Creating Traces, Sharing Insight

Explorations in Embodied Cognition Design

Jelle van Dijk

Uitnodiging

voor het bijwonen van de verdediging van dit proefschrift op 28 mei om 16.00 uur In het Auditorium, in Collegezaal 5 van de

Technische Universiteit Eindhoven

Aansluitend bent u van harte welkom op de receptie

Adres:
Den Dolech 2, Eindhoven
+31 (0)40 247 9111
http://www.tue.nl/universiteit/kolom-3/route-en-plattegrond/

Paranimfen:
Sietse Nagelkerke
sietsenagelkerke@gmail.com
06-43905986

Philip Mendels
p.mendels@gmail.com

Jelle van Dijk
+31 6 14737778
jelle1975@gmail.com
www.jellevandijk.org
tue.academia.edu/jellevandijk
dqi.id.tue.nl/web/dqi-group/jelle-van-dijk/
www.technologieeninnovatie.hu.nl/

Creating Traces, Sharing Insight

Jelle van Dijk

Creating Traces, Sharing Insight

Explorations in Embodied Cognition Design

A catalogue record is available from the Eindhoven University of Technology Libarary.
ISBN: 978-94-6191-699-0

Opmaak SEB|DAAN - www.sebendaan.nl

Creating Traces, Sharing Insight

Explorations in Embodied Cognition Design

Proefschrift

ter verkrijging van de graad van doctor aan de
Technische Universiteit Eindhoven, op gezag van de
rector magnificus, prof.dr.ir. C.J. van Duijn, voor een
commissie aangewezen door het College voor
Promoties in het openbaar te verdedigen
op dinsdag 28 mei 2013 om 16.00 uur

door

Jelle van Dijk

geboren te Utrecht

Dit proefschrift is goedgekeurd door de promotor:

prof.dr.ir. C.C.M. Hummels

copromotor:
dr.ir. R. van der Lugt

For Kees

Contents

Acknowledgements

This is the part that most of you actually read. So you understand I am quite nervous about getting it right. In particular, in case I forgot you – I am truly sorry. Of course you should have been in here as well. Thank you so much!

*

My many thanks go to: Janneke Sluys, and the first NOOT team, Marnick Menting, Jirka van der Roest, Edouard Messager, Gerrit Willem Vos, Sippe Duisters, Sijme Geurts, Tim Bakker, Aniek Lambregts, Mendel Broekhuizen, Reinder de Vries, for your help in designing and researching the prototypes figuring in this thesis. Your work grounded all I learned * Creativity Company, Future Centre LEF, YOUMEET and Van Berlo Design (Especially Sjoerd Hoyink), for your hospitality, interest and time. * Joep, Bart, Pierre, Oscar, Philip R., Philip M., Jelle S., Miguel, Remco, Ambra & Stoffel, and everybody else at DQI: for a refuge, with classic 'engagement' in the air; something hard to come by these days. I hope to return often. * All colleagues at Oudenoord 700, for your interest and help, even when I mostly brought chaos and confusion. Rob, Pieter en Paul, for covering my back * Janny, Anny & Mariëlle, for all back-office support * Iris and Pim, for our memorable discussions in Nijmegen, which created the basis for this thesis. I found myself talking to you both while writing. Thanks for thinking with me! * Martijn, our grandfather had some fine genes for sketching and crafting. It was inevitable we would collaborate at some point. Thanks for the great art-work! * Marijn, for pimping the English, in the limited time available. I will thank you ;-) Café Springhaver, thank you for making thinking and writing so much more pleasurable. Thanks Sietse brother, for being there with me in the longtails!

*

Remko. Lately, Sil has been running about the house, shouting: 'What we could also do...' He reminds me of your endless optimism, and of your talent of always being able to think of another possibility. That, and the way you take your other job - being a dad - very seriously, keep reassuring me it was a good decision to team up with you. I learned a lot from you. Let's think of many more possibilities, and do all of them.

*

Caroline. We connected twice over. First, at the TEI conference, you got me hooked on to this strange crowd, all busy mixing up physical objects, human values and technology as casually as if fixing a salad. The second time was not planned at all. I am grateful you immediately stepped in when Kees suddenly passed away. You wrote you would be 'honored' to supervise me, which makes me shy. I am honored to have been your PhD student. I once thought my supervisor would have to be a grey-haired patriarch. Kees came close. Now I know grey hair is at all not required: your trust and kindness were all I needed.

*

Mirjam. Lichaam en geest met elkaar te verenigen: dat is gemakkelijker gezegd dan gedaan. Misschien eerst eens doen, en dan pas zeggen. Eerst ervaren, dan pas benoemen. Ik lees er boeken over; voor jou is het je meest natuurlijke modus. Dank voor alle ruimte – ik geef ze je terug, met liefde.

*

Jonas, ik denk dat ik in de afgelopen tijd nogal eens 'weg' was, zelfs als ik in de kamer zat. Verstopt in mijn computer. Ik probeerde uit te vinden hoe mensen weer 'uit hun hoofd' kunnen komen, terug, de echte wereld in. Wij weten nu allebei dat dit vanachter een laptop in ieder geval niet zo goed gaat! Het gaat veel gemakkelijker met een potje judo, of met samen tekenen, of dansen. Ik geniet van jou Jonas en ik leer van je: je hebt vele talenten, in denken en in doen. Koester beiden! * Dag lieve Sil, het was al snel duidelijk: niemand hoeft jou iets te vertellen. Ik ga mijn best doen om dat dan ook niet te proberen. Wat leuk dat je er bent, alle 100%! Ik ben benieuwd naar 'wat we ook nog kunnen doen!' * Jos en Cora, dank voor alle liefde en betrokkenheid, en voor het leren kijken naar mensen; wat we doen, wie we zijn, en waar we naar toe gaan.

Preface

“You try too hard to draw the picture you have already in your mind, and you become frustrated when it doesn’t come out exactly the way you imagined it. That’s when you start spoiling the work. Let the pencil just go on the paper and observe what emerges from its tip. Carry on from there.”

(My High School Arts teacher)

This project started with the ambition of integrating two fields of interest that, until then, seemed to me to be quite unrelated, other than that I had a personal interest in both. The first of these interests goes back to the time I studied Cognitive Science. In the mid-nineties, at the same time I entered university, a number of books were published that together put forward a new, quite radical theory of cognition. All of these works stated, in one way or another, that the famous ‘computer metaphor’ of mind was seriously flawed. According to these new theories, the mind is not a piece of ‘software’ stored in the ‘hardware’ of the brain. Instead, our *body*, situated within an environment and in continuous interaction with that environment, forms the basis of the way we make sense of the world (e.g. Clark, 1997). This was all some time ago, but since then, *Embodied Cognition* has been successful in explaining a range of cognitive phenomena, and the theory itself has even become somewhat of a ‘mainstream’ position in cognitive science[1].

The second field of interest stems from the Human Centered Design courses I teach at the University of Applied Sciences in Utrecht. Due to historical circumstances, my job is not in the department of computer science but in electronic engineering, with physical product design ‘just down the hall’. This means that in the projects we do, students create prototypes that form a mixture of hardware (sensors, actuators, light, sound, etc.), software (e.g. connecting to databases, the web, etc.) and graphical interface forms. From an interaction design perspective, this means the focus is more on the ‘physical’ aspect of the technological system as compared to a purely graphical interface for a web-application.

