as musicians and composers make use of their musical memory, creativity and communication skills in making music; our designers of full-body interaction made use of their kinesthetic memory, creativity and communication skills in the design process.

Merleau-Ponty´s phenomenology and his concept of *the lived body* have helped us frame our research. A consequence of this perspective is that we should aim for design processes that allow the participants to make use of their kinesthetic memory and creativity, and that foster their bodily empathy with the end user. The aim of our future research will be to identify factors that support this, thus giving participatory design facilitators guidance on the kinesthetic dimension of design.

Acknowledgements

We thank the participants for taking time to participate.

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Formal modeling of Embodiment

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

In this paper we discuss Milner's Bigraph notation as a means for exploring Embodied Interaction. Our long-term aim is to build a platform of principles for successful interaction. Along the way we also consider the place of embodied interaction along side other approaches and philosophies in HCI with the long term aim of producing a "whole person approach" to interaction design and research. We present a short example (informally) modeling an augmented interaction as a bigraph.

Keywords

Formalism, embodied interaction, space and motion

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Formal methods, interaction, design

Introduction

Formal Modelling has had a long though chequered history in HCI. Early attempts using CSP [1] showed some of the advantages but also some of the limitations in terms of

- The focus on computation and the wrong level of abstract
- The need for mathematical skills in understand specifications
- The difficulties in formulating and updating specifications.

These contrast with the dynamic, evolving and fuzzy nature of interaction and interaction design. More recently however, researchers such Wegner [9] and Milner [6] have demonstrated formalisms which attempt to model interacting systems (in the broadest sense). The formalisms themselves are still difficult to use directly. However, the lesson from the Keystroke Level Model (the first notation to model physical, all be it low level, interaction) is that the future role of formalisms is in supporting meta-level descriptions inside user level tools. These tools embody (sic) design and interaction rules [7]. So the challenge for researchers in embodied interaction is how can we, discover, capture and express the appropriate meta-level rules?

Before we move onto that task, we will digress into some of the current philosophical approaches to embodied interaction. Phenomenology as expounded by Dourish [3] is one of the dominant themes in embodied interaction; the idea that the knowledge required to interaction with artefacts is expressed by the user's interaction and experimentation with the artefacts themselves. This knowledge-in-the-world view is contrasted the cognitive, or knowledge-in-the-head view predominant in HCI through much of the 1980's and 1990's. The cognitive perspective has demonstrated its limitations with recent moves to context aware design and the rise of user experience engineering. However, we would argue that Phenomenology also has its limitations as a basis for thinking about interaction, for example

- How do we discuss emotion in a Phenomenological framework? Where is the knowledge-in-the-world that represents emotional states?
- Secondly, Phenomenology has been criticised for downplaying the role of individual perspective on the world. It has been particularly been attacked by feminists [8] as denying the possibility of a gender (internal) world-view.

So, neither, a wholly knowledge-in-the-world nor a wholly knowledge-in-the-head perspective is adequate for given broad explanations of interaction. Applying a wholly knowledge-in-the-world viewpoint to embodied or tangible interaction risks limiting them to certain classes of interacting.

This is where Milner's Bigraph notation comes into play. Bigraphs give a dual expression of computational scenarios with related space and link graphs of the scenario. Thus, broadly, they give an integrated view of space (knowledge-in-the-head) and information (knowledge-in-the-world) and that is a very important feature in all kinds of modern interaction scenarios. Milner himself had used Bigraphs to explore ideas in ubiquitous computing, showing for example, the formal relationships between movements within and around physical space(s) and changes in information space, and vice versa. Benford [2] elaborates further on benefits of Bigraphs, namely

- The modelling of mutual awareness between actors in real and virtual spaces
- The variety of relationships between objects in real and virtual spaces
- Revealing seams in ubiquitous interaction

An Example: The Mixed Spell

As a small example let us consider *The Mixed Spell,* an artwork*,* which is a combination of Nimoy's camera vision piece *Mixed Hello* and Botto's physical interaction*,* piece *C0D3 [The mechanics of a spell],* [4 and video]. In Mixed Spell we wish to augment Botto's physical interaction with camera vision interaction. Whereas Mixed Hello is fairly direct in its interaction, C0D3 is more mysterious and the system's responses do not always follow the user's actions. How do we retain this air of mystery? Let us consider C0D3 as a reactive information space, following Milner. It produces a series of 3d graphic, video and audio manipulations. The initial triggers for the manipulations are user inputs from either voice, data glove or floor pads. However the mapping between trigger and response is dynamic, with random switches both between triggers and responses but also in the how the source material (video, graphics and sound) is selected. So C0D3 confounds the notion that embodied interaction has to be based on knowledge in the world. Conversely camera vision interaction generally demands immediate (usually visual) feedback. Hence we move to look at the space part of the bigraph and look to provide an overlay on the reactive information space. In this case we provide visual feedback to the camera vision actions, which need to be carefully overlaid with the information spaces's output. The overlay needs to provide sufficient feedback to the user's immediate actions without seeming to provide direct feedback to the responses of the information graph. Hence we maintain some of the mystery of the system.

Discussion

Milner and Wegner are chiefly concerned with correctness and verification with (interactive) systems whereas in HCI we are more concerned with preserving design qualities. However, Milner's bigraphs do give us a perspective on embodied interaction that considers complex interplays between physical and information spaces. In our artwork we wished to preserve the quality of mystery and were able to do this by considering the different spaces and their relationship. There are many other aspects both of this artwork and of bigraphs that need further investigation. The most pressing need for embodied interaction would be to produce tools which embody good design principles and enable designers and experimenters to benefit from the underlying meta-level descriptions of design goals and qualities, without engaging with bigraphs directly. We have previously taken this approach in [7] where domain knowledge and meta-rules about how that knowledge can be manipulated are encoded in the Situation Calculus. Birgraphs offer support for a similar approach that can deal with more complex scenarios of embodied interaction. In the long-term, however, we consider that embodied interaction is at one end of a range of interaction styles, which is more correctly encompassed by Whole Body Interaction [5]. And it is within the framework of Whole Body Interaction that bigraphs will find their fullest potential.

Acknowledgements

The author's interest in bigraphs was sparked by a Volcano Brown Bag meeting led by Steve Benford and Tom Rodden, following CHI2010, Atlanta, GA. Thanks to the hospitality of Georgia Tech.

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Cueing the Past: Designing Embodied Interaction for Everyday Remembering

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Abstract

Inspired by Dourish's view on embodied interaction and his design principles, a concept termed 'What are the odds' was developed in order to explore the possibilities of embodied interaction in storing, retrieving and enriching everyday remembering. Our findings indicate that everyday remembering may be a suitable application area due to its abstract and personal nature.

Keywords

Everyday Remembering, Embodied Interaction, Interaction Design, Autobiographical Memory

ACM Classification Keywords

H.5.2 [User Interface]: Interaction styles, Theory and methods; H.5.m [Miscellaneous]

General Terms

Design

Introduction

Digital recording devices, such as mobile phones and digital cameras, make it possible to digitize our past and present experiences, using various types of media. This results in new questions on how interaction design can re-establish the physical interaction with media in the digital world. Do we want to replace physical actions in the world by virtual representations? As Klemmer et al. [8] argue, "although the digital world

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

can provide advantages, there is so much benefit in the physical world, that we should take great care before unreflectively replacing it". From that perspective, they specifically state the room for improvisation in action that the physical world offers and cannot be neglected when integrating the physical and the digital world. Dourish [1] preceded this view with his approach on embodiment and embodied interaction where he states that "Embodiment is how these physical and social phenomena unfold in real time and space as part of the world in which we are situated." Specifically focusing on the physical world we live in, embodiment searches to connect that world to the world of digital data.

This paper works towards creating an understanding of how to design for embodied interaction with interactive systems in the context of everyday remembering. Our study speculates on the value of principles of embodied interaction to that specific context.

Embodied Interaction

In his influential book "Where The Action Is", Dourish [1] approaches embodiment as a phenomenon underlying the two trends that have been emerging in the field of human computer interaction (HCI); Tangible and Social computing. Tangible computing integrates physical representations and mechanisms for interactive control into graspable user interfaces [5], while social computing is put forward as an attempt to incorporate the understandings of the social world into interactive systems [1].

The key to developing an embodied interactive system is based on the understanding that not the designer, but the users themselves create and communicate meaning by interacting with the system. This led Dourish to recommend the following design principles concerning embodied interaction [1] into account: *Computation is a medium; Meaning arises on multiple levels; Users, not designers, manage coupling; Embodied technologies participate in the world they represent* and *Embodied interaction turns action into meaning*. There are very few design case studies to our knowledge showing how these principles have been applied in practice. The aim of this paper is therefore to report one, based on the design of tangible interactive technology to support everyday remembering.

Everyday Remembering

Remembering and how human memory works has been studied extensively. The theory on memory we will use is the constructionist approach [2] which was put forward, amongst others, by Freud. The approach describes how the human memory is a constantly adapting system [6], which changes connections between how ideas, concepts, recent events and patterns are stored in the brain. These events can then be reconstructed when parts of them are cued. Such cues can be of different modalities; e.g. visual cues like photos prove to be effective in reconstructing everyday events [7], whereas scent is strongly linked to emotional memory [3].

Everyday remembering includes activities such as recollecting, reminiscing, retrieving, reflecting, and remembering [9]. Sellen and Whittaker [9] further describe these five activities as beneficial to the current LifeLogging culture, which takes everyday remembering to more extreme levels. The functions of everyday remembering include construction of a self-concept, regulating moods, maintaining relationships and problem solving [6].

Design Explorations

Combining the principles on embodied interaction with the knowledge about everyday remembering, three concepts were developed at the faculty of Industrial Design, Eindhoven University of Technology. All of these explore the possibilities of embodied interaction in storing, retrieving and enriching memories in a 4-day pressure cooker setting. Due to space limitations only one concept will be addressed in this paper. We aimed at exploring the interaction possibilities and interpretations of the Embodied Interaction principles.

Design Concept: 'What are the Odds'

figure 1. The concept: dice showing icons and screens showing photos

By using a set of dice, users can add memory tags to digital photos that are displayed on a set of three thin screens. Each dice offers different possibilities within its own theme. This way tags can be added linked to: whom, what, when, where and weather (this final dice expresses circumstances of the weather that can serve as memory cues). The dice can be used to link the preferred tag to the picture.

The dice can also be used to search through digital images; either by selecting the faces of the dice or by throwing the dice for a random search task. A selection of appropriate photos will be shown on the photo screens. Flicking the screen will scroll to the next picture, thus allowing a manual form of browsing.

Since memories change or adapt over time, links to other memories could start to occur, therefore tagging is a dynamic process. Thus the user can change the tags for each photo collection and can link new collections to older collections by, for example, creating a dedicated dice or icon for that specific memory cue set.

People can use this concept to tell their stories to their friends and family. The concept enables both private viewing with one display and group viewing when all displays are put down, e.g. on a table, for everyone to see.

This concept has been developed into a demonstration video and series of photos that communicate the functionality and interaction method of the product. In group discussions we then evaluated the effects of integration of principles of embodied interaction on the interaction with memory artifacts such as photos.

Discussion

It was our aim to study the compatibility of embodied interaction with designing for everyday remembering. Taking Dourish's main principles [1], we can say we were successful in allowing the user to *create meaning* because the users determine what tags to use and how to compose their memory artifacts, we also see the value of users *managing the coupling* in this situation for they are the ones linking their memories to the cues they prefer.

Remembering is a highly personal activity and we found the principles of embodied interaction applicable because they facilitated users to create their own meanings. In our design case the memory cues were embodied in the dice, which were flexible in linking and appeared usable in a range of reminiscing activities. Still, the dice are predefined artifacts, therefore their appearances and associated meanings are always somewhat influenced by the designer.

Our design case explored the value of embodied interaction to storing and retrieving memories. We believe that by linking more tags to a single digital object (e.g. photo) inherently this object gains more value to its owner. This means that storing a set of tags can cost more time or effort, but will be rewarded when retrieving. For example the photos in the design case: we assume the number of memory cues linked to one individual photo increase through the activity of tagging, because you reflect on that memory from a different perspective, such as the weather. When that photo is later accessed, these tags (visual cues) are expected to enrich the recollection of the associated memory.

In our explorations we looked into linking digital media to the complex nature of memory recollection. Embodied interaction offers a tangible frame for users to work with such memory artifacts (e.g. [4]), whilst still allowing the users to create and add their own meanings to the artifacts.

Conclusion & Recommendation

Through our case study we found that there are many opportunities for designing for everyday remembering from an embodied interaction perspective. Some of the principles appeared particularly suitable to apply to such design concepts, e.g. *embodied interaction turns action into meaning,* and *users (not designers) create and communicate meaning*. Even though this sounds obvious, human memories cannot be accessed directly, therefore a designer should look into the opportunities for coupling (potential) tags to tangible memory artifacts. We found that the embodied interaction perspective offers an approach through which memory artifacts can be created flexible enough for users to create their own meaning and can fit their everyday use and context.

Acknowledgements

We thank our colleagues in the Industrial Design department for fruitful discussions on the theme of this paper.

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Instruction and Embodied Design

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

We present a recent embodied-interaction instructional design, the Mathematical Imagery Trainer (MIT), for helping young students develop a grounded understanding of proportional equivalence (e.g., 2/3 = 4/6). The implementation of this design serves as our context for developing a heuristic design framework for instructional embodied-interaction activities.

Keywords

Educational technology, mathematics education, embodied cognition, Wii remote, design-based research, design theory.

ACM Classification Keywords

H.5.2. [Information Interfaces]: User Interfaces—input devices and strategies; user-centered design; child-centered interaction.

General Terms

Design, Human Factors, Theory.

Introduction

Humans develop embodied reasoning through sensorimotor interaction in their respective environments, a capacity that has been implicated as fundamental to reasoning [3]. As learning scientists whose work intersects both theory and design, we are interested in

- how students may be guided to leverage their embodied reasoning in accomplishing pedagogical tasks; and
- with embodied cognition frameworks gaining ground in instructional technology [2,4,6], how might we as a field move toward articulating a heuristic design framework for embodied-interaction activities?

Embodied interaction

Embodied interaction (EI) is a form of technology-supported multimodal training activity. Through engaging in EI activities, users are expected to build schematic perceptuomotor structures consisting of mental connections between, on the one hand, physical actions they perform as they attempt to solve problems or respond to cues and, on the other hand, automated sensory feedback on these actions. Emblematic of EI activities, and what distinguishes EI from “hands on” educational activities in general, whether involving concrete or virtual objects, is that EI users’ physical actions are intrinsic, and not just logistically instrumental, to obtaining information. That is, the learner is to some degree physically immersed in the microworld, so that finger, limb, torso, or even whole-body movements are not only in the service of acting upon objects but rather the motions themselves become part of the perceptuomotor structures learned. EI is not simply “hands on” but “hands in.”

As instructional activity, embodied interaction designs are often inspired by Constructivist pedagogical philosophy that draws on the genetic epistemology of Jean Piaget, the important Swiss cognitive developmental psychologist. Specifically, the design rationale of embodied-interaction instructional activities draws on the implication of goal-oriented sensorimotor interaction as mediating cognitive growth leading to conceptual knowledge. The design is further inspired by grounded-cognition research, and notably the empirically supported conjecture that human reasoning consists of simulated modal activity and not of processing symbolically encoded propositions [3].

In one form of embodied-interaction activities, representative of our work, the designers contrive a microworld wherein the physical solution actions inscribe the conceptual image of the emerging disciplinary notions. We now elaborate on one such design currently active at the Embodied Design Research Laboratory (Abrahamson, director).

MIT: Mathematical Imagery Trainer

We conjectured that students’ canonically incorrect solutions for rational-number problems—“fixed difference” solutions (e.g., “2/3 = 4/5”)—indicate students’ lack of dynamical action plans to ground proportional concepts. Accordingly, we engineered an embodied-interaction computer-supported inquiry activity for students to discover and practice presymbolic dynamics pertaining to mathematics of proportion.

Our instruction design, the Mathematical Imagery Trainer (MIT, see figures below), leverages the high-resolution infrared camera available in the inexpensive Nintendo Wii remote to perform motion tracking of students’ hands. We used battery-powered, hand-held IR emitters that the students point directly at the Wii camera. With LEDs repurposed from generic TV remote controls, these emitters have a wide enough angle of operation to robustly capture students’ hand motion.

The Wii remote is a standard Bluetooth device, with several open-source libraries available to access it through Java or .NET. Our accompanying software, called WiiKinemathics, is Java-based and presents students with a visual representation on a large display in the form of two crosshair symbols (trackers).

When a user raises her hands at a fixed vertical distance from each other in front of our "mystery" device, the screen turns red, but when she raises her hands at a proportionately increasing distance (e.g., right hand at twice the height of her left hand), it turns green. In our research, students are tasked—individually or in pairs —to "make the screen green."

Over the course of the interview, the MIT provides students with an opportunity to experience proportion in a controlled, progressively mathematized setting.

This student is holding the IR emitters at appropriate heights (2 and 4, in this case), effecting a green screen. A black matte surface on the desk helps reduce glare that can confuse the Wiimote's IR camera into seeing two IR sources. See http://tinyurl.com/edrl-mit2 for a 5 minute video clip showing the MIT in use.

figure 1. The MIT in use by a 5th grade student during a clinical interview.

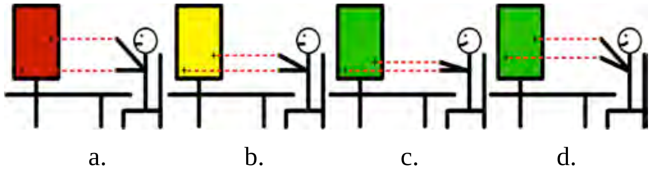

figure 2. An example of MIT in use with crosshairs and a 1:2 ratio. A student exhibits (a) incorrect performance; (b) almost correct performance; (c) correct performance; (d) another instance of correct performance.

figure 3. MIT in use by a pair of students. Shown above is an advanced stage wherein students control the MIT via a table of ordered pairs.

Towards an embodied-interaction framework

Drawing on data from a recent study involving 4th-6th grade students interacting with the MIT [1,5], we are presently engaged with developing a theoretically coherent, empirically grounded heuristic design framework for embodied-interaction mathematics problem-solving learning activities. While grounded in our work with the MIT, we believe the principles we have articulated thus far are general enough to apply to a range of instructional problems:

1. The designer selects/engineers a learning environment that includes a device linking simple physical actions remotely to generic virtually displayed objects.
2. The designer plans and implements mathematization-trajectory supports in the form of layerable/removable symbolic artifacts.
3. Students' physical action should not only enable the gathering of data but actually constitute an integral component of the data. Moreover,
4. Students' physical solution procedure has to inscribe the conceptual metaphor of the targeted mathematical notion.
5. The inquiry should be self-adaptive, not prescriptive, so that each child can gather the data they need when they need it.
6. The student should be able to move back and forth between embodied and symbolical control operations.
7. The student should be supported in coordinating among various meanings emerging from the activity by explicating relations among the different strategies they discover.

Embodied-interaction media thus appear to bear the capacity to enable student presymbolic inquiry into complex mathematical ontologies, such as proportion in the case of our work. The approach we have taken is to craft designs that manifest the target concept by creating a problem for which the physical solution procedure dynamically inscribes an innovative conceptual metaphor of the target content. While our work is in its early stages, we hope to have conveyed some of our enthusiasm over the instructional possibilities offered by embodied interaction technologies. Our future work will continue to seek improvements in both theory and design.

Acknowledgements

The MIT project was sponsored by a UC Berkeley Committee on Research Junior Faculty Research Grant (Abrahamson, PI) and IES pre-doctoral training grant R305B090026.

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Extending Interaction to the Periphery

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

Communicating information in the periphery of human perception is common practice in the design of ambient systems. However this normally leads to passive, non-interactive displays. We propose the concept of peripheral embodied interaction, which is carried out in the physical world on the periphery of the users' attention. We offer a classification of peripheral embodied interaction consisting of five design dimensions and show two initial prototypes, which incorporate peripheral interaction capabilities.

Keywords

Embodied interaction, peripheral interaction

ACM Classification Keywords

H5.m. [Information interfaces and presentation]: Miscellaneous

General Terms

Design, Human Factors

Introduction

The concept of ambient information – information, which resides on the periphery of the users' attention but can move to the focus [4] – is widely accepted in HCI research. Many systems have been proposed but only very few of these systems are interactive. We believe that the notion of ambient information can be extended to include interaction, leading to an interaction style that can be carried out alongside the users' current primary task without asking for their full attention.

A related concept was introduced by Darren Edge: peripheral tangible interaction [2, 3]. He defines it as "episodic engagement with tangibles, in which users perform fast, frequent interactions with physical objects on the periphery of their workspace, to create, inspect and update digital information which otherwise resides on the periphery of their attention" [3]. By considering further physical capabilities, this idea can be expanded from tangibles to embodied peripheral interaction. This paper proposes a classification of peripheral embodied interaction and shows two experimental prototypes.

Peripheral Embodied Interaction

Our understanding of embodied interaction is in line with Dourish, who describes it as the attempt "to move computation and interaction out of the world of abstract cognitive processes and into the same phenomenal worlds as our other sorts of interactions" [1]. Users do not have the feeling of interacting with a computer, but rather act in the non-digital, physical world.

In our everyday life excluding the personal computer, we carry out small activities with a flick of the wrist in parallel to our current primary activity without really focusing on them. We can, for example, easily move a cup out of the way while talking to somebody. This is very natural to us and does usually not require a very precise execution. On the PC in contrast, even very simple tasks often require a context switch, precise pointing or exact knowledge about certain key presses.

We argue that especially simple things, which do not belong to the current primary task (e.g., typing a text), but still matter and require interaction (e.g., setting the status in an instant messenger) will benefit from new forms of embodied interaction. Our goal is to improve multiple task situations by moving secondary tasks away from the classical computer interface into the physical world around us. Ideally we keep the interaction belonging to the secondary task simple and casual, not requiring precise actions, and thereby reduce the mental load caused by it to a minimum. This form of interaction we call peripheral embodied interaction.

