INTERNATIONAL CONFERENCE ON DESIGNING PLEASURABLE PRODUCTS AND INTERFACES, DPPI09
13- 16 OCTOBER 2009, COMPIEGNE UNIVERSITY OF TECHNOLOGY, COMPIEGNE, FRANCE

LET'S TAKE THIS CONVERSATION OUTSIDE: SUPPORTING EMBODIED EMBEDDED MEMORY

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ABSTRACT
In a research-through-design project we developed NOOT, a tangible interaction device that links conversational context to texts and sketches generated during creative sessions. We assumed an *embodied embedded cognition* perspective; i.e.: cognition was assumed to be embodied in human activity and embedded in the local environment. Observations showed how post-its and sketches are used as *cognitive scaffolds* during the session, while being less effective as memory stores afterwards. Audio context enhances the scaffolding power of text and sketches such that they retain their meaning even outside the session's context. NOOT thus supports *embodied embedded memory*; to be contrasted with digitalized explicit descriptions. We see embodied embedded cognition not just as a guide to interface design, but more fundamentally as a key towards finding new functions of digital computation within real, embodied embedded practices.

Keywords: embodied embedded cognition, tangible interaction, memory, creativity, practice

1 INTRODUCTION
Two of us once had a brainstorm session over the present project. After the event we left inspired and full of ideas. We met again two weeks later. A flip chart with sketches, phrases, arrows and diagrams functioned as last session's minutes (See Figure 1). Staring at the materials, we couldn't remember what was supposed to have been so great about it. Some of it even seemed completely meaningless. Struggling to recount how the conversation had evolved, we managed to reconstruct some of the ideas. But our initial enthusiasm had been replaced by a slight fear that we hadn't made any progress at all. It felt as if we were seriously wasting time having to redo most of last session.

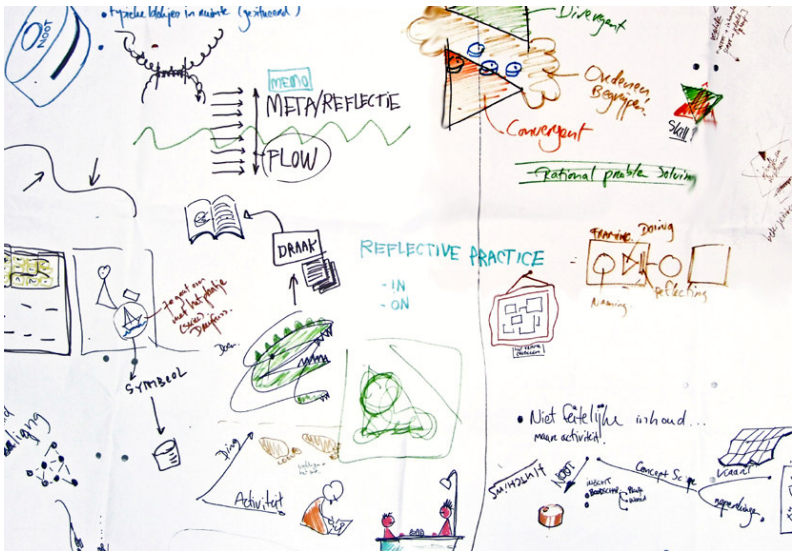

Figure 1: The flip chart that didn't ring a bell

With this paper we present a way to support the recollection of thoughts, ideas and concepts from creative design sessions. It forms part of an investigation into the question of how the theory of *embodied embedded cognition* [1] may inform the design of tangible interaction.

1.1 Embodied Embedded Cognition

Embodied embedded cognition (EEC) portrays cognitive processes – for example, memory processes – as emergent properties of a subtle interplay between brain, body and world [1]. Cognition is said to be grounded in sensorimotor *couplings* between the environment's *affordances* and the body's *action possibilities* [2]. Cognition is also seen as *embedded* in the environment, contingent on individual action histories and situated in a social context [3]. Hutchins [4] showed how cognition is *distributed* over systems of people and artifacts. Clark [1] argued how couplings between the body and the environment (including artifacts) may create locally available *cognitive scaffolds* that facilitate cognitive processes (See also [5], [6]).