When I started working in the department, students would be asked to engineer an interface for a certain system function, using technologies such as forced feedback, movement detection by camera, multi-touch surfaces, and other forms of embedded electronics in physical devices. If user research played a role, it focused on basic usability, aiming to optimize the interface to the user’s characteristics.

What bothered me about these assignments was that the question of what the system should be used *for,* its main function that is, was being separated from the question of *how* to design the *interface*. In comparison, if we think about conventional tools, there is nothing in the way of designing such tools that dictates such a separation. For instance, there is nothing in the analysis of what a hammer is and how it does functional work in the hands of a carpenter that asks us to distinguish conceptually between the 'part that does the hammering' (the functionality) and the 'controls with which one operates the hammer' (the interface). In a hammer, the functional part *is* the control part, and this *is* the hammer in its totality. We may even look beyond the hammer and its narrowly defined function (hammering), and see that hammers are part of a carpenter's means by which he (or she) can express hammering skills, thereby even enacting an identity as a carpenter within a social community of practice (Heidegger, 1927). In the way people deal with objects and tools in everyday circumstances, these various levels of description seem pretty much mixed up in one holistic experience, while in conventional computer systems, as a result of their very design, these levels are treated as separate. Would it instead be possible to address questions of form and function of modern technology in the same holistic manner?

I started asking students to do three things at the same time:

1. Iteratively design the concrete form of the interaction (the physical form and the interactive behavior of the system),
2. Iteratively design/get insight into the main function of the system as a whole
3. Research the physical- and social context within which the system is used.

These questions are pursued in parallel, and iterated over several working prototypes. I believe it is very difficult, if not impossible, to think out such complex design questions 'in advance': in order to think about what next steps to take, one needs multiple rounds of feedback based on people interacting with actual prototypes in the real world. For one thing, this means that the student uses her engineering skills not just for prototyping something already designed, but also for the design process itself. Already quite early on, in the 'fuzzy front-end', technical skills enable one to build interactive 'probes'; to be used both in user studies as well as to help the designer reflect and find direction.

Luckily enough, I got to work in the research group of Remko van der Lugt, who, with a background in Industrial Design, fuelled the communication of these more 'designerly' influences in the engineering context. Remko was also the one who led me into the domain of 'creative meeting practices'. As this was his expertise, and we were just setting up a 'creative meeting space' in our school, it provided a concrete practice to work with.

For me this new approach to design was largely unknown terrain. However, a very similar view on design and education was already implemented in the curriculum at Eindhoven Industrial Design. In 2008, I met Caroline Hummels at an inspiring conference on 'Tangible and Embedded Interaction'. Caroline showed me the way to Kees Overbeeke, then head of the Designing Quality in Interaction group in Eindhoven. It turned out that, for Kees and his group, designing interactive systems was all about embodiment. And so my two interests suddenly connected. While talking with Kees, Caroline, and the people at the DQI group, I saw that collaborating with them meant I could learn a lot about how to design interactive systems. At the same time, I realized I would also bring something to the group, since I had the background in Embodied Cognition theory, that these designers were very much interested in.

(I also thought, from the first minute: I like this Kees. I want to work with him. Discussions with him will get me through a PhD project. Unfortunately, Kees passed away a year ago; a terrible loss. It would have been great to discuss the final results with him. Thankfully, Caroline is the best ever replacement for a professor I could wish for.)

The result of it all is this PhD project, which aims to integrate the field of design of interactive systems (with the vision and practice of the DQI group as a starting point) with theories of Embodied Cognition, always grounding the investigation firmly in the real-world human practice in the creative meeting space. The best and most fun part of it, however, has always been to get students from various backgrounds and educational levels involved, working together with me to create the designs that form the basis of this thesis.

Utrecht, March 7, 2013.

1 *See for instance the "Cambridge handbook of situated cognition" (Robbins & Adydede; 2009), and the "Handbook of cognitive science: an embodied approach" (Calvo and Gomila, 2008).*

1.

Inviting Interactions

At the design department...

Mary creates a mock-up of an interactive bracelet on her own arm. She explores how to design the way in which children, wearing the bracelet, can 'share' experiences, recorded first as short audio-samples. After 'acting out' various options, she considers a 'shaking hands' gesture. It is familiar to children. It says "Nice to meet you", but also "Truce?" after a fight. This could actually work, thinks Mary. Based on this gesture, she starts exploring further what the system could and should do. Does it store multiple audio-samples? If so, how does one browse through the samples? How can one select one sample for sharing, discard another, perhaps even edit one? Along with the handshake idea, many new questions pop up in need of an answer[1]*.*

In the creative space...

Three people brainstorm ideas for an App to stimulate citizens to help the police. Adam, at the whiteboard, draws a pyramid. "Look", he says, "This top five percent [points at the top section] is already helping the police. The majority of people here [points at bottom] will never contribute. We need to reach this middle group, here." [Encircles the middle section] "We need a service that moves these people up here [draws an arrow from middle to top]". Meanwhile, Bernice gets up from her chair and walks slowly over to the whiteboard, taking position on other side of the diagram. She catches Adam's eye and takes her turn, facing the group: "Maybe.... what we could do is have these people [hovers her hand over the middle section] play a game: earn credits, or something?" A short silence follows, upon which Colin, who has been writing notes, looks up: "I was thinking, all these people that walk their dog. They chat, exchange gossip. What if we make this App called: 'The HoundRound?' Dog walkers can report stuff, like, a broken lamppost? They could even earn credits [looks at Bernice]. Enthusiasm in the group, while Adam writes "HoundRound" to the right of the pyramid, next to his arrow[2]*.*

In a book...

[O]ur body is ... the origin of the rest, expressive movement itself, that which causes [the rest] to begin to exist as things, under our hands and eyes. ... The body is our general medium for having a world. ... Sometimes the meaning aimed at cannot be achieved by the body's natural means. It must build itself an instrument, and thereby project around itself a cultural world. ... We say the body has understood ...when it has absorbed a new meaning, and assimilated a fresh core of significance"

(Merleau-Ponty, 1962, p. 169).

1 Initial questions

In this thesis I explore relations between three fields of interest:

1. *Embodied Cognition*: a theory about the way people make sense of the world;
2. *Interactive systems design* - with emphasis on bridging the digital and the physical, and
3. *Creative meeting practices*, in which people collaboratively address a creative challenge.

In this first chapter I provide a brief introduction to each of these fields and consider possible interactions between them. As a start, let me list a number of questions that come readily to mind when thinking about these topics. They will give some initial orientation for what follows next:

1.1 Questions about theory and design

A first question might be how to design interactive systems[3], while taking explicitly into account the idea that the cognition of the users of these systems is *embodied*. In return, we may also ask what is to be learned about this *embodied cognition,* by designing these interactive systems, especially when they are to be used by actual people in real-world settings. What does the embodiment of cognition actually look like in such real-world settings? And how can observations of these 'embodied practices' in turn inform design?

1.2 Questions about the digital and the physical

What about the challenge of integrating *physical form* and *digital process*, a challenge that currently is of concern to many designers of interaction (Hornecker & Buur, 2006)? Can the theory of Embodied Cognition help designers to find a meaningful integration of physical form and digital process? And can we use a design project that tries to meet this challenge as a research-tool for investigating embodied cognition?