Design Dimensions

Peripheral embodied interaction can be carried out in many different ways, e.g., speech, gestures or eye tracking. More formally, one can categorize each interaction in five design dimensions: explicitness, input mode, granularity, privacy and proximity.

Explicitness

Explicit interaction is the common way to interact with a computer. Commands are purposefully given by mouse or keyboard to execute an intended step. In contrast, implicit interaction is defined as "an action performed by the user that is not primarily aimed to interact with a computerized system but which such a system understands as input" [5]. Explicitness hence is a dimension ranging from explicit to implicit interaction.

Input Mode

For peripheral embodied interaction, many input modes can be imagined. Gaze can be tracked and serve as input, as well as speech. Hands can be used to perform gestures or manipulate tangible objects. Other body parts can also be used depending on the situation.

Granularity
Depending on the form of interaction, a different number of commands can be encoded. For example, glancing at an object encodes two levels – looking or not looking at it. In contrast, speech input enables an infinite number of commands. Casual hand gestures, such as wiping to and away from oneself, leave fewer options, while more precise gestures, e.g., a single or multi stroke gesture, can encode much more commands. Granularity for manipulation of a tangible depends on the tangible and its characteristics.

Privacy
When we are typing or using the mouse, bystanders can really only tell what we are doing if they see the display. Peripheral embodied interaction can be observed much more easily, depending on the input mode. For sensitive data, this should be taken into account when designing such a system. In addition to public and private data there is personal data belonging to the user but not secret to others (e.g. presence in the office).

Proximity
Interaction can happen over a variety of distances. While manipulating a tangible usually requires the tangible to be reachable by hand, glance and speech recognition can be carried out over a larger distance.

Prototypes

We have built two prototypes using the notion of peripheral embodied interaction:

Ambient Appointment Projection
The ambient appointment projection (figure 1 left) offers a spiral visualization of the overall time flow of upcoming appointments, which is projected on the users' desk. Once an event is coming close, the spiral starts pulsating to remind the user about the appointment.

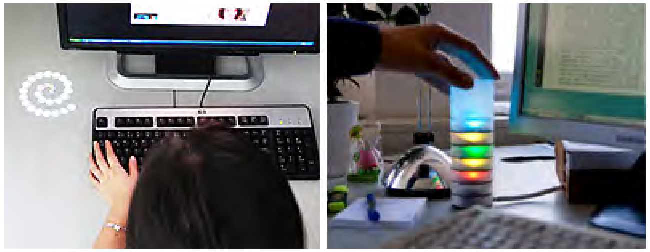

figure 1. Two prototypes: the ambient appointment projection (left) and the tangible presence indication (right)

Peripheral interaction happens by a wiping gesture of the hand, which is tracked by a camera. Wiping towards the user will offer details about the next appointment as a balloon tooltip. Wiping away from the user stops the pulsating of a reminder. Using this embodied approach, the users do not get disrupted as forcefully as by state-of-the-art reminder pop-ups. The gestures have been selected to meet the metaphor of fetching wanted or pushing away unwanted things. The casual nature of the gestures ensures that the users do not need to focus their attention on this interaction.

The appointment projection was tested in a lab study with twelve participants and smooth handling of appointments was attested to it.

Tangible Presence Indication
A cylindrical object consisting of several levels (figure 1 right) shows presence information about the user (biggest and topmost level) and selected contacts (other levels). The object is connected to Skype and encodes

customized statuses (communicated in Skype as mood messages) besides the standards “available”, “away” and “do not disturb” in a color-coded way. We hope to support more accurate and detailed statuses with this prototype and thereby reduce unwanted interruption but also encourage communication.

By turning the topmost level, users can set their status, by pushing down this level, which integrates a button, they set the time they expect to be in this state. Again, this can be carried out without switching the context on the screen. Adjusting information by turning or pushing a button is very natural in the physical world (e.g., for controlling a stove or audio equipment). The object was built based on the results of a survey with 46 participants. A long-term user study is being planned.

Classifying the Prototypes

Figure 2 shows the two prototypes classified along the five design dimensions. Both systems use explicit interaction, operate on personal data (calendar data and presence information) and need to be nearby for interaction. The appointment projection interprets gestural input with a low granularity (wiping towards and away from the user) while the tangible presence indication supports interaction trough object manipulation with a medium granularity (nine statuses).

Conclusion and Future Steps

In this paper we proposed the concept of peripheral embodied interaction and a classification for it along five design dimensions. We built two initial prototypes for peripheral interaction – the ambient appointment projection and the tangible presence indication. First user study results support the concept and the expectations we have for its usefulness.

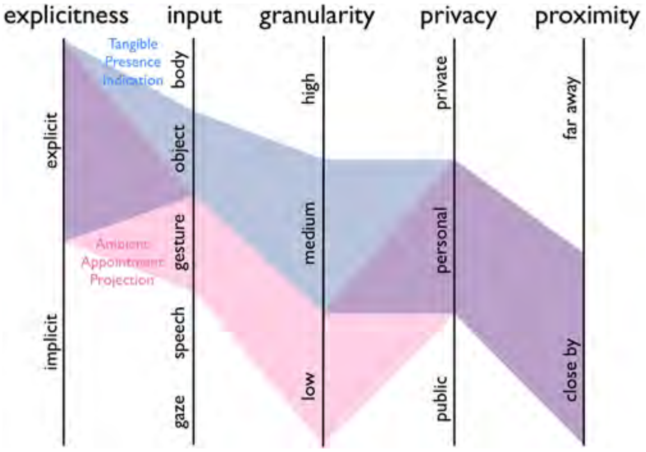

figure 2. Classification of both prototypes along the five design dimensions

In the future more prototypes need to be built to test the whole spectrum of the classification and to depict best practices for peripheral embodied interaction.

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How to facilitate physical skill development in Exertion Games

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

Throwing is an important physical skill that lays the foundation for the ability to participate in many physical activities and sports experiences. We aim to support the development of physical skills through exertion game design; our focus here is on the design of an exertion based throwing game that aims to help children improve their ability to throw. We discuss the results of some initial play testing, and how these observations can inform future game design to offer us insights into how technology can support the development of physical skills, important for physical health.

Keywords

Exertion Interface, interaction design, kinesthetic literacy, learning, gaming, whole body interaction

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation: Prototyping, User-centered design

Introduction

The virtuosos in any professional sport are those who started playing the sport at an early age and had positive experiences. For them, sport is a form of entertainment, an exertion activity that they're good at.

Children who are not physically well coordinated find such exertion activities strenuous, both physically and mentally. Miracle and Reese [3] cite instances where athletic participation can inhibit character formation. Negative youth sports experiences can erode motivations for participation, produce excessive stress, and destroy feelings of self-worth. Physically ill-coordinated children often find it hard to catch, throw and dribble, which are fundamental activities in many sports. This inability to catch and throw needs to be addressed at an early age to give the children a better chance of picking up or learning to play a sport in the future.

Given that today's average college student has spent over 10,000 hours playing video games [2], we propose to use this digital technology, coupled with exertion activities like throwing and catching, to encourage children to play more physical games, and gain kinesthetic literacy in the process. Would pairing a traditional sports game with interactive digital technologies help make it more fun for children to play? What would such a game look like and what aspects of game play would make children want to play it again and again? These are some of the questions we set out to answer. Specifically, we would like to understand the opportunities and challenges involved in using technology to make exertion games for children more engaging. We believe by making games more engaging, we can enhance opportunities for learning physical skills, which will contribute to further participation.

Embodied Interaction

Our work aims to make a unique contribution to embodied interaction as it asks the question how technology can facilitate kinesthetic literacy. As such, it points not to the common "learning through body skills" (e.g. gaining knowledge about tactics in football by playing football), but rather to "learning body skills" (learning how to throw by playing football), and asks the challenging question of how we can support the development of bodily skills [5]. We are interested in understanding how technology can help children who might have some knowledge about throwing (move your hand in a particular motion and release the object at the right time), to develop the skill required to throw through the practical experience of doing it and seeing the results [5]. We therefore propose to use an embodied interaction approach to investigate exertion games [1] to help develop the kinesthetic literacy beneficial to execute a throw.

By the "embodied interaction" approach we mean an approach that considers the aspects of bodily skills that are integral to the learning process, and in which the supporting technology facilitates gaming, learning, and bodily skills at once.

Sheridan et al. [6] suggest that kinesthetic literacy involves two major learning objectives, *learning to move* & *moving to learn. Learning to move* asks participants to focus on an understanding of the body in order to acquire the skills and techniques that are required to participate in physical activities. Doing so allows participants to take control of their body and to know its range and capacity for movement. Learning in this context often focuses on "fine-tuning" motor control and fundamental aspects of movement such as hand-eye coordination, coping with space, speed and distance. In *moving to learn,* the physical activity is the context for a means of learning. Sheridan et al. have also used tangible exertion interfaces to explore this concept [4, 5]. Our game will explore the first of the two objectives, while also attempting to take it further. We would like to present the game so it seems less about learning to throw, and more like a game that children would like to play repeatedly. By abstracting the pedagogical aspect of the game and getting the children engaged in the act of throwing repeatedly through game play, we hope they will develop the kinesthetic literacy required to execute a throw.

Game Prototype

To ground our design decisions and lay the foundation for the game design, we developed a game prototype and informally play tested it. The goal was to ascertain what aspects of a throwing based exertion game would keep children engaged. The main components of the prototype were a baseball pitchback (5' X 3'), a baseball/softball, a Wiimote, Processing code on a laptop, a projector and speakers.

Figure 1: Pitchback with Wiimote

Children threw the ball at images that were projected on the pitchback (Figure 1). The vibrations on the net of the pitchback varied based on the intensity of the throw. A Nintendo Wiimote was used to pickup the vibrations from the pitchback. The Wiimote was connected via Bluetooth to a laptop running Processing code. The code was written to pick up the vibration data being sent from the Wiimote and give appropriate visual/aural feedback, which we describe below.

Participants for this play test were two children aged 8, who were actively involved in a variety of sports. For the purposes of anonymity, the boy will be referred to as Jack and the girl as Jill. We first projected the image of a glass pane onto the pitchback. The harder one threw at the glass, the more it cracked. The sound of the breaking glass also changed based on the intensity of the throw.

The next set of images we used were those of the kids themselves and their family members. We used these to see if the kids would be willing to throw the ball at images of themselves, their dad, their sister and their dog. Different sounds were also played to match who was hit with the ball.

Results / Observations

The results were based on our observations and interviews with the kids, both during and after the game play. Some of the interesting results that came out were

- When asked to throw the baseball, Jack started off by taking a short run-up and throwing the ball with all his strength. When asked to throw with an imaginary ball, Jack just stood there and moved his hand, pretending to throw. While he believed his movements were identical, it was obvious to an outsider that the bodily actions were very different. This leads us to believe that having a real ball in the hand makes a difference to how kids would execute a throw.
- The kids enjoyed throwing the ball at images of the glass as well as their family. When asked which of the images came first in the sequence, the kids said their dad's; while actually, it was the images of the broken glass that were shown to them first, before the family pictures came up. The personal connection that the children shared with the images seemed to have influenced their engagement with the game.

- Jill was initially discouraged by the game as her throws did not produce any visible or audible feedback, i.e. the glass did not crack. This was because the program had been coded to provide feedback on higher levels of vibration received from the Wiimote and Jill's throws were not strong enough to produce these vibrations. Once the code was modified to pick up lower level vibrations as well, Jill enjoyed the game more. Having the ability to customize the game based on the player's ability might be a worthy feature.
- Jill was scared to catch the ball when it bounced back from the pitchback, while Jack, who played more and was more passionate about sports, was comfortable catching the baseball. A softer ball would have reduced the risk of injury and may have been ideal for Jill. A softer ball might also enable children of all ages and abilities to play the game.

Limitations

Our play test did give us insights into what children might like in a throwing game but we had only two participants, who were pretty excited about playing outdoors. Although our game does cater to this demographic, we would also need to test the game with children who don't enjoy or have not played much sport. We were not sure how much our participants learnt about throwing, if anything at all and were mostly concerned about engagement and to this extent, we believe the play test gave us some interesting ideas to explore.

Conclusion

We've presented here our approach to developing an exertion game that incorporates learning of body skills into game play. We did some initial testing which gave us interesting results about children and engagement in games. To take the game to completion, we're planning an iterative process of design, prototyping and play testing. This project is in its early stages, and we're looking forward to feedback from the workshop participants.

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Embodiment: We’re Just Human

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Abstract

This paper advances the proposition that the embodied mind is one that supports activity in a physically spatial, temporally dynamic, social and cultural, and emotional world. Embodied interaction then is the design of interactive systems that engages this mind. We discuss each of these aspects, providing examples of research motivated by the concepts.

Keywords

Embodied Interaction, Theory of Mind, HCI

ACM Classification Keywords

H.1.m. Models and Principles: Miscellaneous

General Terms

Theory, Human Factors

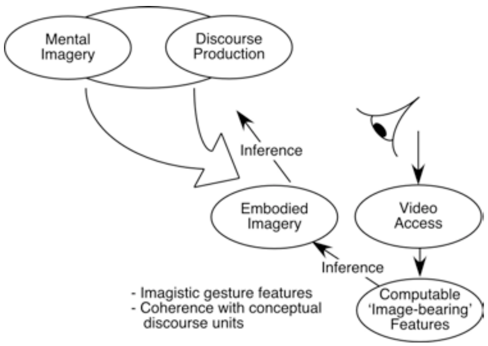

Figure 1. Catchment Model of Multimodal Language

Introduction

A student in my Embodied Interaction class once asked if a keyboard and mouse are embodied because obviously the body is used in operating such interfaces. Curiously, the answer must be ‘yes’. They engage our ability to offload work into automatic motor activity with a familiar keyboard layout, and our Heideggerian capacity to couple action through the mouse as tool. Without such capacity for ‘what our body knows’, mouse and keyboard activity would be impossible. The challenge with this perspective is that the concept of embodied action may become so trivially true as to become scientifically uninteresting. Furthermore, for HCI, on what criteria may one judge one interface as being more ‘embodied’ than another? In this paper, we shall explore a model of embodiment that focuses on mind. Put succinctly, the proposition is that *the embodied mind is one that supports activity in a 1. physically spatial, 2. temporally dynamic, 3. social and cultural, and 4. emotional world*. Embodied interaction then is the design of interactive systems that engages this mind.

Embodiment and Language

What led me to the study of embodiment is research in multimodal human language (MHL). When we speak, our heads, eyes, bodies, arms, hands, and face are brought into the service of communication. A common thread that flows through modern gesture research is that spontaneous gesture and speech are inseparable parts of the same whole. While gestures are brought into the service of communication, this is not their sole purpose. In fact, gestures are performed not so much for the hearer, but for the speaker [1] (this is why we gesture while on the phone). It reveals how we use the resources of the body-space to organize our thoughts, keep context, index our ideas, and situate/shape our mental imagery out of which our talk flows. Our capacity for spatial memory, situated attention, and motor activity fuel these embodied resources. Our approach to understanding multimodality in language is illustrated in Figure 1: mental imagery and spatial structuring participate in the pulse-by-pulse conceptual construction of discourse (language at the super-segmental level of units of ideas rather than specific syntactic units). These imagery and spatial structuring present themselves in body behavior that is temporally situated with speech at the micro-level (gesture-speech synchrony reveals this tight causal relationship). The units of cohesion are the specific imagistic features that carry the unit of thought. We have demonstrated segmentation of speech into idea units by the features of hand use, oscillatory action, hand motion symmetries, and spatial loci [2-5]. Hence the ‘multi’ part of multi-modal lan-

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

guage is entirely in the eye of the beholder – for the speaker, the genesis is single. From the perspective of the viewer or sensing technology, the signals appear several (audio, visual, and tactile channels).

That speech, which is often thought of as the means of encoding purely symbolic information, is permeated by embodied conceptualization suggests that embodiment is not just about the body. We explore this ascension of embodiment into mind in this paper.

Functioning in a Physically Spatial World

The mind is 'designed' for us to function in a spatial world. Our tremendous capacity for spatial memory and reasoning can be brought into service of a broad range of activities as we have observed in human discourse construction. This has implications in how we develop systems that employ physical space to support reasoning, information access, and general interaction.

It is not just space that is important, but that this space is physical, and not just graphical, virtual, or abstract. This space has physical extent, and is populated by physical objects. Here, Vygotsky's concept of the *material carrier* (*MC*) helps us to frame interaction. *MCs* work with another Vygotskian concept – that of signs as the mental objectification of thought, and allows us to bring our capacity to manipulate that which is abstract or distal from our physical presence.

One example of an interactive system that employs space and physicality is our TanTab system [6] to support learning of geometry in PreK to Primary 3 students. We employ smooth transitions between physical manipulation of geometric objects, multi-touch interaction with concomitant graphical entities, and direct control of geometric parameters (via proxy tangible objects) to support the equivalent transition between intuitive geometric problem solving and learning of abstract geometric concepts. A critical aspect of this design is that we employ a horizontal display surface as a table on which physical objects may be manipulated, and the same space is employed for graphical and parametric interaction to support concept development.

Functioning in a Temporally Dynamic World

Another aspect of our embodiment is the temporal and dynamic nature of our world. *MHL*, for example, shows how gesture and speech are exquisitely timed, and how the complexity of the cohesion and multimodality suggest that the imagistic display could not have been consciously constructed. Because the world is dynamic, embodied cognition is similarly dynamic.

One challenge to HCI, however, is to understand how one may harness this dynamism in real-world interactive systems. Here, we connect our model of embodiment with an allied concept – that of situated cognition and context, and with two further concepts: attentional focus and familiarity. I suggest that the structure of the world leads to predictability within context. This permits the development of experience, and experience essentially allows us to focus our processing so that we attend to those things that are essential, and ignore things that are unimportant. An experienced driver does not think faster, she knows where on the road to direct her focus, and where dangers lurk. An experienced chess player may not examine more alternatives, but she knows what alternatives need to be examined. Context allows the human mind to optimize for function within situations – with a finite set of resources. It is part of the strategy of mind to deal with finite bodily action within a complex time-pressured world.

I am not saying that we need to build interfaces entirely based on familiarity. This would be counterproductive, locking us into the past, and ignoring possibilities presented by new technologies like new slate-type computing. Fortunately, human embodiment is not marked by familiarity, but the capacity to become familiar. Drop an American into the chaotic traffic situation in Malaysia where they drive on the other side of the street, and she would become disoriented. With experience, she would adapt and know that she needs to look right, then left, then right again before crossing a street (as opposed to the other way around in the US). The seeming chaos eventually yields to a framework of predictability. A deer, on the other hand, would never learn the order to look before crossing a street in either country.

This intuition about familiarity to function in a dynamic world led us to develop a gaming system grounded in narrative as opposed to performance for older adults [7]. As one ages, a trade-off takes place between functional capabilies (e.g. mental processing speed, short-term memory capacity) for experience and knowledge. We showed a preference among older adults for familiar narrative game scenarios.

Functioning in a Social/Cultural World

Society is not an accident. Humans are social beings, and our mind and body are designed for us to function within community. It has, for example, been posited that humans have distinctive white sclera to support nuances of social communication, and that the capacity to recognize human facial displays has both innate and learned components. Our work on *MHL* has, for example, shown how social gaze behavior participates in the construction of a 'joint mind' in discourse [8].

One direction of research that this perspective has motivated is to investigate how we may organize and re-find our information through socially-grounded tagging. Our SocialOrb system employs physical proximity detection, digital communication tracking (e.g. e-mail attachments, instant messaging), and tracking of computer operating system events (e.g. files being opened, closed, or saved, and internet sites visited) to tag files with their use within different social orbits [9]. The intuition is that social context furnishes a powerful mechanism for users to recall information.

Our work on supporting multimodal instructional discourse for individuals with blindness or severe visual impairment (IBSVI) is similarly motivated by the concept of embodied social communication [10, 11]. We developed a *haptic deictic system* (*HDS*) to help IBSVI students to navigate a raised line version of a graphical presentation over which a sighted instructor speaks and points. The *HDS* tracks the instructor's deictic focus and the student's reading hand, and guides the student to where the instructor is pointing via a haptic glove. This research showed how discourse requires more than the pure ability to sense directions in the glove. To support embodied discourse, the student's ability to navigate with the glove had to become automatic (or embodied) so that she can focus on the higher-level cognitive task of discourse fusion (linking the instructor's speech with the focal information on the graphic).

Human society evolves over time through cultural advancement. This brings the study of creativity support directly into purview of embodied interaction. Human innovation, and the social mechanisms by which these innovations are admitted to alter the culture are the means by which the individual contributes to culture. To operationaize these concepts, we return to the theories of Lev Vygotsky that describe creativity as having two components: process and substance. For Vygotsky, the creative process is one of recombination of prior knowledge that has been properly decomposited and internalized as usable signs. Fluency (familiarity) with the prior knowledge is the substance to be recombined. This perspective may explain the apparent torrent of (embodied) creative activity in young children before they achieve sufficient knowledge to truly contribute to culture. Innovative activity is as much a part of being human as hunting is to tigers. Consequently as tiger cubs practice the kill in play, so human young exercise the process of creative recombination ahead of acquiring sufficient knowledge to create.

This perspective motivated us to start a project in supporting creativity in children in the 'at risk' period of 9 to 13 years where creativity wanes (known as the 4th grade slump). We developed a system by which children can construct animated stories by recombining elemental knowledge fragments [12].

Functioning in an Emotional World

The fourth aspect of our model is that emotions are part of the situated embodiment of the mind. Emotion and affect are critical to our functioning within society, and play a critical role in our decision-making and sense of well-being. Hence, emotion is part of the aspect of mind that helps us to function in a dynamic and social world.

Our work on remote affective touch explores how affect may be conveyed remotely through a haptic armband device. Our hypothesis is that touch is an immediate conveyer of affect in that it does not require encoding of a symbolic message by the originator and subsequent decoding into a symbolic message by the recipient. A child hugs her parent not to pass a message, but simply because she wants and needs to. We posit that since similar touch can convey a range of affect, and affect can be conveyed by a range of touch (type of touch, location of touch etc.), touch can generally be immediate only if it is accompanied by another contextualizing communicative channel. Our study coupled an affective reading of an emotion-laden story with co-temporal touch via our haptic armband at emotional high points. We demonstrated significant difference in emotion in participants experiencing both touch and audio recording compared against participants experiencing the audio recording alone [13].