Dourish [7] conceives of *embodied interaction* as "an approach to design and analysis of interaction that takes embodiment to be central to, even constitutive of the whole phenomenon". When designing for interaction, he argues, "inhabited interaction in the world" should be favored over "disconnected observation and control" [7, p. 102]. In relation to this, Djajadiningrat, et al. [8] emphasize how "meaning is created in the interaction". Their *direct approach* stresses the "sensory richness and action potential of physical objects as carriers of meaning in interaction", with high "respect for perceptual and bodily skills" [8].

One of the concerns for designers of interactive artifacts is what this means for connecting computation and physical form. According to Klemmer et al. [9], "solutions that carefully integrate the physical and digital worlds are likely to be more successful by admitting the improvisations of practice that the physical world offers". The question is of course what it means to "carefully integrate" in successful ways.

1.2 Memory in ConceptSpace

Our prototype forms part of our in-house *ConceptSpace*, a physical space enriched with several tools for stimulating creativity and co-design. One of the questions was how insights generated during the session can be saved for later use. Video-analyses of several creative sessions in ConceptSpace suggest that people seldom take explicit notes on what is being discussed during a session. We speculated that people are particularly bad at note taking when immersed in creative flow, because taking explicit notes threatens to break the flow. At the same time, we did observe the walls and tables getting filled with physical residuals of people's activities: loose phrases and sketches on paper, whiteboards and post-its. After the session, however, these physical residuals proved to be poor triggers for rich memories of the session, if they triggered anything at all. The danger is a poor transfer of valuable insights from the session to later stages in the design process.

1.3 Memory scaffolds

Instead of addressing explicit note taking, we asked first why physical residuals are such poor memory triggers. Based on the EEC perspective, we speculated that ad hoc texts and sketches are used primarily as cognitive scaffolds [11, 1], enabling creative thought and guiding conversation between participants during a session. Text and sketch, on this view, function so as to guide and sustain satisfactory interactive couplings between the various participants and the emerging idea *in situ* [12, 13]. For example: when two participants experience conflict over some idea, one of them might walk over to the whiteboard and draw a sketch, after which the sketch functions as an external 'anchor' to which both participants can relate their thoughts, guiding the conversation towards resolution. This is very different from cases where participants deliberately take notes in order to 'store' ideas for later use. In the latter case, one has to step out of the flow in order to try as good as possible to describe "the idea" as it emerged in flow. Texts or sketches created as scaffolding elements within a creative flow generally do not function well as "offline" descriptions of the process, even though people may attempt to use them as such. This is because the scaffolding function is created and sustained "in the interaction" [8, 3]. The physical prop is only one coupling element within a larger embodied embedded memory system [14]. Once the participants' contextual activities end, the scaffolding power of the prop quickly disappears. Moreover, even if a sketch or text does trigger an elaborated memory,

it will to some extent always be an active reconstruction, subject to distortions caused by later experiences [10].

1.4 Tangible interaction and memory

There are various tangible interaction systems concerned with memory, as reviewed by van der Hoven & Eggen [15]. As an example, their own system, the *Digital Photo Browser*, utilizes people's use personal souvenirs as memory cues. The system associates these souvenirs with digital photographs, thus enhancing memory [15]. Another recent example is *Other Brother*, a semi-autonomous device that spontaneously takes snapshots from everyday life, enabling people to re-experience these moments in a playful way [16]. As a last example, *Experience Clip* [17] is a mobile tool for capturing personal experiences on video while in the flow of ones activities. It functions as a user-research tool for designers. These examples differ from traditional memory tools because they are not aimed at the storage of complete, explicit descriptions. As [15] concludes: "augmented systems cannot [by themselves] store memories". Rather, digital information in these devices takes on meaning only in the context of personal, situated activities of the people involved.