1.3 Questions about system and context-of-use

Finally, can Embodied Cognition theory help designers to find a meaningful integration of the system as a whole (its overall *function*, or role); the concrete interactions it allows for (its *form*, or behavior) and the physical- and social environment in which it is used (the *context*)?

2 Objectives

At the end of this chapter I will narrow down these many, and rather complex questions, to two main research questions. At the same time, the research in this thesis is intended to be a broad exploration relating Embodied Cognition principles and design practice. My aim is to provide some first steps in thinking about these relations - it is certainly not intended to be the end-point of the inquiry.

2.1 From answers to questions

Considering the broad class of interactive systems that are meant to play a useful function within people's everyday lives, the main aim of this investigation is to *reframe* the overall design challenge for such systems. The goal is to make sure that the overall conceptualization of what it is we should be designing, takes into account the embodiment of cognition in a fundamental way. I take it to be necessary to first consider such a conceptual shift. Only when we know how to look at the design challenge in new ways, will we be able to ask new sorts of questions - and these may be the more relevant sorts of questions for a designer that wants to design for embodied cognition. This means that my research is not so much geared at finding out concretely what to design for a particular context; that is, at finding a 'design answer'. Instead, I am first of all concerned with finding out what would be fruitful *design questions*.

At the same time, we can only really reframe our perspective *through* design: We can only find out how to look in new ways, once we dive into the matter and start working on it given a concrete design challenge and context (we can only find out about what the questions are, by trying to answer them; Schön, 1983). And so it is precisely on the basis of the concrete design process and its resulting prototypes, evaluated within the context of actual human practice, that we can get a better grip on what the underlying conceptual issues are really all about (Koskinen et al, 2011). Note however that, in this thesis at least, the designs produced (the 'answers') function primarily as *research vehicles* in service of making the conceptual shift (the reframing of the underlying 'questions').

2.2 Confronting the theory with the practice of use and design

This thesis builds on two design cases, both of which involve various working prototypes, a number of user-studies, and several rounds of (theoretical) reflection. As said, the basic rationale for my research is that it is done 'through design'. This means that I put the theory of human cognition to practice by taking up the challenge of designing an interactive system that supports the users' embodied cognitive process in a meaningful way. The question is whether, and to what extent, the theory is helping us in doing so. I therefore 'confront' the theory with all the sorts of practical problems, issues and questions that are involved in real design projects, and see how it manages to live up to these challenges (Stappers, 2007; Schön, 1983; Koskinen, 2011). This research approach is further described in chapter 3.

2.3 Inviting new interactions between fields

Apart from the specific insights gained, I hope this research helps to reconnect theoretical- and scientific research in cognitive science to the field of interactive systems design.

There is already a tradition that connects cognitive science quite explicitly to human-computer interaction (Newell & Card, 1985; Carroll, 1997). This tradition is grounded in the classical, information processing perspective, which maps the psychology of the user quite straightforwardly to the kinds of information processing models that computer engineers use (Newell & Simon, 1972). At present, both the theoretical advancements in cognitive science, as well as recent trends in interactive systems design, are reaching out well beyond the classical information processing perspective. This is why I believe there is space for some new connections to be made between these fields, with new opportunities for collaboration.

In the remainder of this chapter, I first introduce the idea of Embodied Cognition. (For a detailed review of theory, the reader is referred to chapter 2). Next, I introduce the context of practice that is central to this research, which is the 'creative group meeting', of which the 'brainstorm session' is perhaps the most familiar form. After that, I present some relevant trends in interactive systems design. I end with the two main research questions pursued in this thesis.

3 Embodied Cognition

This thesis starts from the idea that cognition is fundamentally *embodied* in nature. In recent years there has been a growing interest in theories that understand cognition as an *embodied* and, its related term, *situated* phenomenon (e.g. Suchman, 2007[1987]; Varela et al, 1991; Brooks, 1991; Hutchins, 1995; Clark, 1997; Clancey, 1997; Beer, 2008; Dourish, 2001; Anderson, 2003). Theories of Embodied Cognition (henceforth: *EC*) have been around for some time now, with the main rise in the mid-nineties. Historical antecedents of EC can be traced back further, for instance to phenomenological thinking (Merleau-Ponty, 1962; see also the opening quote above; Heidegger, 1927), pragmatism (Dewey, 1910), cybernetics (Bateson, 1972), and various other roots (see Clark, 1997; and Clancey, 1997, for rich overviews).

The word 'embodiment' has become somewhat en vogue, with people using it in various guises. Related theories use other terms like 'distributed', 'situated', 'enactive', or 'interactionist', and so on, but on the most general level, the basic claims are comparable. In chapter 2 I provide a detailed introduction of EC and distinguish between three variations.

3.1 Why study EC?

What interests me most in EC theory is first that it shows in various ways how people deal with the world 'in action'. That is, it explains how people improvise and tinker and find out about how the world is meaningful, right in the act of engaging with it. This is a very different picture from the classical model offered by cognitive science (Simon, 1996; Fodor, 1983) in which cognition is some-*thing*, located *in the head*, detached from the world, planned ahead, something reasoned about first internally, before being acted out in the real world.

This brings me to the second aspect I find appealing about EC theory, which is that it conceives of cognition primarily as a dynamic process. Cognition is inherently connected to change, learning and development. EC explains how meaning arises from self-organizing principles within ongoing action, instead of pre-supposing it as fixed, pre-wired, inborn, etc. (Thelen and Smith, 1994).

A third aspect of EC is that it makes no essential distinction between 'sensing' and 'acting' - between 'input' or 'output'. Each person is always already in the business of interacting with the world, and the stream of 'sensation' always runs parallel with that of 'action'. Even 'just looking', implies one is already acting; moving ones eyes in saccades. According to EC, then, action and perception are inherently *coupled* (Gibson, 1979; Edelman, 1992; Brooks, 1991).

Finally, EC conceives of cognition not as an isolated affair but as *situated* in a context, which can be both the physical environment as well as the social setting. The situation strongly influences how people make sense in action, and our understanding of cognition cannot be abstracted away from that local setting without losing meaning (Suchman, 2007).

I believe that these four aspects: action-orientedness, dynamics, coupling and situatedness, already show why EC is worthwhile investigating in the context of the design of interactive systems. (In this I build further on work of Dourish, 2001; Hornecker & Buur, 2006; Robertson, 2002; Klemmer et al, 2006; Ferneaus et al, 2008).

3.2 The cognitive phenomenon

When I talk about cognition, I'm referring first and foremost to a *phenomenon* of interest, and not to a theoretical construct that is already committed to the theoretical position of Cognitivism, the classic model of human cognition (Simon, 1996; Newell & Simon, 1972, see also chapter 2). I am interested in the kinds of activities that we can observe and would usually refer to by using terms like 'thinking' or 'reasoning' or 'knowing' or 'insight', without claiming that any of these activities necessarily involve dedicated neural processes that store and process quantities of 'knowledge' in some way. This *phenomenon* of cognition, as I see it, refers to the way people, as part of their ongoing interactions with the world around them, are constantly 'making sense' of the world (De Jaegher & Di Paolo, 2007). Crucially, this does not necessarily mean one is conscious and deliberate about it. As Dreyfus (2002) shows, understanding the world means first and foremost experiencing yourself getting a 'grip' on things: it means that when you are confronted with a situation, you basically see what needs to be done. This involves being able to see things 'the right way' and, in adaptation to changing circumstances, being able to 'see things a different way', in order to transform ones range of suitable responses (Schön, 1983). In other words, having insight essentially means being able to deal, or 'cope', with a situation successfully (Dreyfus, 2002)[4].