Conclusions

In a sense, embodiment can only be understood when thought of as a departure from a dualistic Cartesian framework of a disembodied intelligence. The title of this paper suggests that embodiment is about just being human. Humans are corporeal beings functioning within a physical world within time. We are not solitary beings. Society is part of being human, as are the emotional imperatives that aid our function. Our focus is not on the obvious physical function of the body, but more particularly on the implications for mind, and how such conceptualizations may impact our interaction with technology. We have set forth a four-part model of what this implies, and provided brief examples of research that operationalizes some of the concepts.

Acknowledgements

This research has been supported by NSF grants CRI-0551610, NSF-IIS- 0451843, & IIS-0954048.

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Eliciting Embodied Metaphors through Augmented-Reality Game Design

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Abstract

In this paper we present our experience of eliciting metaphors through the process of game design with children. For the purpose of determining a set of user interactions desired in children's augmented-reality experiences, we have conducted a study in which children used craft materials to design augmented-reality games. Game interactions and mappings between physical and virtual worlds were then analyzed to reveal metaphors in children's thinking. This paper describes the metaphors elicited, and argues for the use of game design as a process for metaphor elicitation.

Introduction

We approach cognition from the view of embodiment, adhering to the philosophy that human thought is grounded in the body and its interaction with the external environment. Through this view, we assume that some cognitive schemata are developed from gestalts of physical experience, which Johnson [1] calls *image schemata,* and which we will refer to as *embodied schemata*. Further, we use the term *metaphor* to refer to similarity relationships between mental concepts (ex: "the mind is a machine" [2]), and specifically *embodied metaphor* to refer to relationships between a concept and an embodied schema (ex: "happy is up" [2]).

Embodied metaphors are difficult to elicit from children, since children may not be conscious of them [3]. One method of eliciting such metaphors is to ask experts [3], while another method is to ask children to act out concepts by using their body [4]. In this paper, we present the use of game design as a process of eliciting metaphors. We are interested in studying the relationship between metaphor and user interactions in mixed-reality environments, as we believe that metaphors are invoked when a coupling between the physical and virtual worlds "makes sense" to users. Generating interactions in mixed-reality environments through game design may thus be a fun method for revealing metaphorical thinking.

User Study

We conducted a user study to study what kinds of interactions are desired by children when playing in augmented-reality experiences. This study was part of the development of the SPOT system [5], which is a children's tool for authoring augmented-reality experiences, based on the Scratch programming environment. A primary aim of the user study was to

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

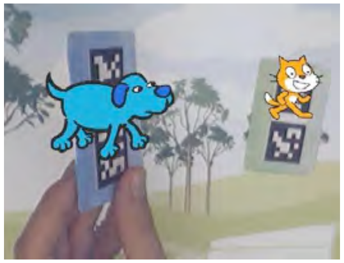

Figure 1. The augmented-reality view of a SPOT game, showing a virtual dog and cat overlaid on physical blue and green cards.

determine how children would like to interact with the augmented-reality games they create. Peripherally, we were interested to understand why the interactions made sense to children, and to identify how knowledge of the physical world is transferred in children's expectations of augmented-reality (AR) experiences. In the SPOT system, children program the behaviors of virtual sprites (2D graphical entities appearing on a computer screen), which can respond to the movement of physical cards. The cards are flat physical objects whose position, distance to the screen, collision, rotation and tilt can be sensed in the game (Figure 1).

Method: The study was conducted with a classroom of grade 5 students (12 students in total, ages 11-12 years), which had previous experience with Scratch, but had never seen the AR system. The study lasted 45 minutes, and consisted of three phases. First, the SPOT environment was presented; during this phase, children were exposed to interactive examples of AR experiences created with the tool. Examples typically used the physical cards to move virtual sprites that used literal representations and actions (ex: a raindrop carried on the physical card slipped off when the card was tilted); some of the examples were abstract, where actions performed on the physical cards did not have an intuitive effect in the virtual world (ex: the color of a virtual circle was changed when two cards were brought close). In the second phase, children were paired in 6 groups, and tasked with generating potential ideas for AR games. Each group was provided with a set of physical cards which they would use for controlling the game, a set of images which would make the elements of their game (people, animals, pencils, fruits, geometric shapes, etc), and craft materials which would be used to build a paper presentation of the game (colored pencils, scissors, glue). Finally, children presented their game ideas to their classmates through a show-and-tell session.

Results and Discussion:

Each group of children created one game. Moving physical cards was the control mechanism for all games. In all games but one, the player controlled a virtual actor which had to collect and/or avoid other entities. (For example in one game, the player controlled a virtual dragon and gained points by touching the dragon to virtual food). Virtual actors were not used in one game, which resembled the Breakout game where the player controls a virtual paddle that bounces balls toward a wall. The children's games employed a variety of interactions, coupling actions in the real world with actions in the virtual world. These mappings, along with knowledge that may have been employed in making the mappings, are shown in Table 1.

Physical Action	**Virtual Action**	**Knowledge / *Metaphor***
Card moves (3D)	Actor moves (2D)	Carrying physical objects
Card moves (3D)	Actor moves (1D)	Dragging physical objects
Card moves closer to user's view	Actor volume increases	Moving toward sound sources OR *CLOSE-FAR schema*
Card is tilted / shaken	Actor/object falls off	Dropping physical objects
Card is popped	Actor jumps	Throwing physical objects
Card moves, touching a physical or virtual object	Actor/object collides and / or is hurt	Colliding physical objects
Card is tilted	Actor moves in direction of tilt	*Card is like a game console controller* OR *Card is Pointer*
Card is tilted	Actor fires in direction of tilt	*Card is like a game console controller* OR *Card is Pointer*
Card is rotated	Game speed increases	*Card is like a volume control knob* OR *STRAIN-UNSTRAIN schema*
Card is rotated	Musical object changes timbre	*Card is like a radio control knob*

Table 1. Mappings between physical and virtual actions in children's games. *Italics indicate use of metaphor or embodied schema.*

Observing the mappings created in children's games can lead us to speculate about what knowledge children employ when experiencing mixed-reality applications, and can potentially reveal embodied schemas in children's thinking. We caution that knowledge related to each mapping is hypothetical and has been generated by the researchers' intuition.

Children frequently decided to simulate physical phenomena such as linkage, collision and gravity (eg: carrying a virtual object on the physical card, then tilting the card to drop it). This unsurprisingly indicates that when using the body to directly control an interface, children frequently appeal to previous knowledge of interacting with physical objects. In some cases, children associated tilting motions with directing the virtual actor to move or fire in a specific direction. This may indicate that children used knowledge of "pointing" in a direction of interest; or, that children may be using the metaphor of "physical card is a game-console controller" (since in some TV-console systems, the user tilts joysticks to control the game). In one game, children associated the motion of rotating a card with changing musical timbre; in this case, the children may be employing the metaphor "card is like a radio control knob", using previous experience with knobs in audio devices. Embodied metaphors may have been revealed through two instances in our study. In one interaction, a child has suggested coupling sound volume to the distance between a card and the computer's camera. This may indicate a metaphorical connection between the concept of volume and the CLOSE-FAR schema; or, this connection between volume and closeness comes from experiences with physical sound sources, as bringing a squeaking toy closer makes it sound louder (such experiences can also function as origins of the embodied metaphor). In the second instance, children coupled the rotation of a card to the speed of their game. This interaction may have been chosen simply because children employed knowledge of rotating volume-control knobs, indicating that children metaphorically understand "speed as volume". Or, the observed interaction may connect to an embodied schema related to rotating objects with the body - rotating a card may be related to twisting an object (such as a water tap, arm, or branch), and can be experienced as increasing strain, showing a connection between game speed and the schema of STRAIN-UNSTRAIN.

We have found Fishkin's taxonomy [6] to be useful in classifying the observed couplings. The taxonomy considers two dimensions of tangible interactions: the physical distance between physical input and virtual output, and the match between representation and action in the physical and virtual worlds. We find that interactions that are literal and are tightly coupled in terms of input/output distance (eg: carrying a virtual actor on a physical card and tilting to cause the actor to fall) do not reveal metaphors since they directly mimic the physical world. In the produced games, children frequently decided to create experiences with literal elements, thus yielding a limited amount of metaphors. Table 2 gives some examples of other metaphors that could have been created, along with possible interaction mappings.

Further Elicitation through Game Design

Several aspects of the game design activity may be changed to reveal metaphors on specific topics. *Constraining the game theme or game elements* can lead children to create experiences where interaction metaphors relate to specific concepts. For instance, asking children to create AR games where music is generated may lead to embodied metaphors similar to those found in [4]; similarly, asking children to use game elements which represent numbers or functions may lead to metaphors employed in mathematical thought.

Metaphor	**Virtual Action**	**Physical Action**
The mind is a container	Virtual "thoughts" are put in / out of a virtual mind	Physical card moves in/out of a virtual area
Happiness is a substance	Virtual "happiness" is poured out of a container on people	Physical card tilts the virtual container
Love is a force	Virtual boys are attracted to a girl like magnets	Physical card moves the virtual girl
Grades (ex: "C", "D") are objects	Virtual grade objects are blocked from falling on a test	Physical card movement blocks the virtual grades
Pitch is upward movement	Pitch of a virtual instrument increases / decreases	Physical card moves up / down
Power is active movement	Power of a virtual gun increases	Physical card carrying gun is shaken

Table 2. Examples of other possible metaphors and their interaction mappings.

Conversely, *constraining the types of user interactions* in the game can cause children to reveal specific embodied schema. For instance, telling children that a game can only detect actions of "shaking" will lead children to control games by shaking motions – for example, mapping a shaking motion to making a character flap its wings, making a music instrument play louder, or causing a paintbrush to draw more colors; these could indicate metaphorical mappings between "body activity" and concepts like "flight", "volume", and "colorfulness".

Finally, *changing the craft materials and/or game technology* may also cause children to explore different kinds of mappings. For instance, providing 3D objects instead of 2D cards for the craft activity would potentially cause children to explore the embodied schemas of ABOVE-BELOW, IN-OUT and AHEAD-BEHIND. The representations of the craft materials may also influence the metaphors created – if children are provided with abstract 2D shapes to use as controllers in their game (such as geometric shapes rather than concrete objects), they may be biased to design more abstract games such as Tetris. Changing the game technology will cause children to explore other kinds of metaphorical mappings – for instance, a game which reacts to temperature may reveal children's use of a HOT-COLD schema; technologies where the whole body can be used may reveal metaphorical mappings to a BENT-STRAIGHT schema, etc.

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Some themes in bodily interaction

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Abstract

We identify and reflect on a number of themes that we argue has been underexplored in embodied interaction research. This work is based on findings from own design work and studies of artifacts for bodily forms of interaction in leisure oriented contexts, together with related theoretical and empirical literature. Three themes are discussed: the temporality of bodily experiences, the difference in scale of bodily interaction, and the social construction of bodily experiences.

Keywords

Embodied interaction, leisure activity, bodily engagement, leisure activities

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

People's movement and interaction with specialized artifacts in leisure activities are often highly engaging and joyful, complex, precise, and people may spend a lifetime perfecting a particular movement. What we find particularly intriguing with such practices is that it seems that through the artifacts people use, they are put in touch with, and are able to experience and see the physical world in essentially new ways. Looking at skateboarders' creative usages of skateboards on the different surfaces and artifacts in city spaces, they seem to see infinite opportunities to invent and try out new tricks, and similarly, golfers walk around their surroundings and see potential golf holes or exciting golf shots in the nature around them. The question that our work evolves around regards how we could design interactive artifacts for bodily interaction that had similar properties? What if we could design artifacts that provided for a similar kind of long-lasting physical-bodily engagement and for possibilities of similar kinds of personal development and social interaction?

We argue that people's bodily experiences and how they see and relate to the artifacts they use in such leisure practices offers one path towards understanding some of the critical experiential qualities that could be used designing leisure oriented technologies for body and movement. In our work we are using this as a starting point to develop an understanding of the *body in embodied interaction*.

We aim to arrive at a conception of bodily interaction that accounts for the body. not as a device for interaction, but as an existential/experiential entity. Such a conception would support a way of considering the body in interaction, no matter if it was about ways of moving around technology or simply being still. The conception should allow us to effectively design for and take the human body into account in design, not only for the sake of manipulating a device. This resembles the arguments of embodied interaction as put forth by Dourish regarding how design must account context, social interaction and body not as separate entities but as an integrated system. In this paper we identify and reflect on some themes that we find to be critical for such a conception.

Background

Much HCI research is currently turning its attention towards "the body" and how to design for the body in interaction. How to explicitly design for bodily aspects of interaction has been explored in a diversity of areas such as for dance & performance [7, 12], health & well-being [10], to for movement-based interaction [3], bodily musical interaction [9], gaming interfaces, sports training aids [14, 8], gesture based interaction emotional interaction [16], bodily social interaction [5]. Most successfully perhaps, gaming consoles such as Nintendo Wii and Microsoft Kinnect has led the way in this development together with the increasingly growing market for sports technologies such as the Nike+ running sensor. This development is paralleled by a number of technical and intellectual developments in HCI research, such as the fast growth of cheap and accessible sensor-based interaction technologies, and the interest in grounding interaction design in phenomenological and pragmatic philosophy that resist mind/body dualisms.

Through Paul Dourish's [1] seminal book, the concept of embodied interaction has been established as a way of conceptualizing interaction as a social, bodily and practice phenomenon. The arguments of embodied interaction as put forth by Dourish regarded how design must account for context, social interaction and technology not as separate entities but as an integrated whole. Dourish drew on the phenomenological philosophy of Husserl and Heidegger, to conceptualize human meaning making in relation to interactive technology. Despite the use of the term "embodied", in Dourish's original conception of embodied interaction, there was no specific elaboration on the qualities of the body and its relation to interaction. Instead, drawing on the ethnomethodogical tradition introduced in to HCI by Lucy Suchman, Dourish emphasized how meaningful interaction is formed through interplay between social, material, and bodily practices. Through the contextually rich perspective of embodied interaction, aspects of the body are occasionally brought to the fore depending on their role in the meaning making practices under stu8y. However, as argued in much recent work, HCI need to further develop an understanding of how to specifically design for bodily aspects of interaction [11, 6]. Examples of studies with specific focus on bodily experiences include Höök's [4] autobiographic study of horseback riding and Tholander & Johansson's [11] study of bodily experience in golf and skateboarding.

These had the specific aim of drawing out design qualities is the actual purpose of the studies.

Scales of bodily interaction and the interplay between the small and the large

Many perspectives of the role of the body in interaction and HCI focus upon it through what is happening in the immediacy around the body at each instant, or in the immediate interaction with artifacts. Two approaches that has influenced HCI that illustrate this interest in the minute comes from, firstly, analysis of social interaction and the descriptive accounts of how it the interplay between talk and body, and secondly, notations for dance choreography. The vast amount of work studying practices of social interaction have attended to the moment-by-moment details of bodily action such as gesture, gaze, and body language and how these play out in conversation and meaning making in a number of different social practices. Similarly, Rudolph Laban's notation for systematic descriptions of bodily movement in dance has brought attention to the fine-grained aspects of bodily movements and positions. These approaches have turned attention to the minute details in how we use our bodies in interaction design. Tholander & Johanssson's [18] exemplifies this in their study of how practitioners of leisure activities such as golf and skate attend to the small details of bodily interaction. Much of their experience involves paying sensitivity to nuances and tiny details in body position, body movement, and changes in material circumstances. These aspects need to be taken as integrated facets of a constantly changing relationship between body, artefact and physical space in the making and unfolding of experience. What more rarely has been considered in HCI, concerns aspects of the mobile body and how perception and experience is constructed through bodily engagement and movement occurring over longer stretches of space and time. In the literature on location-based interaction, aspects of mobility, space and place and in relation to novel technologies have been widely discussed. This has lead to important insights into how technologies contribute in forming new kinds of spatial and location-based experiences. However, the role of the physical body and movement through larger spaces are more rarely taken as a point of departure in studies of mobility and location-based interaction (see [2,13]). In the following, we attempt to outline some aspects that contribute to a conception of bodily interaction that also takes the relation between the physical body and the larger spatial aspects into account.

In studies on people's perception of large environments the relationship between body and place has been analysed. Spinney's [15] ethnography on the experience of cycling up the Mont Ventoux in France at over 2000 meter above sea-level serves to pin-point the kinesthetic basis of people's perception of a place and space. Spinney argues for how cyclists develop an experience of the landscape of the mountain not primarily through visual experiences and representations, but through an engagement with all the body's senses. In particular he emphasizes the role of the increasingly intense kinesthetic sensations from the straining and exhaustion of the body, such as the muscular pains, strong breathing, and tunnel vision. What guides the cyclist through the landscape is not primarily what is perceived through the visual sense, but just as much the kinesthetic experiences, i.e. what is felt in to body, such as temperature sensing, pulse, and lactic acid. In ascending the mountain there is an array of senses that go in and out of the cyclists focus in building up the experience of the mountain landscape. Spinney, points to how the senses are "reprioritized " in the project of moving up the mountain. The senses that become peripheral or central at a particular moment are rarely obvious, for instance in orienting towards the cool of the shade the visual sense might get relegated in favor of other senses such as the bodies sense of temperature.

Understanding the body in interaction need thus also be looked upon from the point of view of the movements of the body as well as how the body moves around in the world. We have to consider how perception and bodily experiences are built both out of the movements of the body and how the body moves in world.

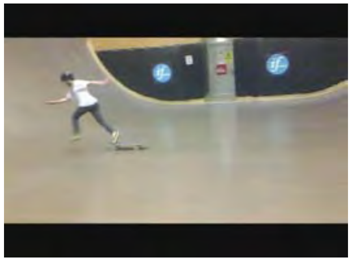

Figure 1. A beginner skater losing balance as the curve of the ramp changes from vertical to horizontal

An interesting example including mobile technology that touches upon the relationships between bodily experiences and how movement in a large physical landscape is Ferreira and Höök's s [2] study of novel mobile phone users at the Vanuatu islands in the Pacific Ocean. They reveal the some of the ways that the people adjust their bodily conduct in order to coordinate their interaction with the technology and their everyday endeavors. These adjustments range from the small scale of involving for instance subtle bodily repositioning with respect to the artifact and surrounding circumstances such as water, sand, and vegetation, to the larger scale of moving to different locations on an island to find the best possible network coverage. This resonates some of Shklovski et al's [13] findings in their studies of gps-tracking of paroled sex offenders wearing a device that sends an alarm whenever they trespass into areas within a certain distance of schools and pre-schools. They showed how the gps-device structured not only their immediate choices how to move around a particular area, but the wearers' actual choice to only visit some parts of a city, and even avoiding whole cities due to the fact that the technology made it too complex for them to move around.

What we would like to point at here is how bodily interaction and experience need to looked upon as occurring in different scales. Interaction and experience is happening both around the body as well as with reference to the larger physical space. While most work in designing for bodily interaction has focused on the smaller scale interaction close to the body, the larger scale bodily action and interaction need also be included as a dimension to a conception of the body in interaction that puts the body in a situation at core.

Temporality

In our studies of golf, skateboard and body bug users a critical issue that repeatedly came up was the timing between bodily action, in relation to the physical world and the responses from artifact. For instance, in skateboarding, shifting the weight of the board need to be made at exactly at the point where the ramp goes over from the bent to flat ground (see Figure 1). Without timing the weight shift appropriately, it is likely that balance is lost with a small chance of recovery. If the weight is transferred too early you fall forward, or if transferred too late you fall backward. This involves a process of understanding how the board reacts with respect to actions made by users and to the properties of the surface.

In a similar fashion, users of the body bug we saw how users had to learn to time their actions to the

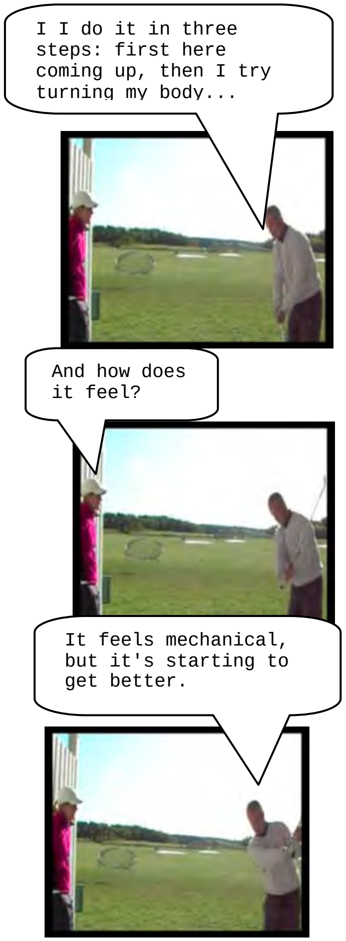

Figure 2 - 4: Talking about how the body feels in the golf swing

responses made by the bug. In the case of an interactive device, designers also have craft the responses from the device in a way that makes it possible for the user to act on the responses in meaningful way.

The situations described above involve bodily actions that often have to be timed at a very fine-grained level, down to at least tenths of seconds.

However, bodily interaction also unfolds over much longer stretches of time, such as minutes and hours. This is especially relevant for the case of bodily interaction since our body and mind changes over time, we get tired, our bodies strain. To illustrate this we would like to come back to Spinney's study of ascending The Mont Ventoux is the experience of pain throughout the duration of the ascent. For the cyclist in the study, the ordeal of cycling up to the summit of Mont Ventoux involves a significant amount of pain and suffering. However, in the context of this achievement, pain was not primarily something negative. Instead, together with struggling and finally reaching the summit, pain is experienced in a positive sense. Despite all the bodily feelings of exhaustion and fatigue, pain gets reinterpreted as something pleasurable. However, Spinney argues for how it is not the pain as such that is pleasurable, it is the achievement of controlling the pain throughout the duration of the 26 kilometer long ascent. This points to how the experience of ascending the mountain need to be understood as an interplay between the kinesthetic sensing of the cyclist, a large physical landscape, throughout hour-long duration of the ascent. This mirrors Sörlin's [17] idea from the study of how the practice of becoming a world champion cross-county skier involves a dialectic between suffering and passion (two closely related words in Swedish 'lidande' and 'lidelse') that the athlete constantly negotiates with. In both these cases, pain (or suffering) is not only to be understood as something that has to be overcome but as an aspect that is critical to forming the meaning of the experience.