1.5 Design objective

The motivation for our design was a need to support memory and communication of ideas generated during a session. The question was whether computational power would add value to physical sketches and texts. The goal was to develop an interactive prototype supporting "embodied embedded memory" in the context of concrete creative design activities.

1.6 Research objective

Our research objective is to gain a better understanding of how embodied embedded memory can be supported by interactive artifacts. We approached this question by developing a prototype based on EEC principles and reflecting on knowledge gained from the design process, as well as from user-research on the evolving prototype.

2 DESIGN & RESEARCH APPROACH

We followed a cyclic research-through-design approach consisting of three iterations. Each iteration resulted in a mock-up or prototype that allowed for experiencing the intended interactions and functionality in the context of use. The evolving prototype was evaluated in each cycle with respect to the original design objectives. Both for generative as well as evaluative purposes we videotaped and analyzed several sessions with potential users (students of design education with no prior knowledge of the project). See Table 1 for an overview of these user-studies.

Table 1: User studies during the design process

Study	Description
Initial orientation	Observing video of; and participating in, several creative sessions as inspiration for the first concept.
Investigating the creative practice	Qualitative analysis of video of 17 students of engineering divided into three groups doing a 150 minutes session each. A 'words not allowed' phase and a 'no sitting allowed' phase served to stimulate bodily action and suppress a detached' mode of thought. Goal: elicit suitable embodied interactions as a basis for the main interaction with the physical object.
Creative sessions with end users	As above.The session topic was to think of ways to use the environment and tangible objects for organizing and communicating ideas during a session.
Evaluation of the prototype	Two groups (4 and 5 students) engaged in 3 creative sessions each, together lasting a day per group, either with or without NOOT (Wizard of Ozz set-up regarding the audio recording). Participants commented on the basic usability of the product. Speech-length was also analyzed.
Evaluation of the prototype II	3 participants from study 4 received the session's ideas one week later, either only 'on post-it' or combined with the audio-sample. They were asked to report freely on what they remembered of each idea.

3 THE NOOT PROTOTYPE

3.1 Description of the system

NOOT[1] (see figure 2 below) consists of a large amount of graspable objects mounted with a wireless transmitter, a PC with receiver, and an audio system that digitally records the entire session out of the participants' immediate attention. The basic scenario is that participants, while engaged in a conversation, support their discussions with sketches and texts created on the fly. Each time a new idea is brought to the fore, one takes up a NOOT object and clips it onto the text or sketch that refers to the conversation, as if to say: "let's mark this moment". At the moment a NOOT-object is clipped to a sketch/text, it sends a signal to the PC, upon which a time-marker with ID is placed in the audio-recording. The NOOT object is now associated with a particular part of the audio-file. Later, activating a touch-sensor on NOOT causes playback of the recording from 10 s. before the time-marker up until 10 s. after. (This length resulted from the prototype evaluation; see Table 1. It can be adapted in an offline GUI that also allows playback of all audio and export as wave files). In effect, by touching the NOOT-object attached to a physical prop, the system replays the part of the discussion centered around that prop, just before and right after one decided to "mark the moment".

3.2 Evolution of the concept

Early in the project we were open to the question of what exactly the function of the tangible system should be. Based on our observations we decided to take our focus away from the task of explicit note taking, because in practice people often have time to neither write nor read explicit notes. Since sketch and text created on the fly are accompanied by rich conversational context that is typically not stored

The NOOT system. 1) NOOT can be attached to paper by inserting the paper into the NOOT while pressing the circular button. 2) NOOT can be used to organise text and sketch on a whiteboard. 3) Inside NOOT: The 4) micro-electronics and antenna, 5) battery holder and 6) push-button mechanics. 7) The 433MHz AM radio and 8) the PIC16F688 microcontroller. 9) NOOT in action. When paper has been inserted, the microchip detects that the button has been pushed and paper is in place. It then transmits a wireless signal to the PC (not shown), upon which a time-marker is placed in a digital audio recording of the entire session. When the user is physically present in ConceptSpace he can play back the sample associated with each NOOT via Dolby Surround Speakers by touching the sensor positioned just below the push-button on the NOOT.