I am interested in how cognition happens in actual, everyday practice: 'in the wild', as Hutchins calls it (Hutchins, 1995). Apart from theoretical or methodological motivations (Hutchins, 1995; Lave & Wenger, 1991), a focus on actual practice keeps me close to the design question of how to create interactive systems that should support such practices. Cognitive practices center on the mundane circumstances we find ourselves in every day. While engaged in some activity, local issues pop up, which have to be dealt with on the spot. Think about deciding when to cross a street while a car is approaching.

Think about how you might quickly jot down a list of things to remember, while engaged in something else. Or, during a team meeting, when you try to figure out what caused the complete misunderstanding between you and your colleague. Or think about Adam, Bernice and Colin in the opening scene above, as they try to make sense of their brainstorm challenge. In all these cases, cognition is at work, even though we most often act routinely, without conscious deliberation and without explicit reasoning (Van Dijk et al, 2008).

4 Creative group meetings

As a context of practice I focus on the practice of *creative group meetings*. A practical reason for choosing this context is that our research group[5] has been involved in setting up a creative space in which interactive tools were developed to support such meetings. As we saw in the case of Adam, Bernice and Colin in the opening story, in creative meetings people are presented with a *creative challenge*, which usually involves coming up with a set of creative solutions to a complex real-world problem.

4.1 Creating an understanding of the creative challenge

Although methods for creative 'thinking out of the box' are often emphasized in this regard (Osborn, 1963), other processes take place that are equally crucial for success. In particular, people not only have to come up with creative and sensible solutions to a set problem; they also have to *understand what the problem really is* (Ylirisku et al, 2009). Many of the kinds of 'problems' posed for creative group meetings are not clear-cut problems at all, in the traditional sense of being able to define in clear terms what the current situation is, what the desired situation is, such that the question can then be asked of how to get from the current state to the desired one (cf. Simon, 1996). More often than not, it is not at all clear what the current situation is, it is not at all well-defined what the desired situation is, and trying to solve the problem may even change the problem definition itself, as is the case in so-called 'wicked problems' (Rittel & Webber, 1984). Hence, in most creative sessions, a better, richer and shared understanding of 'what it is that we are actually trying to do here', is just as important a result of the session as are the proposed solutions that come along with it.

In fact, in many sessions I have observed and participated in, the 'solutions' (for example, sketches of design concepts created as the final outcome of a creative meeting) were not only solutions, but also formed concrete instantiations of the insights gained in regard to the original problem. Solution proposals are not just the outcome of a creative activity, to be collected and taken home afterwards: they function as communicative vehicles for participants *in* the activity itself. By means of these proposals people express in concrete terms what they have in mind, and this may spur a round of reflective discussion in the team about what the problem really is or should be (Schön, 1983), and whether they agree.

Finally, consider that the ultimate aim of creative sessions is not just to create ideas, but also to make sure that something is actually done with these ideas later on. This means it is all the more important that the people involved really understand the value and background rationale of the ideas proposed, to ensure people get committed to the session outcome and will apply it in practice, after the creative session has ended.

4.2 A design orientation for creative meeting practices

Given this context, I focus on the way people gain *shared insight into the creative challenge* during a session, while engaged in creative activities in a physical space. Creating a shared insight is has been studied in the context of creative meetings (Kleinsmann, 2008), but not explicitly from an EC perspective. At the same time, EC theory may be relevant here, because people in creative meetings readily create shared insight in close interaction with each other, as well as through using all kinds of physical artifacts in the space. In other words, this thesis will be oriented towards the question of how the physical space itself may be used as a central driver for a team to develop shared insight. Of particular interest is the way people use physical representations such as text on sticky-notes, sketches, diagrams on the whiteboard, or even physical mock-ups or complete product prototypes, in support of the creation of shared insight. The further question is of course how we can enhance the supporting function of the environment – an environment partly shaped by the participants themselves - using interactive technology.

Figure 1.1. Participants in a creative meeting use a physical mock-up to explain their ideas to other participants.

5 Interactive systems design

As I use it here, the term interactive systems design refers to design and research practices drawing from various backgrounds, including computer science & engineering (in particular, human computer interaction, or HCI), industrial design, electronic engineering and the Fine Arts. In this thesis I am particularly concerned with design that crosses boundaries between the physical, the social, and the digital (Hornecker & Buur, 2006; Klemmer et al, 2006). I will now shortly introduce some of these practices.

5.1 Human computer interaction (HCI)

HCI developed as a branch of computer science, asking how digital process should interface to the human user (Caroll, 1997). In HCI, focus has shifted over the past years from interfacing software by means of graphical user interfaces on fixed desktops, towards designing interactive tools on handheld mobile phones, multi-touch surfaces, and basically any other physical platform one can image. In particular, we see a growing trend towards integrating physical form and digital process, for instance within such fields as ubiquitous computing, tangible interaction, wearable computing and augmented reality (Figure 1.2 shows an example of tangible interaction). Even though *embodiment* is a term used in research in these fields, a strong theoretical grounding is still lacking (For recent treatments see Dourish, 2001; Hornecker & Buur, 2006; Klemmer et al, 2006; Ferneaus et al, 2008; Robertson, 1997).

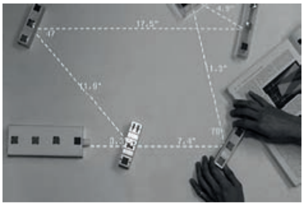


Figure 1.2

Figure 1.3

Figure 1.4

Figure 1.2. Interactive systems in HCI. Illuminating light, a digital projection augmented with tangible controls (Underkoffler & Ishii, 1998)

Figure 1.3. Interactive systems in Industrial Design: Philip Ross' interactive lamp, displaying sensuous interaction qualities grounded in philosophical notions of aesthetics. (Ross & Wensveen, 2010)

Figure 1.4. Interactive systems in social computing: The illuminated tablecloth, mediating social interaction between family members via interactive traces on the table (Gaver et al, 2006)

5.2 Industrial Design

In Industrial Design we see a similar trend towards integrating the physical and the digital, although historically starting at the other end: the physical product increasingly becomes an 'interactive' product, enriched with sensors and actuators, which creates new design challenges (Frens, 2006). Comparing this field with HCI, we see differences in style and overall objective. Industrial Design work on interactive systems shows integration of social, physical, emotional and psychological levels of meaning into complete product concepts (rather than 'mobile apps' or 'tangible interfaces'. For an example, see figure 1.3). Several trends in industrial design relate to notions of embodiment, as put forward in design frameworks such as 'rich interaction' (Frens, 2006), 'aesthetic interaction' (Djajadiningrat et al, 2004), 'inherent feedback' (Wensveen, 2005), and design based on skilled movement (Hummels et al, 2007) and choreography (Schiphorst, 1992).

5.3 Social computing

A third movement that occupies itself increasingly with the physical-digital divide, and has a conceptual interest in theories of *situated cognition*, seeks to understand computing technology from the perspective of social theory and anthropology (Suchman, 2007; Dourish, 2001; Robertson, 2002). Here, the most relevant work concerns designs where physical artifacts, either technologically enhanced or not, mediate social interaction between people and the shared meanings arising from it, given that the artifact becomes appropriated in rituals, cultural habits, situated communication, work practices, and so on (For an example, see figure 1.4).