The social construction of bodily experiences

While "first wave" HCI focused primarily on the cognitive and intellectual aspects of interaction, more recent experience-oriented perspectives have shifted towards a focus on aspects such as affect and embodiment. However, we argue that we need to understand interaction in a fashion that does not leave out one or the other. Even though many bodily experiences are pre-dominantly described as non-intellectual, such as Höök's autoethnographic study of horseback riding, much of our physical experiences with the world are mediated and made meaningful through intellectual reflection and social interaction. A critical question is then how bodily experiences are shaped by the cognitive aspects of meaning making. Let us illustrate this with an excerpt from our studies of golfers. We saw how their experience of how their golf swings felt were structured by the discourse of talking about the swing and knowledge of how a technically correct golf swing should be, that they had learnt from instructors, books and magazines. The social practice within which the talk about the feeling of a golf swing brings particular aspects into focus and shapes what the experience becomes about.

By describing a sequence of steps, Lars here verbally together with illustrative moves (see Figures 2-4) deconstructs his experience of the golf swing for the purposes of talking about it with the instructor, thereby allowing him to describe and communicate aspects of how he experiences his swing. This is a form of intellectualization that does not only have a communicative role, but it is also a part of the overall experience in the golfers pleasurable strive to improve his swing and his game. The bodily experience of swinging the golf club should thus be seen as closely intertwined with intellectual aspects of the movement.

The dynamic whole is broken down into smaller constituents in order to make aspects of the experience shared with someone else. The talk about the bodily experience is thus bound to a particular activity and a specific form of social interaction.

This points to how design for bodily interaction and experiences cannot only be understood from the point of view of the individual and his/her body. To a significant extent bodily experiences are also socially constructed through specific social practices and ways of talking. Hence, bodily experiences must be understood through an integration of pre-reflective and non-verbal aspects, together with cognitive, intellectual and social aspects.

Conclusions

By reflecting on our previous research into bodily forms of interaction we have identified a number of themes allowing for an expanded understanding of bodily interaction. In particular, we believe that these themes provide new directions in which to investigate novel forms of bodily interaction, in line with current technical developments.

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Empirically Investigating the Distinction between Phenomenally Present and Phenomenally Transparent Tools

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Abstract

Concepts from phenomenology play a central role in the embodied interaction perspective in HCI. In particular, Heidegger's distinction between different modes of tool use, 'ready-to-hand' versus 'present-at-hand', has been influential. However, other than self-report, there are no established methods for determining how a person is phenomenally experiencing a tool, making it difficult to apply these concepts to the design of systems. In this paper we describe our initial attempts to operationalise different modes of tool use using behavioural measures.

CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Introduction

"Embodied interaction is not a technology or a set of rules. It is a perspective on the relationship between people and systems. The questions of how it should be developed, explored and instantiated remain open research problems". [3, p.192]

Phenomenology is a foundation of the embodied interaction perspective in HCI [2, 9], in particular the work of Heidegger who distinguished different modes of tool use, each having a distinctive phenomenological dimension. In one mode ('ready-to-hand'), a person uses a tool as though it were an extension of their body; their focus is on the task they are trying to accomplish and they are unaware of the tool – it is 'phenomenally transparent'. In the other mode ('present-at-hand'), a tool is treated as a distinct and separate entity and a person is aware of its properties, such as size, shape, colour and mass – it is 'phenomenally present'. Heidegger argued for the primacy of ready-to-hand engagement with the world and an important contribution of the embodied interaction perspective to HCI is that it emphasizes that people often engage with systems in this way. This provides a useful contrast to more cognitivist analyses of behaviour that characterize the relationship between

Figure 1: Experimental set up used to extend Dotov, Nie and Chemero's study [2]. Subjects play a herding game where they move a mouse-controlled cursor to keep one or more boids in the circle on the screen while experiencing different types of perturbation to the cursor movement. We record both their eye and mouse movements and get them to report what they are doing and experiencing. We also test whether they detect changes in the cursor colour.

people and systems in terms of conscious reflection (in Heidegger's terminology 'present-at-hand') [9].

Following Halverson [4] and Rogers [7], we argue that the embodied interaction conceptual framework has descriptive power (it helps us describe and make sense of the world). What it lacks is inferential power (that would enable us to test the framework) and application power (that would en able us to apply the framework to design). For example, although Dourish [3] provides six design principles, they are very high-level generalizations and, as he acknowledges, certainly not rules. Chalmers, in a sympathetic review, points out that "some designers reading the book will feel slightly disappointed with this, as they will be looking for some practical suggestion as to what to do" [1].

In this paper we outline how we are attempting to address two open research questions for the embodied interaction perspective: first, can it generate testable inferences and second, can it provide more practical guidance for designers? Our approach is to empirically investigate the different modes of tool use and their associated phenomenology. To facilitate the generation of testable inferences, we are exploring techniques to measure the conditions under which a tool is experienced as phenomenally transparent or phenomenally present. Operationalising the distinction between different modes of tool use would also provide an important first step in developing a common language for embodied interaction theorists and designers. Three benefits that follow are: first, theory can inform design; second, comparisons can be made between systems, for example, in terms of their ability to support fluid interaction; and third, design experience can help inform theory [7].

An Initial Study

How might we systematically identify different modes of tool use? One method is to use first person reports of phenomenal states. However, two worries with this approach are: first, the accuracy of self-reports; and second, that interrogating participants while they are using a tool might shift their mode of tool use. Another method is to measure people's performance on a task. However, it is important to note that 'smooth performance' of a task does not necessarily indicate readiness-to-hand. Finally, differences in a person's focus of attention are central to most accounts of the mode of tool use and seem a fruitful avenue to explore. The challenge is to find reliable measures of attention shifts.

We are testing these approaches in an ongoing experiment in which subjects use a mouse to play a simple computer game where the task is to move a cursor to 'herd' one or more boids [6] so that they remain in a specified region of the screen (Figure 1). Our study is an extension of an experiment recently reported by Dotov, Nie and Chemero [2], who used a video motion tracking system to measure the hand movements of participants playing a similar herding game, both when the mapping between the mouse and the cursor on the screen was normal and when it was disrupted by randomly shifting the position of the cursor on the screen, causing it to 'jitter'. While playing the game, their subjects also counted backwards in threes from four hundred (400, 397, 394, …), and their counting rate was recorded. Dotov *et al* found that when the mouse and cursor had a normal mapping, the participants' hand movements showed a power law scaling across time scales ranging from around 100ms to 1.5 seconds (Figure 2).

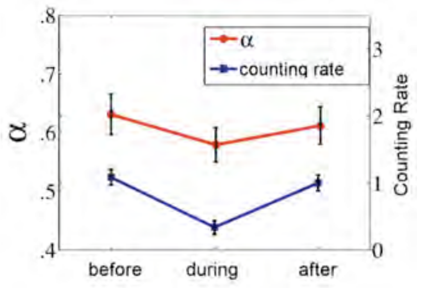

Figure 2: Results from Dotov, Nie and Chemero's [2] experiment showing how the power law scaling of the subjects' mouse movements and their counting rate diminished when the movement of the cursor on the screen was perturbed.

Some authors argue that $1/f^{\beta}$ scaling found in the analysis of some human behaviour (for example, eye movements, mental rotation and postural sway) indicates a particular type of dynamics – interaction dominant dynamics – which result from the complex interaction of a number of physiological processes that extend to the periphery of the body and perhaps to tools. Dotov *et al* argue that this power law scaling relationship in the participants' motor behaviour is not only a signature of an integrated tool-body system but also of skilled, ready-to-hand tool use. They found that when the mapping between the mouse and the cursor was disrupted, the $1/f^{\beta}$ scaling in the participants' hand movements was significantly reduced and their counting rate decreased (Figure 2). They argue that the latter finding is explained by a shift in the participants' attention to the herding task.

We use a range of techniques to further investigate the behavioural and phenomenological changes that occur when the mapping between the mouse and the cursor is disrupted during the herding task. In particular, we want to gain greater insight into the participants' phenomenal experience of using the mouse/cursor tool in the different conditions and whether these are correlated with shifts in the focus of their attention. First, we use a Tobii T60 eye tracker to record participants' eye movements. Second, we use a colour change paradigm to measure whether participants' ability to detect changes in the hue of the cursor they are controlling is different in the normal and disrupted conditions. Third, we use a 'think-aloud' protocol to record participants' descriptions of what they are doing during the experiment. Fourth, we attach an Analog Devices ADXL335 3 axis accelerometer to the mouse to record hand movements. We have tested the effects of four different mouse perturbations: reverse left/right; reverse up/down; mirror reversal; and lag.

In contrast to Dotov *et al*, the results of our experiment show: i) cursor perturbations do not lead to a reduction in $1/f^{\beta}$ scaling; ii) there is as much variation between trials within a condition as between conditions; iii) subjects do not notice colour changes in the cursor; iv) participants' visual attention stays on the cursor, even during perturbations; and v) during perturbations the mouse is reported to become phenomenally present by some participants (and we don't know about the others).

Discussion

There are limitations to all of the techniques we have used to try and operationalise the distinction between different modes of tool use. First, our attention measurement techniques (change blindness, eye movements, first person report) do not clearly indicate shifts between phenomenally transparent and phenomenally present tool use. Second, performance measures (both smoothness and more complex power law scaling analyses) do not disambiguate between the two modes of tool use.

Even though we are not currently in a position to devise a general empirical test, we intend to explore whether we can develop task specific analyses of motor behaviour that might correlate with phenomenal changes, e.g., for the herding task are there other ways of analysing mouse movement? If currently we have to settle for first person reports of phenomenal states to distinguish between different modes of tool use then we would like to use more rigorous methods than 'talk aloud' protocols, for example, second person interview techniques [5].

Following Heidegger, and perhaps as a result of a too literal reading of his term 'breakdown', there is a tendency to see 'ready-to-hand' interactions as the goal of design and 'present-at-hand' engagement as a deficient form of interaction. However, as Dourish [2] emphasizes "I can't use [a] hammer if I am continually, consciously, and attentively aware of how it sits in my hand; I need it to disappear…into the activity. But at other moments I need to be able to consider the tool as an entity in itself, when I need to reorient my relationship to it; when I wonder if the hammer is heavy enough to hold the door open, perhaps". More generally, in psychology, dual processing theory makes a broad distinction between automatic and controlled processing in human performance. An automatic process occurs in response to a particular situation "without the necessity for active control or attention by the subject" and typically develops through extensive training. A controlled process is "activated under control of, and through attention by, the subject" and "may be set up, altered, and applied in novel situations for which automatic sequences have never been learned" [8, pp. 2-3].

Although computer systems can be engaged with automatically, they also offer richer opportunities for controlled engagement than hammers. By attempting to operationalise the distinction between two modes of tool use we hope to gain more insight into the fluid way in which people can engage with computer systems, switching between modes of interaction that are appropriate for their situation. This task is challenging but has the potential to enrich the embodied interaction perspective by enabling theory to inform design, systems to be compared and design experience to feed back into theory.

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Understanding Narrative and Embodied Interactions with "Present-at-Mind"

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

This workshop paper proposes the theoretical notion of "present-at-mind" as an extension of the Heideggarian categories of "present-at-hand" and "ready-to-hand". We argue that present-at-mind allows us to talk about the semantic and aesthetic qualities of embodied interaction, particularly within narrative contexts.

Keywords

Narrative, Embodied Interaction, Semantics, Theory

ACM Classification Keywords

H.5.2 User Interfaces: Theory and Methods

General Terms

Design, Theory

Introduction

In this paper we consider the relationship between embodied interactions and narrative by exploring how Heidegger's notions of *present-at-hand* and *ready-to-hand*, already adopted into the field by theorists such as Winograd and Flores [8] and Dourish [4], can be extended to incorporate a semantic and aesthetic mode. We argue that this third mode of *being-in-the-world*, which we term *present-at-mind*, is essential for understanding embodied interactions as part of the process of meaning making that characterizes our evolving relationship with technology.

Vorhanden and Zuhanden

In 1986 Winograd and Flores introduced the field of HCI to the phenomenology of Martin Heidegger [8]. Their writings dealt primarily with two modes of what Heidegger called *Dasein*, or *being-in-the-world* [5]. These two modes of being were *vorhanden* (present-at-hand) and *zuhanden* (ready-to-hand) respectively, and they have persisted in HCI as a model for discussing how we interact with the world. More recently, Paul Dourish incorporated the notions into his discussion of the philosophical underpinnings of his concept of embodied interaction [4]. Both modes are connected to the notion of "breakdown", wherein a tool fails to function as expected and thus becomes a focus of attention. Before breakdown, use is seamless and the tool is ready-to-hand, working as an unconscious extension of the person using it. At the moment of breakdown, however, the tool becomes present-at-hand, an object distinct from the user. For Dourish, this phenomenological understanding of how we engage with tools is what allows us to create meaning and act within the world. The world reveals itself to us as being available for action, and through embodied engagement with the world we give rise to meaning.

Narrative Interface and Hypermediacy

Switching from interaction design to narrative and new media theory, we see a connection between Heidegger's categories and Bolter and Grusin's concepts of *transparent immediacy* and *hypermediacy* [3]. Bolter and Grusin describe how interactions with mediated experiences, such as films or video games, can produce a state of *immediacy* unless something intrudes and makes the interactor aware of the mediated nature of the experience, producing a state of *hypermediacy*. In the same way that a tool user passes from ready-to-hand and present-at-hand during moments of breakdown, a person experiencing a piece of media moves between immediacy and hypermediacy when the nature of the experience breaks through their immersion. In digital media, interfaces are caught between these two modes of experience: sometimes interfaces disappear into the interaction, while at other times they create obstacles that must be negotiated in order to accomplish a desired task. In our previous work we discussed the notion of *narrativized interfaces*: interfaces that incorporate narrative sensibilities into their design [1-2]. When an interface becomes a site of narrative meaning, the concepts of immediacy and hypermediacy can no longer fully account for the experience of an interactor. It is important to note that not all embodied interfaces are narrativized, and not all narrativized interfaces are embodied. However there are many narrativized *and* embodied interfaces and it is these that most obviously highlight the need to go beyond the modes identified by Heidegger and Bolter and Grusin to a mode of that engages with the semantic and aesthetic aspects of the interface.

Present-at-Mind Interaction

The oscillation between two binary levels of awareness may be sufficient for understanding acting with tools or engaging with passive media experiences, but we argue that something is missing when these categories are applied to the full scope of embodied interaction. The existing categories do not account for the ways in which embodied interaction exists at an intersection of potential meanings, not all of which are related to "action" or "mediation". The two states described represent functional extremes: either invisibly functioning or presently malfunctioning, either transparently immersive or hyper-aware. We propose

Figure 1. From top: The telegraph key object; All the objects on the tabletop; A participant engaging with the object

that there is a third, related mode of interacting with objects and experiences that is differentiated along semantic lines instead of functional lines. We term this category "present-at-mind". This idea of present-at-mind encompasses the ways in which we slip between different associative awarenesses while interacting with an object, tool, interface, or piece of media. We argue that this notion of present-at-mind may be used to describe any situation in which an awareness of an interaction as a *locus of meaning* occurs. Although Dourish states that embodiment gives rise to meaning via engagement with the world, he does not explicate how this occurs in any detail, and his examples focus on actions and practical tasks rather than narrative, emotional or aesthetic meanings.

For example, imagine the relationship between a guitar player and his guitar. While he is playing, he might be transported by the music into a place of transparent immediacy in which the instrument is invisibly ready-to-hand. In order for the interaction to shift toward a present-at-hand mode, something would have to disrupt the playing. A string might snap, or he might miss a note and need to correct his fingering. However, there are other modes of experiencing the guitar and act of playing that do not rely on a breakdown of immediacy. What if the guitarist finds himself reminiscing about the first time he played in front of a live crowd? What if the feel of the strings beneath his fingers and the strap across his shoulder reminds him of playing his guitar at a friend's wedding? What if he owns multiple guitars, each with its own particular story and its own properties? Would playing the Gibson *Les Paul* that he saved all of his money for in college elicit the same associations as the Yamaha Dreadnought that his grandfather had left him in his will?

Tools and interfaces are seldom neutral: they exist in dialogue with our lives and are often impossible to separate from their associative, semantic, aesthetic, and narrative entanglements. When we use tools or engage in interactions we bring our own particular set of associations and awarenesses with us. This present-at-mind mode acknowledges the importance of the specific context and situation in which an interaction occurs. To explore the value of this theoretical notion in the design and analysis of interactive experiences, we describe a system of ours which serves as a case study.

Design Case Study: The Reading Glove

The Reading Glove is an intelligent interactive storytelling system that uses wearable technology, physical objects, and a tabletop display to immerse a reader in a historical narrative puzzle (See Figure 1). Interactors wear a soft fabric glove containing an RFID reader in the palm that communicates wirelessly via xBee radio to a nearby laptop. The physical objects are tagged with RFID chips, so as the interactor picks up the objects, she triggers audio playback of story fragments associated with the object. An intelligent reasoning engine guides the reader through the story by displaying a set of recommendations for which object to pick up next. The narrative of the piece centers around a spy in Algiers during the early 1900s, who discovers that his cover has been blown and must unravel the deceptions and betrayals that brought this about. The uncovering of facts in the narrative mimics the uncovering of story fragments that the readers perform with the objects. We have written about this system more extensively in other papers [6-7]; here we reference it briefly in order to explicate the notion of present-at-mind.

Implications for Embodied Interaction

We believe the Reading Glove is a good case study for the notion of present-at-mind in embodied interaction because its focus is not on the accomplishment of any particular functional task, but rather on coming to understand a narrative via a set of physical objects and sounds. The interaction with the system is straightforward and easily learned; the challenge comes in the semantic untangling of the story and the relationship between the objects. Readers using the system frequently remarked on the power of the objects to engage them with the story. Many of the objects could be physically manipulated, such as turning the crank on the coffee grinder or wearing the goggles and hat. We believe this physical engagement, which functionally did not affect system output, engaged the somatic/muscle memory of the users. Because we selected real, previously used objects from antique stores, the richness of the physical artifacts invited reflection on the specific history of each item as well as personal associations with the reader, inducing a state of being present-at-mind.

We hope this paper provides a starting point for workshop discussion and analysis; we welcome critiques, refinements, and further examples of how to apply these ideas to embodied interaction. Some other points of interest that we do not have space to go into fully here include looking at how new embodied interfaces, such as the Rock Band controllers and Xbox Kinect, put the body into narratively and semantically salient positions, potentially activating a present-at-mind state. There is also more work to be done to explicate the notion of aesthetic appreciation and how the look and feel of an experience contributes to the enjoyment of the interaction, even if the functionality is identical to a less aesthetically appealing version. This can also be seen as a source of the present-at-mind style of engagement.

Acknowledgements

This work is funded as part of the Graphics Animation and New Media (GRAND) NCE project.

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Being Moved: Explorations of Designing Embodied Interaction

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

Increasingly, physical movement (both gesture and larger-scale bodily movement) is becoming a modality for engaging with everyday technology. This is an opportunity to revisit how our bodies engage and are engaged by technology, and to broaden the range of expression and response that is possible. This paper introduces my lab's forays into better understanding how to design for movement-based interaction.

Keywords

Movement mechanics, emotion, social play, games.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Design research, affective computing, embodiment

Introduction

Gesture and motion are becoming an increasingly common mode of engaging with computers. The dream of using sweeping gestures and movements to communicate with machines is now a commercial reality, primarily in the realm of digital gaming, but also in other categories (e.g. the iPhone and iPad). HCI practitioners caution that movement-based interaction could lead to worse usability [9], but these systems also offer exciting possibilities. Greater range of motion, if it leads to more nuanced physical expression and interaction, could expand options for communication and response, allowing richer emotional engagement and social connection [14].

It is also the case that everyday computer interfaces, while they may be efficient, are not necessarily adept at supporting the social and emotional needs and wellbeing of users. Sitting hunched over a keyboard is in fact a posture that mimics the body's natural response to threat [12], which may increase our level of exhaustion and stress. Larger input spaces such as tables and wall screens (or camera-based tracking systems such as the Xbox Kinect) offer the opportunity to change this, and also allow for novel social interactions not possible with the typical laptop or desktop configuration [11]. Smaller, handheld devices also have the potential to shift the user's internal state through gesture—for example, the manner in which an iPhone is unlocked, is a one-finger stroke across the screen, which is a relatively calm and slow movement. Such slow, calm gestures have the potential to create different emotional effects than rapid, clicking motions [2]. The present widespread dissemination of movement-based input devices offers a rare window of opportunity to make substantial changes in interaction paradigms, better supporting those who must spend hours per day with these devices.

HCI researchers have been heralding the return of embodiment to engagement with interface for some time now [e.g. 3], and the discussion of how best to design for these contexts is ongoing [6, 4, 14, 8].

There have been notable experiments with creating new forms of emotional and social engagement through movement [e.g. 7, 16, 17], from which valuable insights can be derived. However, these efforts do not isolate movement as a variable in interaction sufficiently to allow confidence about exactly which aspects of the design are causing which responses.

I am interested in finding a way to generate replicable and extensible knowledge about how movement in particular contributes to the user experience, especially in terms of how it may heighten and broaden emotional and social experience. In essence, I want to understand better how we can make use of the increasing role of the body in interaction with technology, to shape the tone and quality of a person's experience. There are results from Social Psychology and Communication research [e.g. 15], which suggest that movement can 'pull' certain kinds of responses from people in an immediate and reasonably predictable way. I suppose this is where I can offer a working definition of embodiment for the workshop—for me, the interesting question is whether we can use these embodied effects of movement (to move is to create a certain feeling or set of reactions in oneself, simply by moving), to develop a design framework and set of strategies for crafting movement-based interaction.