Figure 2: The NOOT system.

in the physical residuals themselves, we decided to capture this context and digitally associate it with the physical items. Based on EEC, we therefore conceptualized physical props as cognitive scaffolds, instead of taking the conventional view where text and sketches are seen as explicit storage devices.

[1] NOOT means "nut", as in walnut, which is about the size of a NOOT. It also means "Note".

When interacting with the scaffold after the session, the audio-context should 'revive' the conversation, resulting in a re-emergence of the original idea as present during the session. There were various iterations on what the tangible interaction should look like, and our early ideas evolved in parallel with the functional question. Presently, the physical form of NOOT reveals little about its function as a time-marking device in an audio-recording, although clipping it onto a post-it or sketch it does 'mark a moment' in a conversation between participants. We considered giving the object an iconic form or color code which people could use. However, once we were on the track of augmenting people's personal scaffolding activities, we decided not to determine, as designers, the way people use the environment as a scaffold (in contrast to e.g. Ullmer & Ishii's Token+Constraint approach [18]). Instead we see NOOT as a uniform 'tag' that can be clipped onto whatever personal environmental scaffold may be created by the participant.

3.3 Evaluation

We will focus here on the basic way NOOT takes on meaning in a creative session. The analysis of the video and post-interviews of study 3 (see table 1) suggest that participants use NOOT as a natural extension of using post-its and sketches during ongoing conversation. We observed how people write or sketch something while talking about an idea and then quite intuitively take a NOOT, clip it onto the prop and put it on the whiteboard. All of this happens within the same flow of activity and without interrupting the conversation. However, the clipping mechanism, that was refined in two iterations, needs further optimization since it is still not intuitively clear for novice users. We also observed how one participant would talk and sketch, while a second participant would clip a NOOT onto the first person's sketch, thereby marking its significance. Such interactions suggest that NOOT serves a social function by communicating the way people judge the value of other people's ideas, which we intend to study further.

In our last study we send 3 participants all brainstorm results one week after the session, either as a text on a post-it or as a post-it combined with the associated audio-sample. We asked them to report freely on what they remembered of each idea. Audio enriched post-its generally elicited more elaborate responses. As one participant noted:

> *"By means of the audio fragment you get drawn back into the session for a moment and you can relive the session, you remember what the atmosphere was like. Also the parts you forgot come back to you. In my case: the fact that this* idea [a certain food product, which in fact was the participant's own idea] *would be nice for parties. This aspect came back only when I listened to the audio fragment"*.

Our results are preliminary at this point. Currently we are conducting a larger user-study to validate some of the speculations above, in close collaboration with a company that specializes in creative sessions. At the same time a redesign will include an improved GUI with the aim of integrating the system with the concrete work-practice of the same company.

4 DISCUSSION

We undertook this study to explore the question of what EEC can mean to a tangible interaction design project in the context of real, everyday practices. We now discuss how designing from an EEC perspective changed the way we conceived of the design problem for both the function and the interface of the system.

4.1 An EEC perspective on NOOT supporting memory

In our concept, ideas are not seen as "stored descriptions" on the computer; just as, on the EEC view, ideas are neither "stored" as text or sketch, nor "stored" as a mental model in the brain. Instead, using NOOT, people generate meaning by means of physical interactions during ongoing activities. One clips the object onto a sketch that one just created, puts the sketch on the whiteboard, revisits that sketch, in that location and context, and then listens to the original audio context. NOOT illustrates how the idea can be retained as a distributed entity, kept alive over time by ongoing interactive couplings between people's embodied activities, physical scaffoldings and computing power.

A conventional interpretation would see NOOT as a kind of memo-recorder with which people can record, store and retrieve important remarks during a session. Text and speech are seen here as describing the idea, recorded, and stored for later use. The functionality of NOOT, on this view, depends on whether the user can store and retrieve the right descriptions at the right time. The NOOT

object is here primarily a remote control for a digital action. The interface problem then concerns the question of how easy it is for users to activate the audio function and organize the digital samples in the GUI.