5.4 Crossing the physical-digital divide

In wrapping up, we can say that depending on their background, some designers emphasize the social context, others focus on the physical body, and yet others stress the power of tangible computing and external representations. However, all share the struggle of trying to integrate physical- and digital form in a meaningful way. This is precisely the concrete challenge that designer Mary from the opening quote above has to deal with, when exploring the communicative bracelet for children. In more general terms, we can say the overall question is how to meaningfully integrate interactive systems into people's embodied and situated practices (Klemmer, 2006; Robertson; 2002; Dourish, 2001).

6 Studying interaction in the concrete

Traditionally, in studies of cognition, analysis happens in abstract terms, where the phenomenon of interest is first translated into a generic model and where empirical data are acquired in highly artificial laboratory settings in order to test such models. Likewise, the design of computer systems is traditionally couched in terms of high-level models as well, figuring software architectures, database structures, and so on, that purport to describe as accurate as possible the task components and procedures the tool should support. In both these traditions the researcher/designer thinks and communicates in *abstract, generalized* objects and processes. Moreover, the object of interest is assumed to be something *hidden from view*: One assumes either a *cognitive state* inside a human being, causing overt behavior on the outside, or a *software object* inside the technological system, ultimately responsible for the system's functionality.

In contrast, in the current investigation, both the design focus on creating mixed physical-digital systems, and the research interest in observing human activity in its natural context, deal with phenomena that can be found 'on the outside' of both human and system. In other words, this investigation is not concerned with what is inside human beings or inside interactive systems: it is concerned primarily with what lies *in between*: it tries to get to the heart of what happens *in the interaction* itself. What lies between the user and the system is not an abstract, theoretical relation, thought up from theory and described in terms of objects and relations in an abstract model: it concerns actual, real-time interactions between a person and a tool in some concrete setting. This thesis therefore speaks not in terms of abstract models, but as concretely as possible of 'what is going on' in real-world human practices. In this, I follow the ethnographer's focus on everyday human action, as situated in the real world (Geertz, 1973; Suchman, 2007; Agre, 1997; Hutchins, 1995; Winograd & Flores; 1986) as well as several trends in design research that promote a concrete, experience-based point of view (Frens, 2006; Hengeveld, 2011; Dourish, 2001; Ferneaus et al, 2008; Klemmer et al, 2006; Djajadiningrat et al, 2004; Jensen et al, 2005).

Figure 1.5 shows the relations between the user's embodied cognition and the design of the interactive system, as situated in a concrete context of practice. We see that EC theory functions for the design process as a *conceptual driver*: a source of information and inspiration that guides and constrains the design process. In return, the design reflections and the user studies will provide an 'empirical touch-stone' from which implications can be derived for embodied cognition theory. The dialectic between theory and design is takes place within the concrete setting of the practice of creative meetings. The way theory informs design and the way design informs theory, is therefore based on the way people will be interacting with interactive prototypes in actual creative sessions, in search of shared insight.

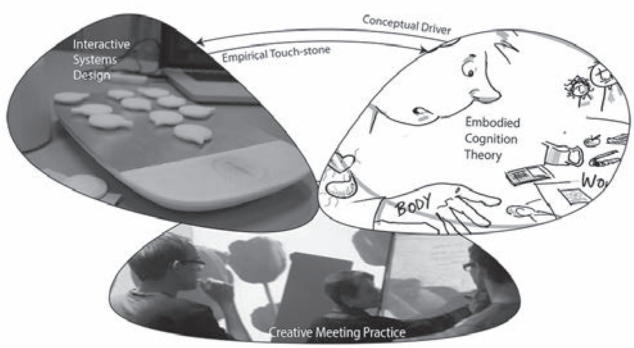


Figure 1.5. In the approach taken in this thesis, design of interactive systems and development of embodied cognition theory mutually inform each other, while grounded in the concrete practical setting of people engaged in creative meetings. EC theory provides a conceptual driver for design. In turn, the design process and the reflection on its outcomes (including results from empirical user studies involving working prototypes) form an empirical touchstone for EC theory.

7 Research questions for this thesis

Based on the foregoing, I state my research questions:

1. How may we design interactive systems in support of embodied cognition?

One partial question in this regard is:

1.1. How does embodied cognition inform designing the relation between the digital process and physical form of the interactive system?

Another partial question in this regard is:

1.2. How does embodied cognition inform designing for the way in which the interactive system at large connects to people's real-world, embodied and situated practices?

As said, the main objective here is to reframe the overall design challenge for interactive systems, such as to ensure that the embodiment of cognition of the user is taken into account in a fundamental way (i.e integrated in the design as more than just 'a source of theoretical inspiration'). In two concrete design projects these questions will be further refined and made concrete.

2. How does (the practical attempt at) designing interactive systems supporting shared insight in creative meetings, inform the theory of embodied cognition?

One partial question here is:

2.1. What is the role is of 'external representations' in the embodied cognitive process?

That is, by designing interactive systems that extend and/or transform how participants in a creative session create and using such external representations I hope to gain more insight into their role within the embodied cognitive process.

Another partial question is:

2.2. What is the relation between the social situatedness and the physical embodiment of cognition (i.e. interacting with the physical environment)?

Both these themes are mentioned in the EC literature, but it is not exactly clear how they relate. Some theorists focus exclusively on either one or the other aspect, while others lump both themes together without further analysis. By designing systems for the real-world context of the creative space, in which people both interact with each other as well as with the physical space (and the objects in it), my aim is to gain insight into the relation between the social and the physical as part of embodied cognitive processes.

Both the design-oriented research questions (1.1. and 1.2.) and the cognitive theory-oriented research questions (2.1 and 2.2.) will be concretized and refined in the following chapters.

8 The structure of this thesis.

Chapter 2 provides a further introduction to the theory of embodied cognition. I discuss three versions of it and show how they differ in the way they can have impact on interactive systems design. After that, in Chapter 3, I describe my research approach. Chapter 4 covers the first case study. It discusses the design and research of an interactive system called NOOT, a tangible tool that connects to live-recorded audio-samples of the creative meeting. Chapters five and six present a second case study, concerning a design called FLOOR-IT; an interactive floor showing personal snap-shots made by session participants. In chapter 7, I first answer research question 2, the theory-oriented question. I discuss theoretical implications following from the design cases, which form the concluding part of the theoretical discussion initiated in Chapter 2. The final Chapter 8 concludes on research question 1, the design-oriented question. I present my vision of an Embodied Cognition Design. This includes listing a number of pitfalls and opportunities one may encounter in the attempt to design interactive systems in support of embodied cognition.