Toward this end, my lab group has begun a series of experiments in which we craft research prototypes which are sufficiently tuned and engaging to allow us to conduct design research, without being end use artifacts in and of themselves. We believe this strategy is a fruitful one for pinning down effects in such highly dynamic systems [5]. One example of our prototypes is Wriggle, a game aimed at testing out whether the

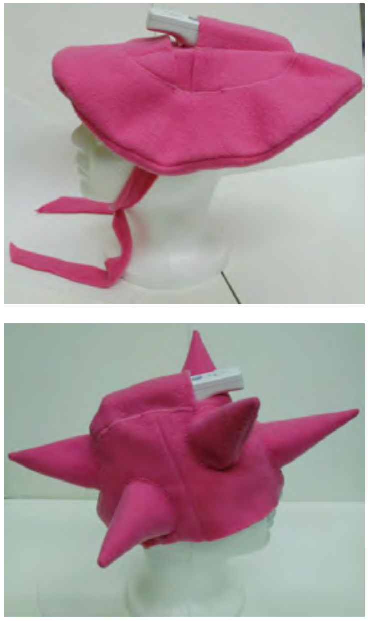

Figure 2. Wiimote hats for playing the movement variant of Wriggle.

presence of lively, vigorous movement as a game mechanic, where everything else about the game is the same, shifts how players feel (figure 1).

Wriggle can be played using either hats (see figure 2) or keyboard input—it's best to see a video, to really grasp game play: http://socialgamelab.bxmc.poly.edu/projects/emotionandmotion/.) Players try to attract onscreen 'critters' into their avatars' bodies by performing the same movements the critters are making (rapidly bowing or leaning side to side). These movements are rhythmic and vigorous, like movements we observed in commercial games that seemed to promote positive and high-energy affect, and social interaction.

We hypothesized that playing the Wiimote-enabled game would lead to increased positive valence and arousal in emotional state (a commonly accepted dimensional model of emotion—see [13]), based on the physical feedback loop effect [15]. We also hypothesized that playing the movement condition would lead to a greater sense of connectedness between players, which we operationalized using the Inclusion of Other in the Self Scale [1].

Preliminary results from a study we conducted in our lab (details can be provided/presented at the workshop) provide mixed support for our hypotheses—it seems that introducing movement definitely impacts arousal, but we did not get an increased effect in terms of positive valence of emotion. The results for social connectedness approach significance, indicating that our hypothesis that movement can lead to greater social connectedness could have merit, and is thus worth further study.

Figure 1. Players wearing the hats, getting ready to play.

Summary

This paper presents my lab's approach to better understanding how to design movement-based interaction with technology to create richer emotional and social experiences—an attempt to make thoughtful use of the increasingly embodied nature of interaction with everyday devices. I briefly described an example of how we are tackling this problem—a research prototype game we built that allows us to test out some hypotheses about how movement impacts experience. We hope, by using this approach, to move toward a practicable body of knowledge about how to design movement-based interaction with technology that is engaging and satisfying for people in everyday life.

There is not yet a shared set of dimensions/analytical framework for understanding how movement impacts the user experience, though there are various forays that are quite promising (e.g. [4, 14]). We plan to continue this research with a more nuanced set of movements based upon well-researched and promising dimensions that are likely to be emotionally and socially meaningful. We would be excited to get feedback, towards refining and extending our approach. If we are invited to the workshop, we will also bring the game and hats, so participants can try it out for themselves.

Acknowledgements

Thanks to all the members of the Social Game Lab for their contribution to the work described in this paper (see http://socialgamelab.bxmc.poly.edu for a list of lab members and projects). Thanks to Kia Höök for many thoughtful discussions around these themes, and for creating inspiring example systems and furthering my thinking about these issues.

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Moving and Making Strange: An Embodied Approach to Interactive Technology Design

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

We describe a design methodology of Moving and Making Strange, an approach to the design and evaluation of movement-based interactive technologies, that privileges embodied, lived experience. The methodology offers designers a set of perspectives, principles, methods and tools, that provide resources for exploring, generating and testing design concepts and prototypes, grounded in sensory movement experiences. The principle of making strange is fundamental to the methodology. Making strange is a tactic for disrupting habitual perceptions and ways of thinking, or in this case, moving, sensing and feeling. The design methodology emerged through a series of empirical studies, with the overall objective of identifying methods and tools for understanding, describing, representing, experiencing and generating movement and its felt experience in the design of movement-based interaction.

Keywords

Design methodology, embodied interaction, felt experience, making strange, movement

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

As the design of interactive technologies is now faced with the challenges of encompassing human experience in all walks of life, new approaches, methods and tools are required that enable designers to delve more deeply into the nuances of human experience and articulate the issues arising from a renewed focus on the body and human agency.

Our research is strongly interdisciplinary and is seeking to inform an approach to human-computer interaction (HCI) and design, with the lived body at the core of inquiry. Our approach to the design of movement-based interactive technologies gives primacy to the first-person, felt experience of movement, where the body-in-motion and its felt, kinaesthetic experience are the generative source and medium for exploration and evaluation of dynamic, qualitative concepts for design. We offer a design methodology of Moving and Making Strange for the design and evaluation of movement-based interactive technologies, composed of a set of perspectives, principles, methods and tools.

The methodology is motivated by the following set of principles: making strange, direct bodily experience, multiple perspectives, openness to phenomena, and creativity. The principle of making strange, in particular, has a prime place in the methodology. Making strange is a tactic for disrupting habitual perceptions and ways of thinking, or in this case, moving, sensing and feeling. It enables designers to arrive at fresh appreciations and perspectives for design, grounded in the sensing, feeling and moving body.

The design methodology emerged through a series of empirical studies, conducted over a four-year period. The studies were devised with the overall objective of identifying methods and tools for understanding, describing, representing, experiencing and generating movement and its felt experience in the design of movement-based interaction.

Our working definition of "embodied interaction" is informed by the twin philosophies of phenomenology and pragmatism. Phenomenology provides a philosophical foundation for the focus on the lived body and the central role of movement in perception and cognition [3]. Pragmatism places experience at the heart of our interactions with the world [1]. Both are concerned with developing understandings of phenomena and practice emerging out of embodied, lived experience. Embodied interaction is thus an approach to design in which meaning arises from our interactions in the world, anchored in the lived body [2, 4].

Moving and Making Strange: A Design Methodology

The methodology is structured around the three perspectives of the mover, the observer and the machine (Figure 1). Each perspective offers orientation, guidance, methods and tools at each stage of designing.

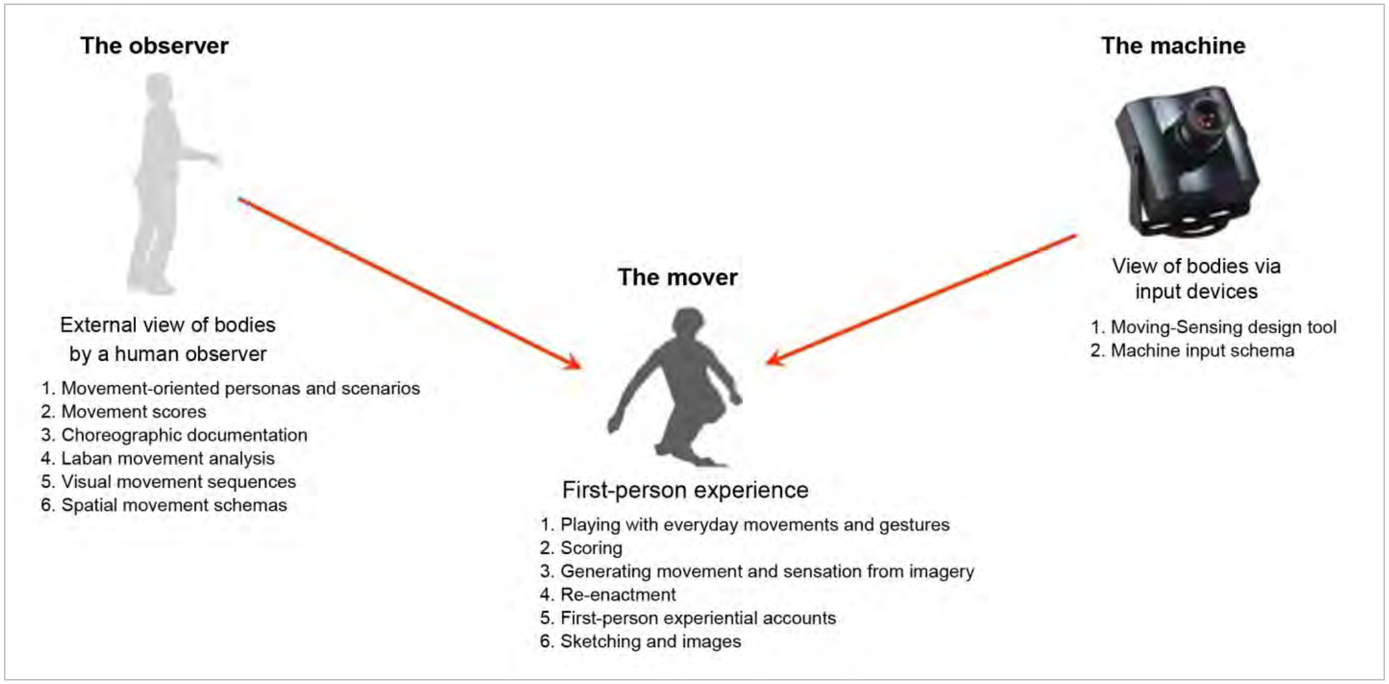

Figure 1. Diagram of Methodology of Moving and Making Strange: Perspectives, methods and tools

The Mover

The mover perspective ensures designers are accountable to the felt, lived experience of the mover and to the potential users of technology. The perspective of the mover generates first-hand, first-person experience of the moving body. The source of knowing is in-the-body, where skills are developed for performing, attending to and articulating movement and its felt experience.

The methods and tools include a set of techniques for experiencing and re-enacting movement, such as playing with everyday movements and gestures, scoring, generating movement and sensation from imagery and the use of movement-oriented personas and scenarios. There are methods and tools for accessing and articulating the felt experience of movement in various forms of representation, including first-person experiential accounts and the use of sketching and images, that preserve the voice and language of the person explaining their own movement.

The Observer

The observer perspective provides the view of the body from the outside as seen by another person, enabling the framing of movement from a range of different and complementary views including, but not limited to, the biomechanical, the social, the cultural and the ecological. It enables the designer to stand in for other people in the environment and to embed the moving body in various domains and contexts of use. The mover can also be in the position of observer of their own movements, for example during review of recorded movements.

The methods and tools work with a range of representations of observed movement, such as movement-oriented personas and scenarios, movement scores, choreographic documentation, Laban movement analysis, visual movement sequences and spatial movement schemas.

The Machine

The machine perspective focuses on the sensing and interpretation of the moving body by the computer, as determined by the choice of input sensors and processing algorithms. It ensures designers are accountable to the machine view of the movements of users and that appropriate mappings are made between user activity and machine interpretation and response.

The methods and tools to achieve this include the Moving-Sensing design tool, derived from Suchman's analytic framework and movement input schemas. These support a close and detailed examination of the mapping and interpretation of movements of the body as input into interactive technologies.

Conclusion

In our approach to researching and designing interactive technologies, the body is regarded as the ultimate test of successful engagement with interactive systems, products and spaces. The methods and tools offered by our design methodology can provide resources for exploring, generating and testing design concepts and prototypes, grounded in sensory movement experiences. Movements can be explored and documented from the three perspectives of the mover, the observer and the machine to allow movements to be transformed in a principled way to become input into sensing technologies.

The general principles of the design methodology motivate a design approach that can easily be extended into other kinds of technologies and design contexts, not just movement-based interactive technologies. The design methodology has great potential for providing a general framework for conducting technology design and research, where the multiple perspectives of the first-person experiential, the observer and the machine are equally valued.

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Recognizing Bodily Expression of Affect for User Testing

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

While recognizing affect from facial expressions has been studied widely, bodily expression of affect received far less attention in literature. We describe our plans to build a non-intrusive system for evaluation of interactive systems, which relies on automatic recognition of affect from the body. From this we envision to distill quantitative data for the analysis of test sessions, e.g. on task-related movements, expression of affect, and social interaction between users.

Keywords

Affect recognition, Posture, Body Movement, Embodied Interaction

ACM Classification Keywords

H.5.2 User Interfaces : Evaluation/methodology

General Terms

Introduction

Embodied Interaction, as coined by Dourish [2], stands for an approach to human-computer interaction, which is based on regarding humans as embodied beings and which acknowledges that the body plays a central role in how we experience the world around us. As such, it investigates the role the body plays when using interactive artifacts. So far, its main focus lies in the creation of new artifacts, which e.g. feature tangible qualities or stimulate social interaction. In our line of research we want to investigate what the body can tell us about the experience of a user, in particular in what way the body expresses affect and how we can use this knowledge for the analysis of user tests.

As the field of human-computer interaction moves beyond task-completion towards providing users with enjoyment and positive experiences, it becomes vital to understand how humans express affect. Such information can be used for the creation of systems that can recognize such signals and react accordingly. We can also use such information when we evaluate systems in user tests.

Background

The majority of research on non-verbal expression of affect has focused on facial expressions. Comparing studies on emotion in humans, de Gelder [4] estimates the use of faces as stimuli above 95 per cent. Amongst other important results this research has led to a well-known and well-established facial action coding system (FACS) [3]. The system encodes how facial muscles and groups of facial muscles (action units) can convey affect to others. Depending on the action units involved, it can for instance help to distinguish a genuine from a fake smile.

Only few studies have investigated whole-body expression of affect. Yet, research has shown that changes in affective states can be seen in changes in posture [8]. It has been put forward that facial expressions can be deliberately manipulated for deceptive purposes. Bodily expressions such as gestures are thought of providing a more honest image of a person's affective state. The relationship between affective state and posture also appears to be bidirectional. Riskind and Gotay [7] present evidence that the sheer posture of a person has influence on the mental state. In their study, subjects put in a hunched and threatened posture report greater stress than subjects put in a relaxed posture.

Kleinsmith presents an approach based on low-level descriptions of body postures for affect recognition [5]. Her dataset includes postures obtained from actors given instructions to portrait specific emotions and non-acted postures obtained from video-gamers, which were subsequently rated by observers. In both cases, motion capture suits were used. While the acted posture set features stereotypical and arguably exaggerated postures, the portrayal of emotion is subtler in the non-acted set.

In our own research, we investigated the movements of video-gamers playing Nintendo Wii Sports games [6]. We found movement-patterns, which correspond to the strategies players used, based on their motivation for playing. Interviewing players revealed that some players are aware of changes in the way they move, depending on their current mood while playing.

Bianchi-Berthouze [1] investigated which types of body movements can be observed in the context of video games. In her model she distinguishes task-related movements (i.e. task-control, task-facilitating, and otherwise task-related), expression of affect, and gesturing for social interaction.

Affect Recognition from Bodies in User Tests

Based on what is known on bodily expression of affect we want to develop a framework, which allows to automatically recognize posture, gestures and body movement and to infer affective states in user tests of interactive artifacts.

This could be used to add an additional channel for multimodal affect recognition systems. The more channels of affective information a system uses, the more robust recognition should be. Should some channels be unavailable, e.g. facial features be hidden from camera view, the system can still rely on other channels. Also, in case of conflicting information, a higher number of channels should make it easier to single out the most likely faulty channel.

Yet, our immediate interest lies in using bodily information of affect for enhancing user test of interactive products. In a first stage we plan to use video games as test scenario and stimuli for test participants. Games seem logical and promising for us in this context as they can be seen as highly emotive environments, which are specifically designed to provoke, excite, arouse, motivate, and sometimes even frustrate their users.

We envision a test environment, in which a single user or a group of users first play a video game and then are interviewed on their experience of the test session. During the test session, players are recorded and the footage is used for the post-interaction interviews.

Prior studies of body movement in human-computer interaction contexts have relied on motion-capture suits. Such suits consist of an exoskeleton frame equipped with sensors. From our own experience we can say that these suits are typically bulky and heavy. Our own test participants have reported that they find them intrusive and feel their freedom of movement limited by the bulkiness of the suits. In a situation where we want to investigate the experience of a person, the suits certainly bias the experience.

For our new test environment we want to use a Microsoft Kinect sensor for motion capturing. Microsoft released the Kinect sensor as input controller for the company’s Xbox video game platform. It features a “normal” video camera as well as a camera, which delivers a depth map of the scenery it records. This allows the Xbox to recognize individual players and their gestures. Since its release, a number of initiatives have released drivers to use the sensor with personal computers and there are even packages available for gesture extraction from its depth camera.

Using the Kinect sensor has a number of advantages for us. It is an optical system, which does not even require optical markers on the user. This makes it by far less intrusive than the exoskeleton suits, with no unwanted biasing effect. Also, acquisition costs are low as it is a system intended for a consumer market and less costly in upkeep as there is no tear.

We envision several benefits of such a test setup. First, we want to use the system for automatic annotation of the movement of test participants, e.g. into Bianchi-Berthouze’s movement categories *task-related movement*, *expression of affect*, and *social interaction.*

Having quantitative data on this as well as other features, which we yet have to identify, can help to analyze and interpret test sessions, without the cumbersome work of manual video annotation.

Conclusions

We discussed our plans for a non-intrusive evaluation system, which is based on analyzing body movements of test participants.

As physical beings the body plays a fundamental role in how we perceive the world around us. In our approach we want to find out how much it can tell us about how another person experiences the interaction. Embodied interaction often focuses on the creation of new artifacts, which acknowledge human embodiment. We acknowledge embodiment in what might be called embodied evaluation.

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Embodied Human-Data Interaction

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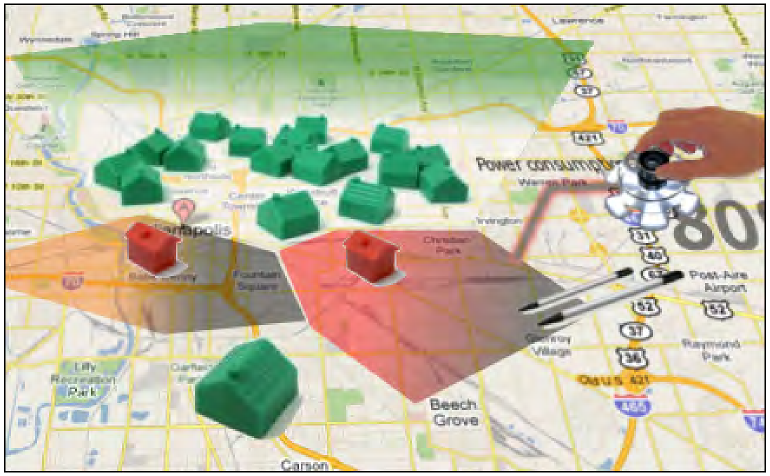

Figure 1: Mockup image of our educational urban planning game.

CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

We propose the concept of human-data interaction (HDI) as the human manipulation, analysis, and sensemaking of large, unstructured, and complex datasets. We then proceed to suggest an *embodied* approach to HDI to build physical reasoning environments for these difficult and polymorphic tasks. We illustrate our approach with two examples: tangible lenses for visual exploration, and an educational computer game with tangible bricks.

Keywords

Visualization, visual analytics, sensemaking, embodiment.

Introduction

Information is without a doubt the single most valuable commodity of the new millenium. It drives the world's financial markets, it imparts knowledge across all Earth's sentient inhabitants, and it governs the ebb and tide of human conflict around the globe. Just like any other commodity, information does not spring into existence of its own accord, but must be extracted from raw data, similar to how petroleum products must be refined from crude oil to be useful. However, where oil refinement is a tried and tested process, extracting information from raw data is still a largely unmapped and idiosyncratic process that is far from being standardized, widely known, and automated. For this reason, *data*—and the extraction of information from data—can be seen as the next frontier for the field of computing and, indeed, society as a whole.

While many separate terms exist for these analytical activities, we propose to call them by a single name: *human-data interaction* (HDI), defined as the human manipulation, analysis, and sensemaking [16] of data. Realistic human-data interaction tasks typically exhibit one or several of the following characteristics:

- **Large scale**. Datasets are on the order of thousands, millions, or even billions of items.
- **Unstructured**. The data is often heterogeneous and lacks coherent structure (e.g., binary).
- **Multiple sources**. The data must be marshalled from several different sources, each with their own data format and with no explicit relations.
- **Complex relations**. Analysis requires synthesis and correlation, not just queries or computation.

Clearly, all of these characteristics contribute to making human-data interaction an extremely challenging task that typically requires analysts to operate at their highest level of performance. In this position paper, we propose to enable analysts to reach this level of performance by applying embodied interaction [4] to HDI, giving rise to what we call *embodied human-data interaction*. The motivation for such an approach comes from ethnographic studies [7, 15] of both casual [14] and expert users alike working in both laboratory settings and “in the wild”: the information analysis process is a highly iterative and polymorphic workflow characterized by a plethora of external visual, tangible, and cognitive aids such as physical artifacts [8], annotations, multiple views [5], environmental cues [15], and arrangements in time and space [7, 15]. So far, most HDI tools rely on standard computing hardware such as monitor, mouse, and keyboard, and very few tools exist that capitalize on these additional aspects of the analysis process.

Related Work

Sensemaking is the process of finding a mental representation of a data collection in response to a particular problem or task [16]. Sensemaking is characterized by the synthesis of new information—*insight*—from the data. Two primary approaches exist for sensemaking: one driven by computation (such as data mining, cluster analysis, and inferential statistics), and the other driven by visual representations (visualization). The emerging field of *visual analytics* [18] combines both approaches.

However, as stated above, most existing visual analytics tools remain fettered to the WIMP paradigm and make little use of novel computing hardware beyond a mouse, keyboard, and monitor. Exceptions include a few recent tools that are beginning to utilize tabletop displays (e.g., [6, 10]), tangible mixing-board interfaces [3], haptics and force feedback [13], sonification [19], and multisensory perception [11]. Bowman et al. [2] propose the notion of *information-rich virtual environments* (IRVEs) as the intersection of information visualization and virtual reality, but limit its scope to virtual 3D worlds and not the real world.