During earlier iterations of the prototype we were sometimes drawn into the latter interpretation. For example, at one point we were very concerned about whether all speech relevant to an idea was going to be captured in a 20 second sample (which, on average, it did). Yet it doesn't really matter whether all 'relevant speech' is captured if one looks at the system from an EEC perspective. Here, the system aims to enhance the strength of situated scaffolding activities of participants during and after the session. That is, while normally text and sketch created in a session quickly lose their meaning after the session ends, the audio-context forms, as it were, a scaffolding bridge between the meaningful activities during the session and other activities later on, after the session. It is this bridge that we claim to be a form of *embodied embedded memory* for ideas.

Important insights during a session need not be completely described and stored in order for them to be transferable to situations outside the session. Rather, the audio-context let's the creative flow within a session be revived and directly integrated with ones activities later on. The function of the system now depends on the question of whether the audio provides sufficient context in order to let one "relive" part of the session, such that the idea can reemerge much in the same way as it did the first time. The interface problem, on this view, concerns not how one can manage digital data, but rather how to ensure a seamless integration of digital media into embodied practices.

4.2 From interface design to design for 'digitally enhanced' practices

Many examples of tangible interaction focus on how to create more or less "embodied embedded" *interfaces,* allowing people to interact intuitively with digital environments [19]. A digital environment however, is itself still disembodied in nature. Our approach has been to use EEC not as a guide to designing tangible interfaces to digital environments but to use the theory more fundamentally to design embodied embedded, digitally enhanced, *functionality*. That is, our approach asks not merely to give tangible *access* to digital functions [20] but to reconsider digital function as a whole: how can digital processes become meaningful within ongoing embodied embedded activities (Cf. [21])? Instead of starting the project with a digital system, asking how the user should connect to it, we started with an embodied practice, asking how digital computation might play a role in it. The practice we started with was the activity where people use writing and sketching as cognitive scaffolds, supporting individual cognition as well as shared understanding. We did not want to replace this practice with a digital tool (making it "virtual" so to say), for that would in effect change the practice. We also did not want to by-pass the practice, for example by creating a memo-recorder that would have to be used outside of the creative flow, in a different cognitive mode. Instead, we took EEC as inspiration for a digital tool that integrates with an already existing meaningful practice in a way that would neither kill nor replace it but instead enhance it. NOOT connects activities within session to activities outside the session by means of digital audio tagged to the session's physical residuals. This means that its function, not just its interface, forms an integrated part of the user's embodied embedded cognition.

4.3 Future work

In a follow-up project we are further researching the way NOOT integrates with the practice of creative design. One of our questions is how and when audio samples can best be fed back into the user's activities. That is, given that a NOOT has been used to place a marker, in what situations will participants benefit most from audio playback? What activities will they be engaged in at such moments (For example: Are they still within the session? Are they at home, sitting behind a desktop computer, writing a report? Are they in a meeting with stakeholders?). And how can we integrate the playback functionality within those practices? The current prototype allows touching the sensor on the physical object containing the physical prop. This scenario seems to be of practical value only in a limited number of cases (e.g. during the session itself or upon returning in ConceptSpace directly after the session).

5 CONCLUSION

By reflecting on a concrete prototype we sought to gain a better understanding of embodied embedded memory in the practical context of creative design. NOOT supports embodied embedded memory of

ideas, to be contrasted with conventional storage devices where digital media are used to "store" explicit descriptions of ideas. Using NOOT, memory is conceptualized as the way in which digital audio can form a scaffolding bridge between meaningful activities within a session and activities outside the session. In this paper we have showed how the theory of EEC can be used not just as a means to creating a tangible interface to a digital environment, but more fundamentally as a guide to designing for the seamless integration of digital computation and embodied embedded practices.

ACKNOWLEDGEMENTS

We thank all the students of the 2008 Interactive Media Products program for their work and the Creativity Company for providing insight into their creative practices.

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