1 *Taken from my personal notes, based on a casual talk with a design student at Eindhoven; slightly adapted. In fact, 'Mary' was primarily concerned with Japanese culture and finding workarounds for social interaction, given the strict social rules and privacy culture in Japanese society. As I present it here the anecdote does not do justice to (the real) Mary's thorough analysis of the cultural aspects of her design project.*

2 *Taken from personal notes based on observing a creative session in ConceptSpace, Utrecht.*

3 *An interactive system includes both digital technology and a physical form. With 'the (technological) system' I denote the complete physical-digital whole, making no a priori distinctions between software or hardware, function or interface, etc. The word 'system' signifies it may consist of a collection of multiple physical or digital objects and processes. The word 'interactive' means that some kind of internal digital processing is involved in combination with sensor technology for receiving 'input' from the environment (in particular the kind that originates from the user's action) and feedback technology (e.g. projecting light, changing pixels on a screen, forced feedback, servo-motor action and so on) providing output back to that same environment (in particular the feedback that is to be perceived by the user). In my use of the word, and in deviation of certain conventions in computer science and engineering, nor the user, nor any other element in the physical- or social environment, is part of 'the technological system'. The term is reserved purely for the (system of) technological artifact(s) that is being created by the designer in the design project under consideration. There is one other place where I sometimes use the word system which is when I talk about the 'cognitive system', a term frequently used by cognitive scientists for the assumed mechanism that underlies cognition. To what extent, and in what particular way, the human cognitive system and the technological system can be said to overlap or even become one, is the overall research topic of this thesis.*

4 *The rise of EC-inspired research has opened up discussion about what is meant with the term 'cognition', and this discussion is sometimes fiercely debated on fundamental levels (e.g. Dreyfus, 1972; Chemero, 2009). In order not to get lost in such heavy debate before we have even started, I choose not to fix on a particular definition of 'cognition' upfront and suffice by describing the everyday phenomena instead. In chapter 7 I give my interpretation of cognition at the most basic level as a form of 'socio-sensorimotor coupling' mediated by 'expressive traces'. This perspective is part of the final conclusions of the thesis, not its starting point.*

5 *Research group co-design, Utrecht University of Applied Sciences, Netherlands*

6 *There are actually quite a few works that discuss principles of embodiment and situatedness in reference to the designer, and the design activity, i.e. discussing how a designer acts and thinks, or should act and think, 'in embodied ways'. Especially work in participatory design movement often touches on principles of situatedness (E.g. Ehn, 2011). There is, to my knowledge, much less work on applying the theory to the designs as such, i.e. to discussing the consequences of this theory for the form that the interactive system may take, with the user as acting and thinking in embodied ways. In this thesis I focus on the latter issue, although I am sympathetic to ideas on the former (as can be seen in chapter 3, concerning my own approach for research and design). One may even find arguments for the idea that in the end both levels of analysis converge into one, but I will not do that here (See e.g. Wakkary, 2005 and Hummels et al, 2008).*

2.

Computation, Coordination, Coupling: Embodied Cognition for Interactive Systems Design

"[I]n using the term 'cognition' we fall into the danger of implicitly following the tradition that we are challenging. ... We need first to examine this understanding [of cognition] more carefully and to recognize its consequences for design."

(Winograd & Flores, 1986, p. 70-71)

"To understand is to experience the harmony between what we aim at and what is given, between the intention and the performance – and the body is our anchorage in a world."

(Merleau-Ponty, 1962, p. 167)

1. Introduction

This chapter presents a general overview of Embodied Cognition (EC) as a recent theory of how people think, act and in general make sense of the world. With the rise of new fields such as augmented reality, ubiquitous computing, tangible interaction, context-aware and wearable computing, we are witnessing an unprecedented trend within human-system interaction towards integrating – or can we say 'reunite' – physical form and digital process. Many theoretical issues that emerge from these design fields, and the challenges designers are faced with, are actually closely related to the themes discussed in EC (Hornecker & Buur, 2006). EC therefore may potentially provide a relevant theoretical ground for the design of these new kinds of integrated artificial forms (Dourish, 2001).

Basic principles of embodiment have been presented to designers before, mostly as a collection of theories that may inspire the designer (e.g. Dourish, 2001; Hornecker & Buur, 2006; Klemmer et al, 2006; Fernaeus et al, 2008). At the same time, EC draws from a wide diversity of research practices, ranging from the engineering of robot insects (Beer, 2008) all the way to cultural anthropology (Ingold, 1995). It is therefore not surprising that there are also considerable differences, and even conflicting claims, in how the main idea is worked out in the detail. The contribution of the present review over others is precisely to flesh out some of these differences, and to relate them explicitly to the design of interactive systems.

1.1. The historical development of this chapter

Presenting theory this early in the thesis suggests a literature review done in preparation of the design work that follows later. In fact, the theoretical analysis below did *not precede* the design work (presented in chapters 4,5,6) but developed alongside with it, and in close interaction with it. As elaborated upon in chapter 3, the theoretical reflection on the one hand, and the practical issues and insights encountered in designing and studying users on the other hand, mutually informed each another throughout the project, in an iterative fashion. This means part of the insight resulting from the design cases is already embedded in the theoretical analysis below. The linear structure of a chapter in a book works somewhat against communicating this iterative development. The main reason for a conventional format is that I intend the present chapter to be a self-sufficient introduction to EC theory for the designer-researcher. Note, however, that the analysis is not finished at the end of this chapter. Chapter 7, positioned after the design cases, presents a final discussion and conclusions regarding EC theory (research question 2). There I look back on the design cases explicitly and present a reconstruction of how the design process shaped my understanding of the theory3 as it is presented below.

1.2. The main structure of this chapter: Three variations of EC

On the basis of the iterative form of analysis as just described, I identify three different variations within the overall framework of EC. These variations are all in line with the general idea, but differ on crucial aspects. In particular, each variation has different consequences when applied to the design of interactive systems. After a general intro (Section 2), I present these variations under the following headings:

Section 3: Distributed Representation and Computation
Section 4: Socially Situated Practice
Section 5: Sensorimotor Coupling & Enactment

Furthermore, in section 6 I discuss phenomenology (see below). In section 7 I end by explicitly relating the analysis to my research questions.

1.2.1. The phenomenological backdrop

With each variation presented below, the discussion moves further away from a modest, information-processing[1] interpretation of EC, towards more radical accounts, which try to do away with information processing notions altogether. For readers with a background in computer science or engineering, this means moving away from (to them) familiar notions such as *computation, representation, input, output, state, memory, problem, solution and information*. In its place, we find a perhaps less familiar vocabulary, containing notions such as: *practice, situatedness, affordance, coupling, grip, skill, coordination* and *enactment*. This alternative vocabulary partly has roots in *phenomenology*, which is a fundamentally different way of looking at the world than is the standard 'scientific' perspective (Morris, 2010). Various researchers in EC indeed adhere to a phenomenological perspective and explicitly reject 'objectivist', scientific theories (Merleau-Ponty, 1962; Dreyfus, 2002). Others, in contrast, define embodied cognition explicitly *within* an objectivist, scientific perspective, staying clear from more radical proposals (Clark, 2008; Haselager et al, 2003). The discussion between phenomenology and objectivist science is complex[2], and we can find many subtle positions and partial discussions within it (Myin & Hutto, 2013; Clark, 2008; Chemero, 2009; Dreyfus, 2002; 2007, Gallagher & Zahavi, 2007; Varela et al, 1991, Merleau-Ponty, 1962; Morris, 2010, Heidegger, 1927). I have added a separate section introducing the phenomenological backdrop to EC (section 6). In the end, however, I leave this metaphysical debate aside. I take the position that both worldviews may yield insight into EC and into the question of how to design interactive systems for it.