Embodiments for Sensemaking

The key cognitive mechanism of sensemaking is external cognition [12], where physical representations in the real world are used to augment the internal cognitive processes of the human. Graphical representations are particularly effective for this purpose [17], which serves as the basic motivation for the fields of visualization and visual analytics. However, additional modalities of external cognition exist beyond visual representations:

- **Spatial arrangements**. Physical space is an important component of sensemaking for external memory [1], environmental cues [15], and partitioning [5].

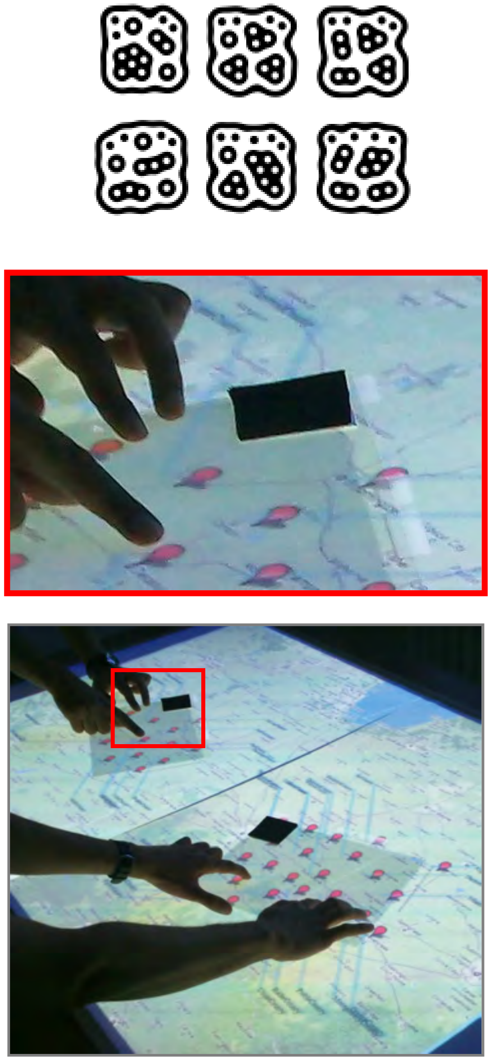

Figure 2: Amoeba markers (for lenses), detail inset, and overview of the Google Map application for our tangible lens framework.

- **Physical artifacts**. Tangible objects provide embodiments of data and computation in the world [4, 8].
- **Natural interaction**. Engaging the entire human body will enable natural and intuitive interaction [9].

More specifically, an embodied approach to human-data interaction will enable us to harness one or several of the above modalities when building sensemaking tools. This will support a fluid sensemaking process when viewing, manipulating, and analyzing complex datasets.

Application Examples

Our EHDI approach is still a largely theoretical exercise, but we have built some simple EHDI tools based on these principles: a tangible lens framework and an educational urban planning simulation using tangible bricks.

Tangible and Composable Lenses

Our framework for tangible and composable lenses combines tabletop displays with tangible lenses as physical embodiments of virtual lenses in graphical space (Figure 2). The lenses are simply transparent sheets of varying shape and size equipped with fiducial markers that allow the tabletop to track their position and rotation. This data is passed on to the underlying application. In particular, the physical affordances of these tangible lenses directly suggest that they can be fully or partially overlapped in physical space, causing lens *composition* in virtual space. We have conducted a formative evaluation studying the semantics of overlapping filtering data.

Using this basic lens framework, we have studied several domain applications of its use. Figure 2 shows a map application where users are exploring different data layers using Google Maps as the cartographic dataset. Each lens reveals measurements within a particular value range for a specific data layer; overlapping lenses yields the union or intersection of results inside the composition. We have also built an image manipulation application, a 2D scatterplot, and a parallel coordinate plot.

Urban Planning Simulation

Environpoly is an educational urban planning simulation that combines tangible bricks with a tabletop display (Figure 1). Essentially a combination of the SimCity computer game and the popular Monopoly board game, the simulation is intended for deployment in a children's museum and designed to teach visitors about sustainable cities and the environmental impact of urban growth. While it is still in early development, our ambition is to combine a square tabletop display with Monopoly-like tangible bricks for placing residential, commercial and industrial zones; tangible pens to draw roads, power, and water; and physical widgets to control the simulation.

The key aspect of the Environpoly exhibit is the use of embodied interaction to expose the large amount of heterogeneous data that the simulation maintains. This is particularly important given the intended setting—a museum floor—and the intended user group—children. For this purpose, we plan on arranging LCD displays around the exhibit that show visual representations of various metrics over time, such as energy usage, pollution, average commute, waste, sewage, and average income. Furthermore, we also hope to incorporate additional multimodal displays into the exhibit, such as ambient traffic noise to indicate the average level of traffic in the city, as well as a steam generator disguised as a small smoke stack to indicate the amount of pollution.

Conclusions and Future Work

We have proposed a novel approach to sensemaking based on applying embodied interaction to the analytical sensemaking of data. We have also presented two examples of ongoing research that attempts to capitalize on this approach. However, much work remains in order to fully exploit the ideas outlined in this paper.

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Advancing Collaborative Discovery through Reality-Based Interaction

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
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Abstract

In this paper we describe two projects that utilize reality-based interaction to advance collaborative scientific inquiry and discovery. We discuss the relation between reality-based and embodied interaction, and present findings from an experimental study that illustrate benefits of reality-based tabletop interaction for collaborative inquiry-based learning.

Keywords

Collaborative learning, multi-touch, tabletop interaction

ACM Classification Keywords

H5.2 Information Interfaces and Presentation: *User Interfaces*

General Terms

Design, Human factors

Introduction

Over the past two decades, research on Human-Computer Interaction (HCI) generated a broad range of interaction styles that move into new physical and social contexts. Examples include augmented-reality, tabletop and tangible interaction. These emerging interaction styles, leverage users' existing knowledge and skills about the non-digital world such as naive physics, spatial, social and motor skills to a greater extent than traditional user interfaces [Jacob et al. 2008]. By basing interaction on pre-existing real-world knowledge and skills, this emerging generation of HCI offers the promise of a more intuitive, accessible and natural form of interaction.

From Embodied to Reality-Based Interaction

The notion of Embodiment has been influential in shaping emerging interaction styles. “Embodiment” refers to the fact that humans are incarnated, physical beings that live in a physical world rather than abstract cognitive entities. The human body and active bodily experiences inevitably shape how we perceive, feel and think [4]. Most directly, embodied interaction refers to the physical embodiment of data and its control through physical devices and body movement [3]. However, Dourish [1] extended this view of embodied interaction beyond physical manifestation. He suggested that embodied interaction is grounded (and situated) in everyday practice including social and cultural contexts. Thus, embodied interaction describes a direct and engaged participation in the world that we interact with.

Jacob et al. [2] proposed the notion of Reality-Based Interaction (RBI) as a unifying framework that ties together a large subset of emerging interaction styles as a new generation of HCI. The term reality-based interaction draws upon the notion of embodiment but focuses on the fact that many new interaction styles are designed to take advantage of users’ well-entrenched skills and experience of interacting with the real non- digital world. Rather than emphasizing the situated nature of interaction, Jacob et al. [2] focus on four fundamental themes of interaction with the real-world that are typically leveraged by emerging interaction styles: 1) naïve physics; 2) body awareness and skills; 3) environment awareness and skills; and 4) social awareness and skills. These four themes play a prominent role in emerging interaction styles.

Jacob et al. further suggest that the trend towards reality-based interaction is a positive one, because basing interaction on pre-existing skills and knowledge from the non-digital world may reduce the mental effort required to operate a system. Thus, they encourage interaction designers to leverage reality-based skills and metaphors as much as possible and give up on reality only after explicit consideration, and in return for other desired qualities.

While RBI has been applied to a broad range of application domains, little HCI research has been devoted to investigating RBI in the context of scientific discovery. However, it is particularly important to study reality-based interaction in this context where reducing users’ mental workload and supporting collaborative work could lead to new discoveries. Those RBIs that examined the possibilities of supporting scientific discovery, focus on the representation of information that has an inherent spatial structure (e.g. proteins, molecules, and maps). We are interested in investigating the application of RBI to areas where vast amount of *abstract* information is manipulated.

Following, we describe two projects that study the strengths and weaknesses of tabletop reality-based interaction in supporting collaborative scientific inquiry and discovery.

Enhancing Learning in Genomics through Tabletop Interaction

G-nome Surfer [5, 6] is a tabletop user interface for collaborative exploration of genomic information. G-nome Surfer was designed to lower the threshold of using bioinformatics tools and to foster collaborative inquiry based learning and discovery through fluid interaction with large amounts of genomic information.

The design of G-nome Surfer draws on users' existing knowledge and skills to provide a reality-based tabletop interface [5]. Specifically, G-nome Surfer uses naive physics metaphors such as inertia, transparency, and mass. The interface also leverages users' spatial skills, allowing them to organize information upon the surface to express relationships between multiple forms of evidence. Like tabletop interfaces in general, G-nome Surfer draws upon users' social skills and existing social protocols to afford collaborative interaction. Figure 1, shows G-nome Surfer in use.

Figure 1, Exploring genomic information with G-nome Surfer

To investigate G-nome Surfer's strengths and limitations in supporting collaborative inquiry-based learning, we conducted a between-subjects experiment with 48 undergraduate students comparing the system to both current state-of-the-art tools and to a collaborative multi-mouse GUI. We examined the similarities and differences in terms of quantitative performance and qualitative behavior in 24 dyads that worked on an inquiry-based task. We considered a range of measures including verbal and physical participation, performance, attitude, mental workload, and collaboration and problem solving styles. Sessions were video recorded and later analyzed. Findings from this study indicate that G-nome Surfer reduces users' stress levels and workload compared to current state-of-the-art tools as well as improves students' performance and attitude. These findings are described in detail in [6]. Here, we would like to highlight four benefits of tabletop interaction compared to a multi-mouse GUI:

1) *Increasing physical participation*: the tabletop condition exhibited significantly higher levels of physical participation. These were expressed by increased spatial manipulation of information. Several theories of embodied cognition suggest that spatial manipulations can help reasoning about abstract concepts.

2) *Encouraging reflection*: in the tabletop conditions participants spent significantly longer time on reflection activities and articulated a larger number of insights. Since research indicates that student's understanding of the nature of science is enhanced through

reflection [7] this is an important strength.

3) *Fostering effective collaboration*: on the tabletop condition participants exhibited turn-taking collaboration style (rather than driver-passenger style) with significantly higher number of coordination utterances, and significantly lower number of disengagement utterances. Thus, participants were engaged in more effective collaboration.

4) *Facilitating intuitive interaction*: in the tabletop conditions there was a significantly lower number of syntax related utterances. Also, users spent less time finding information.

These findings support our hypothesis that the tabletop condition facilitates a more *effective* collaborative learning process, and highlight some advantages for applying RBI to support collaborative discovery.

Supporting Large Research Teams

Following our experience with G-nome Surfer, supporting inquiry-based learning in small teams, we seek to investigate *how to apply tabletop reality-based interaction to support collaborative discovery in larger research teams*. To answer this question, we are currently developing, in collaboration with domain scientists, a large-scale reality-based tabletop interface that utilizes a 6’ x 9’ high-resolution multi-touch display. Our investigation focuses on supporting multi-user interaction in an area that require to access and manipulate vast amounts of abstract information – biological engineering. Specifically, we are developing a platform for designing and assembling synthetic biological systems. We expect the system to be used frequently by research teams of about 8 scientists. We intend to study how the system impact team dynamics, brainstorming and problem solving strategies, as well as insight development.

Summary

Reality-based interfaces offer the promise of a more intuitive and accessible form of interaction that reduces the mental workload requires for learning and operating a system. Our research agenda focuses on applying reality-based interaction to enhance scientific discovery in areas that explore vast amounts of data.

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Interactional Validity: Assessing technologies to support embodied activities

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Abstract

In this brief paper we discuss how we may draw upon workplace studies to inform the ways we assess innovative technologies to support embodied interaction. In particular, we discuss the challenges of designing quasi-naturalistic experiments to assess systems to support distributed embodied interaction.

Keywords

Embodiment, interaction analysis, CSCW, media spaces

ACM Classification Keywords

H5.3. Information interfaces and presentation (e.g., HCI): Computer-supported cooperative work. H4.3.

Introduction

Over the past 20 years a wide variety of technologies have been designed to support embodied activities in some way. Typically problems emerge when trying to assess such systems whether these are media spaces, collaborative virtual environments (CVEs) or robots that serve as proxies; particularly when evaluating the extent to which they support or undermine embodied action [2, 4, 6]. One common way to assess these technologies is through the quasi-naturalistic experiment [9]. This is where participants engage in an open-ended task or set of activities using the prototype technology. These tasks are video-recorded and the

experiments provide materials for the detailed qualitative analysis of embodied conduct through or with the technology. These experiments have been a powerful way to understand how talk and visual conduct, and in some cases, the manipulation of physical artefacts, are co-ordinated when mediated through a new technology. Although the outcomes of such studies are frequently reported [2, 4, 6], their design is little discussed.
naturalistic experiment to assess one technology to support embodied interaction. We discuss how an analytic orientation needs to inform both our analysis of everyday embodied action but also the ways we assess innovative technologies to support it. We consider these issues with respect to recent efforts to evaluate one particular technology: a high-fidelity communication system to support distributed embodied action, called t-Room.

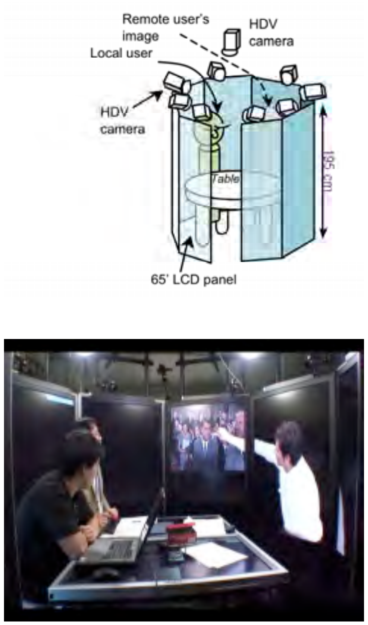

Figure 1
Top: a diagram of one t-Room. Bottom: an image from the Tokyo t-Room where the embodiment of a participant in Kyoto can be seen on the right.

Supporting distributed embodied action

Recently, with high definition video, large screens and image calibration techniques, it is possible to present real-time life-sized images ('embodiments') of co-participants with little delay even when these may be many kilometers apart. T-Room (see Figure 1) is one such high fidelity system. A single t-Room consists of eight modules (called Monoliths) that consist of a camera and a large screen. As well as presenting embodiments of co-participants the Monoliths can be used to present digital contents such as moving images. Given its ability to capture and present a rich form of 'co-presence' t-Rooms (when linked through high bandwidth connections) would seem to offer appropriate capabilities for a Virtual Research Environment (VRE) – environments to support collaboration between researchers from different specialties, between distinct disciplines and across national boundaries. However, it is unclear how to undertake an assessment of the technology. There are practical problems. Each t-Room is large and located in Japan at two sites 250km apart. There are also problems finding appropriate participants for an assessment which needs to be undertaken away from their worksite and tied to materials relevant for them to investigate and explore.

These are familiar problems for researchers investigating novel and complex technologies. Quasi-naturalistic experiments are one solution to these. For the case at hand, studies of the practices of researchers might suggest how we might design an appropriate experiment to assess t-Room. We draw from what might seem a rather unusual and perhaps distinctive research setting – that of classicists - who, as part of their scholarly work, analyse ancient manuscripts written on wooden tablets, papyri and other materials.

Analysing images in collaboration

Classicists use a variety of means to reveal the contents of a text, and recently have begun to utilize complex image processing techniques to make the texts more visible. These ancient texts can be difficult to interpret for a range of reasons: not only do scribes have different forms of handwriting but letter forms change over time. The practice of interpretation therefore relies on a constant shifting back and forth between analyzing a particular mark, considering what a letter might be, what word it may be part of, and reading the text as a whole [1]. As different specialisms are required to make sense of a text classicists frequently analyse them collaboratively. By displaying digital images of the (enhanced) texts on a large screen

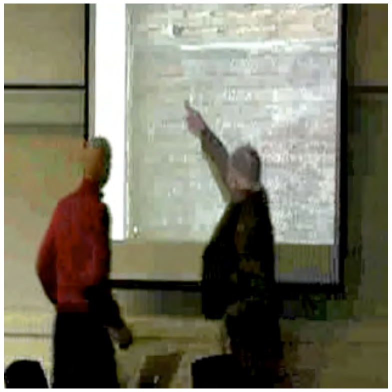

Figure 2
Two classicists analyzing an enhanced image of an ancient tablet

they can not only identify particular features but also animate these, for example by reproducing how a word or letter might have been written by a scribe living hundreds of years ago. Hence the classicists not only need to understand the visual elements of an image, they need to reveal the material qualities of the physical object, and how it was manipulated. The classicists display these through their own embodied conduct, through their talk and visual conduct, when presenting their analyses to colleagues (See Fig 2).

Although these seem to be very distinctive practices there are numerous research settings where participants analyse complex materials collaboratively, not only in the humanities, but also in social sciences (in data sessions for example [3]) and in scientific domains, when complex images, scans, x-rays are analysed by colleagues [5]. In such domains, through their talk, visual conduct, bodily movement, and gaze direction participants animate their understandings of complex images.

A Quasi-naturalistic Experiment: Analysing Hitchcock

Certain challenges emerged when we sought to develop a quasi-naturalistic experiment to assess the t-Room system. It is recognized that some 'ecological validity' is required for assessments of this kind. However, as appropriate participants are unlikely to be involved, it is hard to design a task where the participants could engage in similar analytic practices, even if they had appropriate materials to consider.

For assessing technologies to support embodied interaction a number of tasks have emerged that typically require little expertise from the participants. Perhaps most notably the ‘room design’ task, in slightly different forms, has been used to assess media spaces, CVEs and human-robot interaction [2, 4, 6]. It focuses on activities related to design, planning and navigation and has proved useful when assessing the problems participants face when trying to co-ordinate distributed activities. Tasks such as these provide opportunities for participants through their talk, embodied interaction, and visual conduct to refer to objects and features in both their own and their colleagues’ environments (achieved typically through pointing). By providing opportunities where the co-ordination of such activity can be analysed these can reveal how a technology may support or undermine the accomplishment of referential activities in mediated spaces.

In the case of t-Room, we required participants to undertake analytic work which would involve more than a pair of participants identifying features in an image or solving a generic problem. The tasks needed to be engaging so that an entire group of say four people, would participate in them most of the time. Moreover, as in the everyday setting that motivated the study, the form of participation in the activity of each of the participants could shift from moment-to-moment. Most critically, the participants would need to be able, through their own and ‘presented’ embodiments, to discuss their interpretations of an image, display their understandings and contribute to their colleagues’ analysis of the materials. The tasks therefore needed to have an 'interactional validity', they needed to be able to allow for conduct that resonated with the everyday conduct of those who might use the system.

Drawing particularly from our analysis of classicists’ practices we developed a number of tasks that involve identifying objects from within complex scenes, locating features in dynamic images and reasoning about what is being viewed. These require the participants to: (i) analyse complex images together, (ii) engage in forms of referential activity other than simple pointing; (iii) develop interpretations that relied on matters that were not directly visible in the images; and (iv) juxtaposing details of physical documents with the images. Because the tasks could not require a particular kind of professional expertise from the participants, we designed a task based around the analysis of clips from films of Alfred Hitchcock. The activities the participants were asked to do range from trying to find Hitchcock within a clip, counting people who are looking at a particular feature, discovering the order in which a sequence of actions happens and mapping out the environment in which a scene takes place. The activities mirrored the collaborative research meetings we observed (see Figure 3). These quasi-naturalistic experiments facilitated an analysis of how, even despite particular transformations to the appearance and ordering of their activities, particular kinds of embodied action could be supported through the distributed technology (details in [8]).

Figure 3

Participants engaging in the quasi-naturalistic experiment, identifying objects in a scene from a moving image using t-Room in Kyoto (top) and Tokyo (bottom)

Summary

In designing the quasi-naturalistic experiments we draw upon a similar analytic framework to understand embodied conduct as adopted in naturalistic studies of everyday action [7]. These provide rich data, even revealing how participants through their visual and vocal conduct animate features of physical objects. It is less clear however, how quasi-naturalistic experiments can assess other aspects of haptic and tactile conduct. This is perhaps not surprising as, despite recent concern in the social sciences with the sociology of the object and the body, such initiatives seem to provide few resources for assessing the qualities of embodied interaction.

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Evaluation of Embodied Interaction: Comparing a Public Trial to a Pervasive Game

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ACM 978-1-4503-0268-5/11/05.

Abstract

Our daily lives have are increasingly impacted by ubiquitous technology. In this paper we present interaction in two case studies where pervasive technologies are woven into everyday activities. The first, a public trial of CityWall, which is a multi-touch display presenting images of the urban environment in the local city square. The second, a pervasive game for exploring the surrounds while evaluating a mobile Augmented Reality application called MapLens. Through presenting these two cases we show how both systems afforded observation of how participants collaboratively and embodily interacted with the technology. The public trial and pervasive game prove to be promising approaches for evaluating embodied interaction with functional prototypes. The former oriented towards natural use, the latter drove situations and evaluation tasks through the game goals.

Keywords

Evaluation method, embodied interaction, collaboration

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces.

Studying Reality Based Interfaces in Social Settings

Dourish [1] argues that embodiment means that all things, including technology, are embedded in the world, and highlights the ways in which their reality depends on their situatedness. The introduction of tangible user interfaces (TUIs) and mobile systems has made it even more important to study how interaction is affected by ubiquitous technologies, especially in collocated situations, where participants use technologies together, either in parallel or in collaboration. Dourish's [1] concept of embodied interaction emphasises the idea that people have active representations embodied in the systems that they use—we are not interacting with a computer as such, but with our idea of the computer, which is obtained and inherited through social interaction and shared culture with other people. For example, depending on where an interactive display is installed, it represents different affordances to its users, even if it provides the same features (an email client may prove awkward to use in a public screen environment).

With tangible interfaces, the interface artefacts and the embodied interactions they afford are made publicly available for everyone [2], rendering them particularly important for collocated interaction. We constantly observe other people and at the same time are aware that our actions are visible to others—through interaction we create meaning in an existing social and physical world. Studies on public displays are generally performed in the field and address user approach and observation, positioning of displays, bystander behaviour, and public versus private or individual versus group use [3, 4]. Until more recently, tabletop studies on collocated collaboration have tended to be experimental and lab oriented, focusing on more detailed aspects such as investigating multimodal interaction [5].

In addition, a number of studies have characterised the collocated use of mobile phones. A study on mobile phone use at large-scale events by [6] shows how phones with cameras are used in a variety of group activities. While mobile phone use in general has been studied in real settings, mobile AR and collocated interaction studies have been carried out mostly in laboratory settings [7, 8].

These examples show that the maturity of technology or fidelity of the prototype [9] has an effect how a study has been organised. Public displays and mobile devices have been more the object of field trials while tabletop or mobile AR studies, for example, have been mostly laboratory or experimentally-based. In addition, the focus on collaboration is obviously determined by the type of technology with more frequent studies of collocated interaction with technologies like tabletops that are oriented to collaborative tasks. Studies are largely either in temporary installations in exhibition or offices where naturally occurring behaviour can be observed, for example, the approach to a computer artefact. Alternately, studies are more controlled and prescribe and/or instruct tasks in configurations such as a laboratory setting or by usability tests.

Because of the particular public availability and real world character of these technologies, we have utilised a different approach in our own studies that does not easily fit the above categories. In one case, we discuss how a public permanent installation enables us to study specific aspects of social interaction at a multi-touch

Figure 1. Two persons collaborating at CityWall while others wait for their turn.

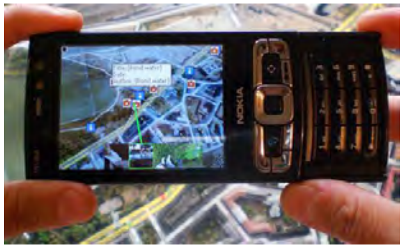

Figure 2. The MapLens prototype, which appends digital information to the camera view of a paper map.

Figure 3. A group of three solving a game task in the MapLens trial.

display. In another, we show how a game works as a study to enable the staging of realistic situations thereby emulating pressure from tasks and multi-tasking in a real world setting.

Observing Social Uses of a Public Multi-touch Screen

CityWall is a large multi-touch display installed in a central location in Helsinki, Finland, which functions as a place for people to interact together with media published by people about the city (see Figure 1). In our studies on multi-touch we have reported so far [10, 11], we used two webcams to capture video and sound at the display. The reflection of the screen also allowed us to capture what was happening behind the current participants at the screen. Through analysis of system logs and manually categorising participation we partitioned the video data into sessions of interrupted interaction. As the data revealed multi-user interaction as the dominant way to use the system, we focused on analysing these episodes qualitatively.

Our findings from the study showed how public availability of media on a user interface that allows collaboration supports embodied interaction and performative encounters—shared experience is constructed in embodied performances elicited by the interface and supported by the architectural configuration. The detailed analysis of how CityWall was used together and in parallel, allowed us to identify features in the user interface that did not support the multi-user setting as we would have liked. As the users had only one timeline to operate with, they often had problems accessing the media objects they wanted as the moving timeline repositioned objects. To overcome this limitation without losing the playful nature of the interface, we redesigned the display to support 3D worlds of content, where each world has its own content and timeline, enabling easy multi-access.

Exploring Embodied Interaction with a Mobile AR Map

To observe the formulation of natural social organisation and public availability of a system installed in public space, a longitudinal study with continual observation of interactions was needed. Other technologies such as mobile devices may require strategies to organise the observation of interaction on the move. In our study of MapLens [12] we used an environmental awareness game as the evaluation framework to explore how participants used the mobile application MapLens while they were on the move.

MapLens (see Figure 2 and 3) is a mobile Augmented Reality (AR) system that works as a viewer on top of a paper map and acts as a "magic lens" overlaying a real map with location based data that identify game clues and users' photos displayed on the phone screen. To address the challenge of evaluating pervasive applications in real settings we see these kinds of games as a promising tool to stage more realistic action for users, and engage users as players. For both games and real tasks, the articulation of tasks is not strictly prescribed but unfolds with uncertainty and through social negotiation. Moreover, the players feel the goals as their own, and games can be extended and integrated into everyday life. We find that by using a game as an evaluation framework we were able to engage users in activities that were meaningful to them, at the same time as imposing realistic pressure with time constraints.

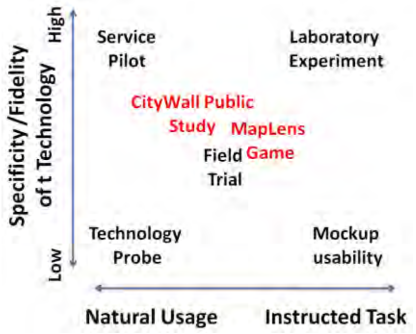

Figure 4. From laboratory set activities to technology probe.

Acknowledgements

We thank our participants and everyone involved in the MapLens, CityWall and Worlds of Information prototypes. This research has been co-funded by the 6th Framework Research Programme of the EU, through the IPCity project (FP-2004-IST-4-27571). We acknowledge Australasian CRC for Interaction Design (ACID) for support.

Discussion and Conclusions

When looking at established approaches to evaluate prototypes we can consider the broad range of instruction going from natural uninstructed usage to prescribed tasks such as in laboratory experiments. Design of field trial depends on the research questions being asked and the development stage of the technology and research that investigates longitudinal, first time or naturalistic use, field testing fits well. A public setting, where social configurations naturally evolve, is an ideal situation for social prototyping and to better understand the active representations embodied in the systems for participants. For a comparison between different approaches and stages of a prototype, see Figure 4.

In our studies both the game and the multi-touch display acted as a stage for the participants to present pantomimic interactions with each other. The public trial orients towards natural use, the pervasive game drives situations and evaluation tasks through the game goals. Our studies show that both prove useful reality-based approaches for evaluating social and embodied interaction with functional prototypes.

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Designing real-time visual feedback for learning the violin

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Abstract

My research is concerned with the design of real-time feedback for learning sensory motor skills. I take the approach that both the communication of information and its effect upon motivation are central, and specifically that the motivational qualities of the task being carried out need to be understood in order to create effective feedback. I then contrast two theories about what makes playing music motivating, one being that playing music is inherently enjoyable due to the embodied link between movement and sensory feedback. Based upon this, two prototype designs for facilitating violin practice are described.

Keywords

Real-time feedback, visual displays, learning violin, performance.

General Terms

Motivation, learning, feedback.

Introduction

Feedback is essential to learning; it helps to identify where improvements can be made. We now have the technology to measure movement and analyse it to give real-time feedback, potentially facilitating a more focused and productive way of learning and practicing. However, it is unclear how such feedback should be represented, and how people can make use of it when engaged in complex physical activities, such as playing the violin.

Submitted to Embodied Interaction: Theory and Practice Workshop at CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Several projects have aimed to give feedback to musicians. The iMaestro project [5] is one example, which gives feedback to students through a 3D visualisation of player and instrument. Key measurements such as bow angle are also represented as graphs or sonification which turns these measurements into a sound the learner hears whilst playing. Another device is the K-bow [4]; this special bow contains a collection of sensors which measure aspects of bowing technique. This data is then displayed on screen in the form of dials and graphs. The visualisations used in these two systems focus upon giving a detailed representation of information to the player.

Other aspects of feedback have also been investigated, for example engagement and exploration or rewarding goal attainment. The Snark game [6] gave visual feedback in the form of different shapes in response to the actions of the children such as flapping their arms or feeding the Snark certain foods. This resulted in a high level of engagement from the children as the ambiguity of the feedback allowed room for exploration and interpretation. The UbiFit garden [3] is a system which rewards physical activity by adding flowers to a "glanceable display" on a mobile phone. This resulted in a significantly higher level of physical activity from those who had the display compared with those who did not.

Visual feedback: limitations and opportunities

An issue when designing feedback for learning music is that pupils spend at least some of their time reading music and this requires their central visual focus. In this situation the detailed representations given by the iMaestro and K-bow systems become difficult to use as they require significant visual attention to be understood. The iMaestro system also offers sonification however this could interrupt the learners' connection to the sound of the violin which is also an important form of feedback.

Our previous research with the MusicJacket [9] overcame this by using vibrotactile feedback to help guide bowing and this system has been used successfully in the classroom with pupils reading music. Our research is now also exploring the possibility of giving real-time feedback through the visual modality. It recognises that this must be in a way that requires only a peripheral level of visual attention at times when students are reading music. Visual and vibrotactile feedback have different qualities. Vibrotactile feedback is more obviously embodied because feedback can be given on the body at the place where action is needed. However, it may also be possible to give visual feedback in an embodied manner and some of the other qualities of visual feedback may make this worthwhile. Vibrotactile feedback is only felt by the learner, whereas visual feedback is more public. This may have consequences for its use in the classroom in terms of intersubjectivity between pupil and teacher. Furthermore visual feedback has more opportunities to be aesthetically appealing compared to being vibrated. Both of these factors could result in giving learners a greater sense of performing as their playing can now be seen as well as heard by a real or imagined audience. Additionally, the feedback itself may act as an audience for the learner, so that just as an expert player may try to draw out an emotional response from a human audience, a learner might try and draw out a particular aesthetic response from the feedback. These qualities may make visual feedback particularly useful for enhancing motivation.

Designing for motivation

Learning the violin is a long term goal this means that motivation to continue playing and practicing is important

Figure 1: Sensor band for sensing bow length. It is worn near the elbow and uses a gyroscope to measure what angle the elbow moves through as the player bows.

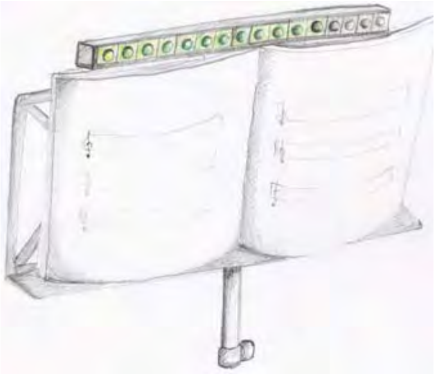

Figure 2: The *Line* design which aims to communicate to the learner in a simple way how well they are performing the aspect of violin technique currently being measured

to success. Any feedback system has potential to affect a learner's motivation to practice and what strategy they use, for example by changing their expectancy of a successful practice [1], or by changing their ideas about their own ability [8]. Since motivation is important in music learning, feedback for this purpose should aim to enhance a student's motivation. Ideally, feedback should amplify the motivational qualities of playing music rather than simply being an external reward. This requires an understanding of what makes learning music motivating.

Models of motivation in music (e.g. [7]) often focus heavily upon external factors, for example parental involvement. When looking at internal motivators they commonly propose that learning to play is fulfilling a person's self-concept in music. Another view is that playing music is intrinsically enjoyable because of the intimate link between the body's movement and an aesthetic response [2]. This leads to the following questions: To what extent is the motivation to play music due to its embodied nature? And what does this mean for designing feedback?

Hypothesis 1

Learning music is primarily motivating because it is a way of fulfilling self-concept or accessing approval from others. Feedback will be motivating if it highlights the student's progression and if they believe the feedback is helping them achieve their goals. The primary goal for the visual representation in this case should therefore be clarity.

Hypothesis 2

People are primarily motivated to play music because it is a particular type of embodied activity, which has complex mappings between the body's movement and aesthetic feedback. This facilitates a sense of exploration, creation and self expression. Feedback should be more motivating if it mirrors and enhances the idea of creating an individual aesthetic performance by responding to measurements in a way which makes a strong but complex link between movements and feedback.

In order to investigate further these two contrasting hypotheses about how to present motivating feedback I propose two designs for prototypes. Both have flexible mappings for giving feedback to a player about an aspect of their playing technique; this could be, for example, length of bow being used or posture of the player. The sensors measuring this information are low cost accelerometers, gyroscopes or bend sensors mounted on sweatbands worn on the arms[1] and can be linked wirelessly to either display (see Figure 1). One prototype takes clarity as its main design aim; the other, a sense of aesthetic creation and performance. Both designs use LEDs controlled by an Arduino[2] mini via a multiplexer to keep the design simple and affordable so that a number can be produced and given to learners to take home. Both designs clip onto the music stand above the music in order to take a place on the periphery of the learner's vision.

Design 1: Line

This design is simply 16 RGB LEDs in a row (Figure 2). Such a display is ideally suited to mapping the desired technique along a simple linear scale i.e. a short bow only leads to three LEDs lighting up, using the full bow makes the whole length of the display light up. Using RGB LEDs also gives the option to map to colour, for example a short bow may map to red and a longer bow green.

Design 2: Shell

This also uses 16 RGB LEDs but these are not positioned in a line but rather distributed around a silk shell-like

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[1] For more information about the sensor set up please contact us

[2] See http://www.arduino.cc/ for details.

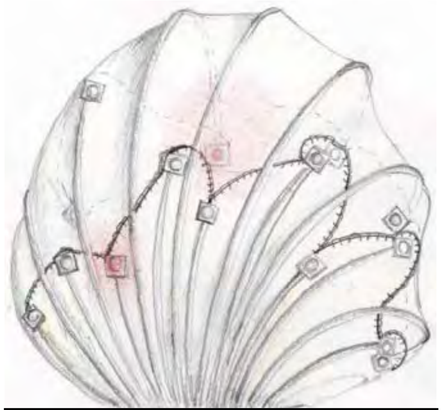

Figure 3: The *Shell* design which aims to use more complicated mappings to encourage a sense of creating and exploring the display through playing the violin.
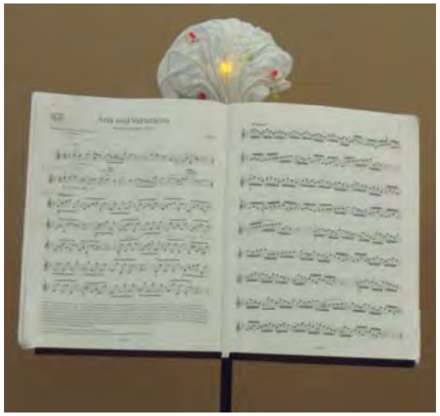
Figure 4: A photograph of an initial prototype of the *Shell* design using standard coloured LEDs.

structure which diffuses and reflects light (Figures 3 & 4). Having the LEDs in a 3D structure means that a linear display is no longer an option, the random distribution of the LEDs and the symmetry of the structure is meant to give each LED equal value rather than having a value based upon their position as in the linear display.

The idea is that the feedback maps good technique to higher activity of the lights – the lights come on and begin to twinkle more rapidly if the learner's technique fits their aims. This kind of mapping begins to touch on the idea that the learner is actually creating the lights in the display through his or her playing. How colour is chosen also may be connected to same element of technique. Rather than a simple traffic light mapping of colour to attainment more complex mappings could be used. A possible example is mapping a particular aspect of good technique to tonal changes in colour while bad technique causes abrupt random changes. In this way by using certain posture or movements the player creates ordered patterns from chaotic randomness.

This display also allows the same kind of simple colour mapping as in the linear display. By also testing the two designs with the same mapping, the structure and materials of the displays themselves could also be compared.

Relevance to this workshop

For me, embodied interaction means designing technology which appeals to the way we understand and experience the world through our body. This paper looks at one way in which embodiment can be applied to designing enjoyable and motivating feedback. This is contrasted with the design criteria which come from more standard cognitive models of motivation. The two prototypes produced from this discussion can now be used to investigate how far ideas about embodiment and aesthetic feedback can be used to create motivating interfaces.

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Embodiment as a route to understanding the role of environment in pervasive interaction

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

In this position paper we discuss space and the choreographic role it can play in human-computer interactions in ubiquitous computing environments – an area that is currently undertheorised.

We suggest that a perspective on embodied interaction grounded in the architectural theory of Space Syntax has much potential in this domain. In particular, embodied diagrams offer a means with which to reason about how the spatial environment might influence the visibility of, and thus interactions with situated technologies.

Keywords

Embodiment, ambient displays, ubiquitous computing, space syntax, spatial interaction, and spatial models

ACM Classification Keywords

H5.m. Information interfaces and presentation: Misc.

General Terms

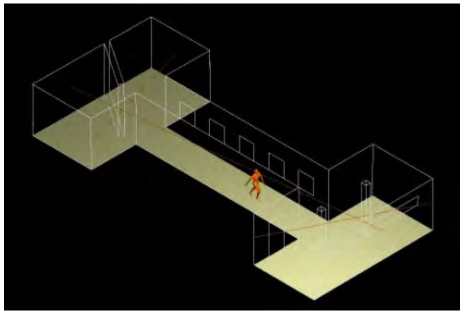

Figure 1 Embodiment and the embodied diagrams

Introduction

A current focus of much work in HCI is on the vision of Ubiquitous Computing [13]. A prominent aspect of that vision was the use of ambient technology to introduce information into the environment, exemplified by displays such as Natalie Jeremijenko's LiveWire [13].

The introduction of digital artefacts into the physical environment has created a number of issues related to the design and evaluation of these ubiquitous technologies, There have been calls for new methods and theories which may extend beyond the traditional domains of human computer interaction [1, 6].

One novel perspective that attempts to create a foundation for the next generation of HCI is Embodied Interaction. Embodied Interaction seeks to understand the role the body plays in the conception, experience and interaction with technology. The experience of ambient displays in real settings is that they are unobtrusive and users engage with them peripherally, in a similar way to a wall clock. We argue that this is a fundamentally embodied phenomenon related to the movement of the body through space.

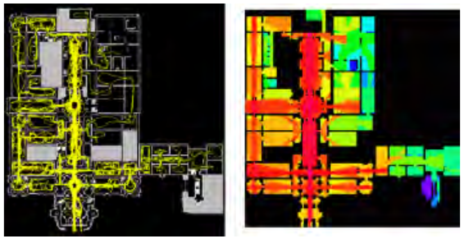

Figure 2 real world movement patterns (left) predicted occupation densities (right) For Tate gallery

Embodied Diagrams

Core to the usability of an ambient display is the environment within which it is placed and how users interact with that environment, each other and the interface. Historically there have been few theories, methodologies or tools with which to understand how space influences bodily movements and social interaction. We have proposed that the architectural theory of Space Syntax may help in this regard and could be applicable to the design and evaluation of ubiquitous computing systems [3]. Space syntax is a collection of empirically verified theories about space that suggests that the spaces manifested by architecture, create affordances which subtly influence human movement through the body and so interaction, in an aggregately predictable manner (see figure 2).

The urban phenomenologist David Seamon [12] has grounded Space Syntax theory in the fundamental irreducibly of space, describing what is termed by many human geographers as 'place' (the affective relationship between space and person) as emerging from the casual 'place ballet' of human social interaction. His work is based on the ideas of embodied interaction arising from generally un-examined movement through space (the 'life world' as Seamon describes it). Seamon has long been a promoter that the findings of Space Syntax are grounded in phenomenology (e.g., [5]). Ruth Conroy Dalton [2] has also made links between embodiment and the representations used in Space Syntax, suggesting that many of the results found in Space Syntax methods emerge from an embodied perspective. The role of these embodied diagrams (see figure 1) is a notion reinforced by Seamon. Franz and Wiener [4] have also advanced that embodied notions sit at the root of syntactical representations, suggesting new developments in space syntax theory.

In the HCI community, the work of Scupelli et al. [11] suggests that it is possible to use Space Syntax theory to gain insight into the spatial and social dynamics of the non-digital displays used to coordinate surgical teams in hospitals. Other researchers [7, 9, 10] have also used Space Syntax representations to explore human-computer interaction at a number of levels.

Extending representational methods

In an ongoing programme of work (cf. [3]) we have been exploring whether these architectural techniques can be extended to represent situations typical of ambient displays. For example, Space Syntax research has focused on the likelihood of chance encounters between building occupants [8]. This theory can be extended to consider the likelihood of chance human/machine encounters. Early pilot studies used an ecologically valid design to project information at different locations within a building, creating a number of simple ambient displays. We found that the recall of information shown on these ambient displays by building users was influenced by the size of space and the nature of the information presented. Specifically, larger spaces were associated with a higher memory for images and conversely text was more memorable when displayed in smaller spaces.

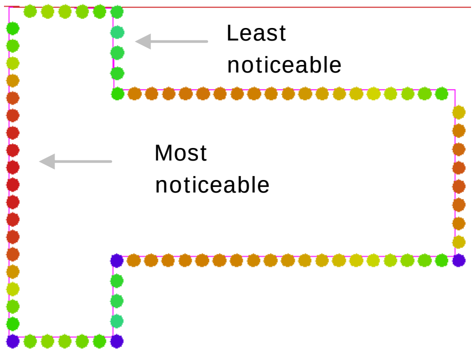

Figure 1 visualization of a theoretical measure of isovist based noticeably of a wall mounted display

While this work is provisional it does suggest the potential for using embodiment as a route to understanding the effect that the environment plays in the interaction process.

Figure 3 serves as a demonstration of the progress that is being made at a theoretical level. Figure 3 shows that visualization of a computed measure of space, based on an embodied isovist representation (built up from the visibility polygon of different locations) but modified to express the 'noticeably' of wall mounted ambient display. This simple example is coloured from red (most noticeable) through the spectrum to green (least noticeable) with blue/violet representing extreme computational cases. The reader is invited to compare the most and least noticeable locations to where they might consider to be the best and worst locations for a poster or display. This theoretical work is also currently being evaluated with user studies.

Conclusion

While the theoretical work mentioned is in development it does suggest that by beginning with an embodied representation it is possible to bring the worlds of computing and environment closer together when attempting to understand the complex ecology of interaction common to pervasive or ubiquitous computing. As such it adds to the growing number of perspectives on embodied interaction arising within HCI.

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Intuitive Interaction: Tapping into body skills to find rich and intuitive interaction methods for Virtual Reality

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract

Intuitive interaction is strongly rooted in embodied skills. We propose to take a human-centered approach to explore potential intuitive interfaces and interaction metaphors that also offer a rich interaction experience. Here, human-centered denotes the systematic exploration of the full body, i.e. all human senses and all control option people have in daily life. We describe a highly intuitive example, the ChairIO, and propose a possible neurobiological explanation of why intuitive interfaces like the ChairIO are perceived as such.