1.2.2. What is not in this chapter

One final caveat is in order. Even though the aim is to give a broad overview of EC theory, the particular selection of work discussed here represents a rather personal journey, constrained by its relevance for designing interactive systems for the context of creative group meetings. As a consequence, certain theories are glossed over very briefly or have been skipped altogether. For example, Lakoff and Johnsson's important work on embodied metaphor is not discussed (Lakoff and Johnsson, 1999), nor do I review in any detail EC's view on the brain (See Edelman, 1992; Skarda & Freeman, 1987; Damasio, 1994; Van Dijk et al, 2008). The influential work on dynamical systems theory (Thelen & Smith, 1994; Kelso, 1995) is only mentioned in passing.

2. Embodied cognition: a primer.

2.1. A reaction to Cognitivism

Embodied cognition asks for a better understanding of how human beings make sense of the world, through and while interacting with that world. EC thereby rejects the dominant paradigm that precedes it, called *Cognitivism* (Simon, 1996; Newell & Simon, 1972; Newell & Card, 1985; Fodor, 1983). According to this traditional position in cognitive science, knowledge essentially consists of *representations,* stored in the brain, and all representations together form a *mental model* of the outside world. The brain performs *computations* on these representations, which enables the selection of an appropriate action, given perceptual 'input'. In other words, the mind is essentially a computer. This is why Cognitivism is called a *computational-representational* or *information-processing* perspective (Figure 2.1).

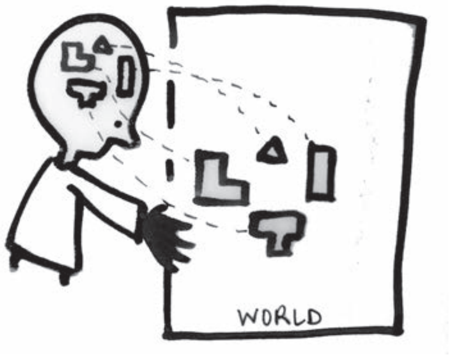


Figure 2.1. Cognitivism sees cognition as (brain)-internal computations on representations of the outside world.

EC rejects Cognitivism, claiming that:

"...minds are not: information-processing engines, receiving external stimuli from a pre-existing world, which are transduced into internal neural representations, from which internal cognitive transformation processes recover, through complex computational operations, objective features of the world so as to generate appropriate motor actions on the world. The story of mind is thus not the story of an 'input-output model' in Susan Hurley's (1998) phrase, where world and cognizing being exist as separate systems linked through the intermediary of internally manipulated representations."

(Torrance, 2006, p. 359)

Instead of a Cartesian split between on the one hand 'inner representations' and on the other hand 'the outside world', EC starts the theoretical analysis first by appreciating the special status of the body, as being neither 'inner' nor 'outer', but somewhere in between. Phenomenologist Maurice Merleau-Ponty illustrates this peculiar ontological status of the body as follows:

I move external objects with the aid of my body, which takes hold of them in one place and shifts them to another. But my body itself I move directly, I do not find it at one point of objective space and transfer it to another, I have no need to look for it, it is already with me ... The relationships between my decision and my body are, in movement, magic ones.

(Merleau-Ponty, 1962, p.107-108)

2.2. Reasoning from the body

With the body as a grounding structure, EC sketches a picture in which cognition is a temporal stability in a self-organizing process, sustained by a network of many interacting elements (Kelso, 1995; Beer, 2008). Critically, this network reaches beyond the brain, to include muscular-skeletal constraints of the body, homeostatic levels in the body, (connecting to emotion; Damasio, 1994), sensorimotor couplings, emerging in action, and couplings between the action possibilities of the body on the one hand and the structure in the physical- and social environment on the other (Gibson, 1979; Clark, 1997; Hutchins, 1995).

In sum, brain, body and the environment, and in particular relations between them, are all considered to be part of the cognitive system - part of the mechanism that makes cognition happen (Figure 2.2).

Figure 2.2. Sketch of the embodied cognition perspective in which cognition is seen as an emergent property of ongoing interactions between brain, body and the physical- and social environment.

2.3. Against modularity

EC presents a stark contrast to Cognitivism, in a number of ways. Firstly, cognition is seen an achievement brought about by a *system*, of which the brain is only one part (Thelen & Smith, 1994). This holistic picture already challenges the cognitivist concept of 'modularity' (Fodor, 1983), which assumes that the cognitive system consists of modules separated from each other and that can be studied in isolation.

2.4. Against linear sequential process

Secondly, EC is fundamentally a *dynamical* view, paying attention to the way elements in the system evolve and come to be related over time, in parallel with action instead of preceding it (Beer, 2008). Such interaction dynamics may even invite a causally circular view in which it is no longer clear whether thoughts cause behavior, or the other way around, claiming it is both at the same time (Haken, 1999; Kelso, 1995). This is a worldview quite distant from the sequential process assumed by Cognitivism, in which cognition begins at some perceptual input, runs through the brain in a number of distinct processing steps, and results in a motor output.

2.5. Cognition happens 'in action'.

Finally, in relation to the foregoing, it has been argued that cognition is something realized *in* the world itself, as an aspect of actual behavior in concrete situations, and cannot be understood as an abstract reasoning inside an abstract, 'descriptive' model (Clancey, 1997), detached from concrete circumstances (Suchman, 2007). As Winograd & Flores (1986) state:

"We do at times engage in conscious reflection and systematic thought, but these are secondary to the pre-reflective experience of being thrown in a situation in which we are always already acting. We are always engaged in acting within a situation, without the opportunity to fully disengage ourselves and function as detached observers"

(Winograd & Flores, 1986, p.71)

Note that this gives the brain a different role, perhaps more one of a 'traffic facilitator' on ongoing interaction, than one of a central planner (Van Dijk et al, 2008; Suchman, 2007). Embodied cognition, in its more radical interpretation, is not just an alternative problem solving strategy, but a radically different way of understanding mind and behavior in general (Van Dijk, 2008; Varela, Thompson & Rosch, 1991; Clancey, 1997; Thelen and Smith, 1994; Anderson, 2003).

Having introduced its basic tenets, I now introduce three variations of EC, each with their particular consequences for design. These are: 1) Distributed Representation & Computation 2) Socially Situated Practice and 3) Sensorimotor Coupling and Enactment.

3. Distributed representation and computation (DRC)

3.1. Knowledge in the world: external representation

Seeds of EC can be found in the work of Don Norman, who showed people often rely on 'knowledge in the world' instead of on 'knowledge in the head' (Norman, 2002). Norman focuses largely on external representation: the way the environment is a form of physically present 'memory', such that one does not have to rely on internal memory. For example, he describes his habit of putting his bag against the front door in order not to forget to take the bag to work (ibid). We can see this as a first step of going beyond theories that assume that all knowledge is stored internally in the brain, recognizing the value of 'stumbling upon' a bit of information (e.g., ones bag) at the right time in the right place (at the door, leaving for work). Andy Clark dubbed this the '007 principle': local aspects in the immediate environment provide you with information on a 'need-to-know basis' (Clark, 1997, p.46). This may reduce cognitive load (ibid) and help to focus on things relevant to the task at hand.