Keywords

Human-centered HCI, Virtual Reality, body skills, embodiment, embodied interaction, enactivism.

Introduction

Intuitive Interaction is strongly connected to embodied interaction. An interaction method can be called intuitive, if a user, without priming, explanation, or help, can instantly, successfully and unconsciously utilize it. For this, the method has to tap into prior knowledge and help to unconsciously apply this knowledge for effective interaction. Prerequisite for this is that this knowledge is ‘embodied’, i.e. deeply internalized and *actively* learnt [4]. Varela et al. called this “enactivism”, describing the experience-based coupling of interactions with our world, i.e. the praxis of our living, shaping interconnected sensorimotor networks that are eventually the basis for cognition [9]. The classical neurobiological concept of efference copy is closely related to this interwoven nature of sensation and action [5]. For this purpose, an internal copy of a motor command is used to predict the resulting sensation, which of course is influenced by our experience and body shape. This quite nicely points out the requirements for an intuitive Virtual Reality (VR) interaction method: the sensation elicited by an action should also hold in an immersive virtual environment.

Virtual Reality interaction methods as a general case

Especially in VR scenarios, where people are surrounded by stereoscopically projected 3D worlds, intuitive interaction is a rarely achieved goal. No help menu can aid users in acquiring understanding about the possible interaction. There is no common interaction set or interaction metaphor like keyboard and mouse for desktop PCs, other than what we know from our everyday life interaction with reality. Arguably, our VR worlds are not yet technologically capable to mimic the Star Trek’s holodeck and provide a 1:1 copy of action in the real world. Also, VR is often used by novices and every installation is different, both concerning the technology/devices utilized and the story/interaction metaphor used. Therefore, especially VR interaction methods have to be designed to be intuitive, preferably self-explaining, while we as designers are not being able to rely on learnt standard methods and tools. Results that work in immersive VR settings will almost certainly work in general.

Our research approach

Our approach to finding suitable interaction methods for VR is to look into the full human potential to actively control the environment. Jacob et al. describe four different aspects to look for such knowledge, i.e. naïve physics, body-, environmental-, and social awareness and skills [6]. We do this by systematically exploring into all senses and control options people have in pursuit of discovering suitable embodied knowledge that then can be utilized to create intuitive interactions and interfaces providing rich user quality and feedback. This approach is strongly related to actively working with the sensorimotor loop and the mind, increasing the presence of people by enaction and by purposefully guiding the mind [2].

Over the last years, we explored the visual, auditive, haptic, and olfactory presentation of information to people and surveyed full body-related ways to control the environment. Walking in place techniques for navigation, tangible devices for interaction, and tables covered with granules for playing in a sandbox are some examples. We also conducted perceptual studies to understand the adaption of a virtual body as our own. In contrast to the rubber hand experiments [3] and tools that extend our body [8], a virtual body is not connected to our own body. Even though, conflicting visual and tactile stimuli can introduce a notion of ownership of the avatar in the user [7].

All this research is aiming for a better understanding of rich and intuitive HCI. We found that physical, passive and implicit feedback, enaction, plus purposeful, directed body movements greatly enrich the experience and, through that, provide intuitive and joyful adventures, merging user and virtual environment.

In the following, we will exemplarily describe one of the results from our research, a chair-based interface for navigation in VR that has proven to be highly intuitive and even complex movements with it need nearly no learning.

Figure 1. Use of the ChairIO in a first-person shooter game as intuitive navigation method completely controlled by implicit body skills.

The ChairIO

The ChairIO is a chair-based computer interface consisting of a flexible office stool, the commercially available Swopper™ by aeris, extended with sensors. The seat has a rotatable, 360° pivot point, height and damping adjustment, and a linkage arm consisting of a spring/shock combination. The seat can be tilted in any direction and rotate freely. Further, the spring/damper system allows the user to bounce. Sensors record the stool's movements transmitting them to a computer that in turn translates this information into movements. The ChairIO can equally be employed for desktop systems as well as for large projections. While navigating through the virtual world sitting on a chair, several factors influence the user's experience:

- The chair's current position and the user's body itself inform about his physical position in space, providing natural, not artificially induced feedback.
- The user seated on the chair controls the chair's movement with his body and through this merges with the interface and interaction to a harmonious ensemble.
- The chair's movement activates the whole body and boosts the body's mobility. Its combination with a computer to control an application encourages those kinds of movements actively. The whole human being is actively engaged and inspired to move.

We employed the ChairIO in different navigation applications of virtual worlds and games (see Fig. 1) [1], as well as in many of our VR studies. In a formal study and while observing over 1.000 people until now, we found that users literally merge with their movement through virtual space. They are part of the installation and receive immediate feedback. Action and Reaction are fully integrated, while the control device fully blends with the body and is not perceived as such. Users frequently do not need any explanation for operating the seat. They immediately start using it for controlling even highly complex movements. We think that this is because users utilize their internal embodied model of how to operate their own motion in the everyday environment (FORWARD-BACKWARD, LEFT-RIGHT, ROTATION), which always involves moving the hips through space as on the seat. Furthermore, they do not even think about the device they sit on. A chair is an everyday tool. Its existence as a sitting support is well internalized and not disturbing. It is immediately integrated as a tool into the body scheme. The connection to operate the hips on the chair, then, is made automatically by combining all these familiar concepts, resulting in a correctly predicted sensation (e.g. for the visual flow).

In summary, the ChairIO is an example of a highly intuitive navigation method exploiting well our body knowledge, in this case of motion direction.

Thoughts on the Creation and Principle of Intuitive Interaction Methods

The ChairIO came to existence while systematically and creatively exploring into all senses and control options of people for interacting with a computer. We call this *human-centered VR* to denote the exploration focus to be on people, their needs, capabilities, and body skills, rather than on technology only. For this newly identified potential interaction method to then also be intuitive it is required that:

1. the interaction method connects to a well placed embodied metaphor,
2. this metaphor is appropriate and expected in the current setting,
3. the interaction device, if any, signals appropriate and inherent affordances,
4. any skill and knowledge about the usage of the interaction device was acquired (embodied) previously, such that it is now perceived as a well known tool, possibly as an extension to one's body ([8] and [3]).

All of the four require to tap into well internalized knowledge of our world, our body and the interplay of both; i.e. embodied knowledge.

Neurobiological explanation for intuitiveness
The conjectured explanation for the overwhelming acceptance of the ChairIO and intuitive interaction methods in general can be ascribed to a neurobiological concept. To discriminate sensory input stemming from external stimuli in the environment (exafference) from sensory stimuli caused by voluntary actions (reafference) a copy of the motor signal, i.e. the efference copy, is needed [5]. This efference copy can be used to make predictions about the resulting sensory feedback. For the rotation movement of the ChairIO it easily can be seen, that this prediction will result in virtual sensory feedback (visual flow) almost identical to experiences gathered on real-world chairs. Hence, it is immediately intuitive. For the forward, backward, left and right actions we have embodied concepts and expectations in what those movements should result in (relying on the direct application of body schemata). When performing these actions they straightaway lead to the expected outcome enabling an intuitive navigation behavior. This potentially explains the success of the chair-based interface and how intuitive, embodied interaction functions in general.

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Embodied Interaction in Immersive Virtual Environments with Real Time Self-animated Avatars

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Abstract

This paper outlines our recent research that is providing users with a 3D avatar representation, and in particular focuses on studies in which the avatar is self-animated in real time. We use full body motion tracking, so when participants move their hands and feet, these movements are mapped onto the avatar. In a recent study (Dodds et al., CASA 2010), we found that a self-animated avatar aided participants in a communication task in a head-mounted display immersive virtual environment (VE). From the perspective of communication, we discovered it was not only important for the person speaking to be self-animated, but also for the person listening to us. Further, we show the potential of immersive VEs for investigating embodied interaction, and highlight possibilities for future research.

Keywords

Animation, Avatars, Communication, Embodiment, Interaction

ACM Classification Keywords

H.5.1 Multimedia Information Systems–*Animations; Artificial, augmented, and virtual realities*.

CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

General Terms

Experimentation, Human Factors

Introduction

Multiple users interact together using computer technology as part of their daily lives, e.g. using Twitter, Wikipedia, Second Life, World of Warcraft [7].

In the former examples, interaction and communication can be carried out using text based interfaces (e.g. discussing an article on Wikipedia). In the latter, people have an embodied representation (e.g. avatars talking to each other in a Massively Multiplayer Online Game). We ask the question, what is important about having an embodied representation in VE interaction. Specifically, an embodied representation in our work means a self-animated avatar: we use full body motion tracking to allow people to animate their own avatar in real time (Vicon optical tracking, and Xsens MVN suits). Our participants view their avatar using a head-mounted display (HMD). The view can be first-person (when the user holds up their hands in front of their eyes, they see their avatars hands) or third-person (over-the-shoulder perspective). See Figure 1.

This ability to control an avatar using motion tracking creates new and exciting opportunities for naturalistic interaction. While controlling an avatar’s movements is not new (e.g. moving using a control pad, using the keyboard to make one’s avatar ‘wave’, ‘nod’, ‘shrug’), there is evidence to suggest a naturalistic interface (i.e.

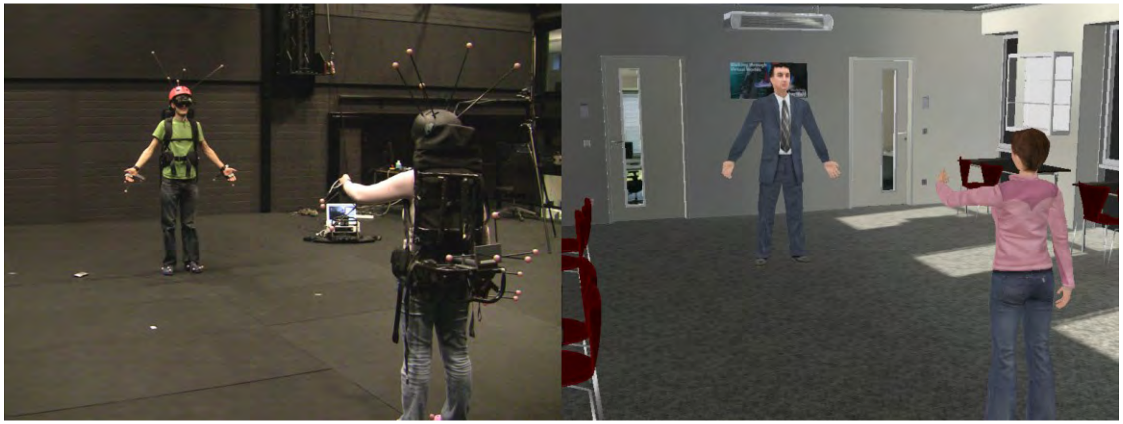

Figure 1: Two users (left) wearing rigid body objects on their hands, feet, helmet and backpack, tracked by Vicon cameras, and mapped onto their avatars (right).

using motion tracking) is actually increasing our sense of avatar ownership [5]. And recent advances in tracking technology, e.g. Microsoft's Kinect, make this type of interaction much more affordable.

Figure 2: Examples of technology for self-animated avatars used by our research: Wearing an Xsens MVN suit underneath normal clothes (left); and Vicon body tracking wearing an NVis head-mounted display (right).

Our group's research has investigated the importance of a self-animated avatar from the perspectives of perception and interaction. In perception, giving people an avatar in a HMD environment helped alleviate the effects of distance compression that are well known to occur in VEs. Participants' distance judgements improved further when their avatar was self-animated. First or third-person perspectives did not have an impact on the magnitude of the effect [4].

In another study, [6], we investigated the effects of knowledge about one's avatar on task performance on three behavioral tasks: locomotion, object interaction and social interaction. We did not find effects of pre-exposure to a self-avatar on these tasks. We did however find effects of testing environment (VE / real world) and testing order (VE first, real world first) on participants behavior. We will further investigate if presence of the self-avatar during the task (rather than prior to task execution) will cause the performance on these three tasks to be closer to real world performance.

A study in [2] focused on the importance of embodiment from the perspective of multiuser interaction. We consider communication an essential subtask of any collaborative interaction, and therefore this experiment investigated how two users communicated in HMD virtual environments.

In HMD VEs, we can systematically manipulate different aspects of our environment, the functionality, and our appearance. In this study, we focused on the manipulation of the availability of body language and gestures in our self-animated avatar. We compared conditions with static avatars, with conditions where users had full-body motion tracking as a naturalistic interface for controlling a self-animated avatar.

The media richness theory claims that more interaction cues such as body language and gestures would improve communication [1]. In addition, work from psychology and psycholinguistics tells us that the gestures that naturally occur with speech carry additional meaning [3]. Finally, work in virtual reality shows evidence that we can have a sense of ownership over our avatars, and we would predict people to use gestures and body language in the virtual world in a similar way that participants would manipulate their own bodies in the real world (i.e. we would see participants and their self-avatars produce some of the gestures that naturally occur with speech).

To evaluate the importance of gestures participants played a communication game where they had to describe the meanings of words in rounds of three minutes, without saying the word itself. This gave us a measure of performance (mean number of words described per round).

The results show participants moved more and performed better in the communication game when both avatars were self-animated, compared to both static (we see the importance of nonverbal feedback, in addition to the usage of gestures by the speaker). This effect occurred in the third-person perspective, and we note the limitations of seeing one's own body in first-person perspective HMD environments (small field of view, meaning one's arms, legs and body are not visible when one is looking at someone in front of them).

Future work will investigate embodied interaction using large screen immersive projection technology, with two users wearing inertial motion tracking suits (Figure 2) and communicating over a network. In this setup we will investigate: What is important about seeing one's own body in the real world, with a naturalistic field of view, while communicating and interacting in VEs? Overall, immersive VE technology, where you can manipulate the visual body of the user in various ways, identity, movement, selective behavior (gaze, gestures), is a powerful tool for investigating embodied interaction between two people.

Acknowledgements

This work was supported by a post doctoral grant from the Max Planck Society, and by the World Class University program through the National Research Foundation of Korea funded by the Ministry of Education, Science and Technology (R31-10008). We thank Ivelina Alexandrova, Tobias Meilinger and Paulina Teneva.

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Other People's Bodies: Communicative Aspects of Embodied Interaction

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Abstract

This paper presents a provisional framework for understanding the communicative aspects of embodied interaction by examining several examples of interaction designs that were explicitly designed to explore the communicative interaction patterns between interactive entities, and discussing how these examples illustrate how embodiment factors into communication.

Introduction

Bodies matter because they affect the way that we interact with one another in the physical world. Just the corporeal presence of another person near you conveys a wealth of important information: you are reminded of that person's existence; their orientation or poster may signal their availability to interaction; their height or poster may convey information about their relative status in potential interactions; and their proximity might reveal their degree or nature of their task engagement.

Since we interact with far more people (and objects) than we come in physically contact with, the communicative aspect of our embodied interaction is as important to understand as the more visceral embodied interactions associated with tactile or tangible interactions. This understanding is made easier by a

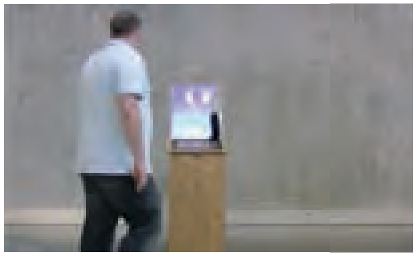

Figure 1. Physically Animated Kiosk with Physical Hand beckoning to a passerby.

Figure 2. The Range interactive whiteboard adapted its functional response based on the users' proximity

switch in our theoretical perspective from the first-person perspective *("What I do/think/feel?")* to a third person perspective *("What is it that other person is doing, thinking, feeling, saying?")*. This paper presents a provisional framework for understanding the communicative aspects of embodied interaction by examining several examples of interaction designs that were explicitly designed to explore the communicative interaction patterns between interactive entities, and discussing how these examples illustrate how embodiment factors into communication.

Reference Projects

This paper draws upon a series of the author's design projects that use embodied interaction for communication in different ways.

Physically Animated Kiosk

This study investigated the role of motion and physicality in drawing people to look and actively interact with generic information kiosks (see Figure 1). Using semi-controlled field studies, we found that the physical gesturing caused 60% more people to stop and interact with the kiosk, regardless of the form (hand versus arrow) atop the gesturing arm. [2]

Range: Interactive Whiteboard

Range (Figure 2) is a public interactive whiteboard designed to support co-located, ad-hoc meetings. Its design was based on observations of the proxemic behaviors of design teams engaged in ad-hoc design meetings. The Range whiteboard employs proximity sensing capability to proactively transition between display and authoring modes, to clear space for writing, and to cluster ink strokes. We used this project to explore the embodied and implicit interaction techniques of *user reflection, system demonstration*, and *override* can prevent, mitigate, and correct errors in the whiteboard's proactive behaviors. [3]

Gesturing Doors

In the Gesturing Doors project, we found that people had strong social and emotional responses to doors on a public building that would gesture in different ways as they walked up to the door or passed by. This project was based on our observations of implicit interactions between doormen and passersby, the way they implicitly offer to open the door by, say, overtly placing their hand on the door handle, or opening the door a small amount, and then the way they watch to see if the passersby respond by walking toward or away fro the door.

Remote Tele-gesturing

In this project, we investigate the role that embodiment can play in augmenting traditional telepresence technologies (such as Skype phone conferences) with remotely controlled robotic gesturing capability. Our telepresence robot (shown in Figure 4) has a robotic arm and an actuated neck, which allows the remote participant to point and wave, as well as orient his head, nod in agreement, or indicate surprise.

How embodied interactions communicate

Reflecting upon these past projects, we find that there are five different ways that embodiment aids communication. Here, we discuss each of these ways, and how they manifested themselves in the previously mentioned projects.

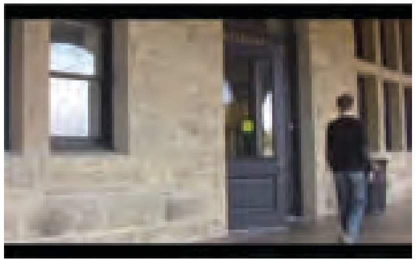

Figure 3. People engage in two-way physical communication with automatic doors by walking toward or away from doors.

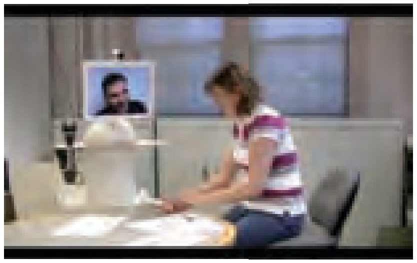

Figure 4. The robotic telepresence gives the remote participant more physical presence in the shared workspace.

The body as presence

Presence is "just being there." Once physical presence was a prerequisite for real-time interaction, and, hence, physical presence signals availability for further communicative interaction. Key interactions between colleagues are the result of unscheduled meetings where people "run into each other" in hallways and common meeting places. [6] Although there are now online ways of denoting "presence," such as the status line on a Facebook page, remote teleworkers still find that having a physical presence improves the awareness of your presence and activity. [7]

All of the projects in the previous section use presence as a way of engaging and anchoring the interactions. The users of these systems don't have to "call up" or "launch" these systems—their physical presence provides a persistence that indicates or reminds people that an interaction is possible.

The body can also perform "saying through doing." That is to say, the pragmatic actions that people take also have an inherent a communicative element. That implicit communication [1] can be made more explicit, or "louder" if the actions of the body are "performed," or conducted in a way that acknowledges and tries to communicate with an audience.

We found in our test deployments of our systems that people often did things that indicate an intuitive understanding of the body's ability to communicate through acting. For instance, if the gesturing door did not register a person's approach in a timely fashion, people would often "walk louder" in a more deliberate and exaggerated fashion, to provoke an expected response. Similarly, if the kiosk's waving arm did not stop waving when a person walked up to and started interacting with the kiosk they would often lift and resettle their body, and shuffle and stamp their feet, as if to reiterate "I'm standing here now."

The body as a focus of attention and communication

The body is used to gesture and communicate explicitly. Physical motion in space naturally entrains the visual attention of others, and people are able to communicate messages without speech through gesture.

Gesture is used explicitly in the interactive kiosk and remote tele-gesturing projects, where the interactive systems use arm and/or neck features that are clearly humanoid in form to signal emblematic messages like "come over here" or deictic messages like "look there." What we found in our studies is that while the physical motions needed to be "human-like" to be recognizable, anthropomorphic forms (such as hands) weren't necessary for people to understand the gestures.

The body as a secondary channel of information

The body can also be used to augment the primary channel of communication. A person's bodily stance might convey the confidence she feels in what she is saying. The distance that a person is standing from another might indicate the degree of trust, or the confidentiality of the information being conveyed. Inconsistencies in verbal and non-verbal cues are often interpreted as a sign of deceit. These non-focal cues are often a way that diffuse information, like emotional state, are conveyed.

The Range whiteboard and the Gesturing Doors project make use of the body's ability to communicate peripherally by responding to the proximate location of the whiteboard users, or the walking direction of the passerby. This enables interaction without breaking up the conversation of the design meeting participants or passersby are critical to the smoothness with which these transactions take place.

The body as spatial context

The body also communicates through its provision of a spatial context. The body “sets the stage” for communication; a tall person is usually considered high status (and he or she might slouch to signal lower status); a broad, wide shouldered stance indicates a wider intended audience than a forward-leaning crouched stance.

Range had the ability to change spatial context through the size of its displayed screen; a smaller screen would indicate a more intimate and private context than the full-screen. Similarly, the robotic tele-gesturing robot’s articulated neck allowed the remote participant to lean in or pull-back, and these gestures were indicate something about who the remote person was talking to, or whether what was being conveyed was a private comment or an official part of the meeting conversation.

Conclusion

While these methods of using the embodied interactions as communication are not mutually exclusive, we believe that the articulation of each of these methods can be useful as design considerations. Designers might look these considerations as design techniques—ways of accomplishing interactive goals—or as cautionary notes—things to look out for to make sure the intended interaction isn’t being undermined.

By looking at these ways that embodied interactions communicate, we understand how the interactions might affect those not only directly interacting with our designed systems, but those further away. Hence, these discussions help us understand the wider implications of embodied interactions

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