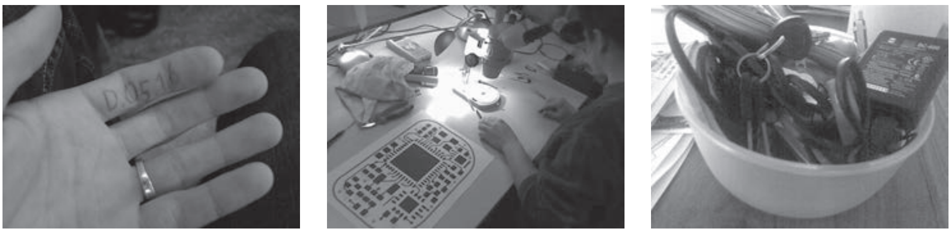


Figure 2.3: Examples of distributed representation. Left: an external memory carried on the body; Middle: Blow-up print-out helps keeping track of a print-soldering activity (components are placed on their corresponding places on the paper lay-out and retrieved one by one as needed); 3) Right: Ad-hoc container in support of retrieving (storing) lost (found) items.

3.2. Distributed cognition

Norman's 'knowledge in the world' belongs to a theoretical framework called *distributed cognition* (Hutchins, 1995; Hollan et al, 2000; Kirsh & Maglio, 1994; Neth et al, 2007; Kirsh, 2010). The basic idea is that both representing information and processing it (computation), is *distributed* over both brain and the environment itself.

Edwin Hutchins, one of the main proponents of this view, based his theory on careful ethnographic analyses of coordinative behaviors on board of a large navy ship (Hutchins, 1995). According to Hutchins, intelligent behavior on board of a ship ('cognition in the wild' as he called it), for instance, making a location 'fix' on a chart, is a cooperative, coordinated achievement of a *system* consisting of the brains and bodies of several people, as well as of the physical structure of the various tools used. Hollan et al propose a set of core principles that describe how people 'establish and coordinate different types of structure in their environment', how people then 'offload cognitive effort to the environment whenever practical', and how social organization further improves this process of 'cognitive load-balancing' (Hollan et al, 2000; see Figure 2.3 for examples).

3.3. Distributed computation

The notion of distributed *computation* is a more *active* concept complementing Norman's distributed *representation*. Distributed computation means not just storing information in, and retrieving it from the physical environment; it shows what a person can *do* in the environment in order to solve problems 'in action', i.e. how people use the structure in the environment to perform computation. For example, people support reasoning using deictic references (i.e. pointing to objects that are directly visible, and using phrases like 'this one' and 'over there'). Using deictic references, implicit knowledge need not be made explicit: one instead show/see directly (Ballard et al, 1997; Clark, 1997).

David Kirsh provides us with the distinction between pragmatic versus *epistemic actions* (Kirsh & Maglio, 1994). Pragmatic actions directly contribute to achieving some goal-state, whereas epistemic actions aim at reorganizing the world in such a way that subsequent actions become easier. Taking out a pen and paper would be an epistemic action that makes a hard calculation less difficult, because pen and paper enable the user to do the calculation on paper instead of by heart.

In general, external objects play an important role in such epistemic actions. According to Hutchins (1995), people's thinking makes use of the way in which externally available resources, either tools designed specifically for the task, or ad hoc recruited objects, will take care of part of the thinking for them. In other words, you do not have to know everything needed to solve a problem, what you have to know is how to operate the tool that solves the problem for you. This is precisely what makes many tools handy: one can offload part of the cognitive burden onto the environment.

3.4. Cognitive scaffolding and the extended mind

Philosopher Andy Clark calls such designed tools and ad hoc recruited props in the environment 'cognitive scaffolds', in reference to Vygotsky's theory of *scaffolded* learning (Vygotsky, 1956). Vygotsky explained how teachers and parents can provide children with just the right kind of feedback at just the right moment during their exploratory learning activities, such that children are able to perform better than they could have by just trying on their own (Vygotsky, 1956; Mascolo, 2005). In line with distributed cognition, Clark offers that also manipulations of physical objects can provide us with just those cues and external supporting structures, cognitive scaffolds, that is, which enable us to solve problems in ways that would have been much more difficult using purely brain-internal computation (Clark, 1997). Pushing this idea to its philosophical consequence, Clark argues for the 'extended mind', claiming that for instance a notebook may be said to have become a genuine part of our 'mind', if it is reliably and routinely used for cognitive tasks in such a way that one may say it has become indispensible in order to be able to think (Clark & Chalmers, 1998).

3.5. Pre-structured environments

Generalizing from the scaffolding function of individual objects, we may say that people in general tend to live in designed, pre-structured 'life-worlds' (Agre & Horswill, 1997) within which task-related actions consume less cognitive processing than would be expected if the same task would be performed in isolation from its regular context. For example, tasks often have a dedicated physical location (cooking is done in a kitchen), which is separated from other task locations, so that tasks do not get mixed up. Tools and materials needed for a task are found close together at the task location. Routine maintenance activities in the background (cleaning up, physically organizing things in groups) help to do tasks more easily, and so on (ibid). In many of these cases spatial constraints, e.g. the fact that one cannot be in more than one place at the same time, are effectively used as a means to organize ones actions.

A summary sketch of the Distributed Representation and Computation (DRC) perspective can be seen in figure 2.4:

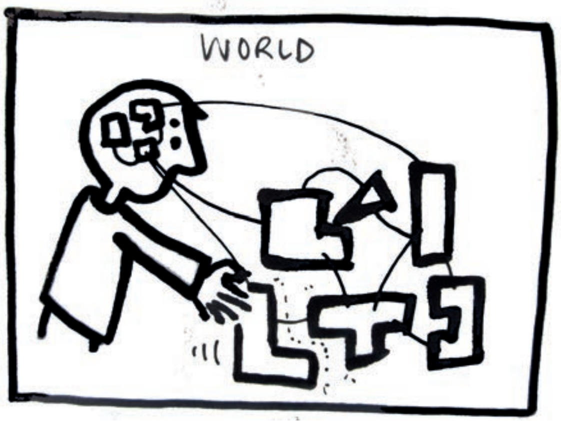


Figure 2.4. The Distributed Representation and Computation perspective. Cognition is a computational-representational process, but extends out from the brain into the world to include objects and other people, which function as external representations or serve to enable external computations.

3.6. The design problem as seen from a DRC perspective

Tangible interaction (Fitzmaurice et al, 1995; Ullmer & Ishii, 2000; Djajadiningrat et al, 2004; Hornecker & Buur, 2006; Ishii, 2008) is a recent trend in interaction design aiming to support exactly the kinds of scaffolding strategies as described in the DRC framework. The most straightforward, classical version consists of physical interface controls connecting to digitally stored information, a vision most prominently put forward by Hiroshi Ishii and colleagues (Ishii, 2008). I restrict the present discussion to two of their earliest examples, transBOARD and metaDESK, both presented in their now classic paper (Ishii & Ullmer, 1997).

TransBOARD is a "digitally-enhanced physical whiteboard, which absorbs information from the physical world, transforming this data into bits and distributing it into cyberspace" (Ishii & Ullmer, 1997, p6). It is explained that "the surface of the transBOARD serves as a one-way filter for absorbing bits from the physical world into "cyberspace". A comparable system is metaDESK (Figure 2.5.), a "bi-directional interactive surface, spanning physical and virtual spaces" (ibid, p7). MetaDESK figures various tangible objects such as 'activeLENS' and 'passiveLENS', which can be used to navigate digital content in various ways (Figure 2.5).

Figure 2.5, metaDESK. Left: passiveLENS. Right: activeLENS (Pictures by Brygg Ullmer, with kind permission)

The basic conceptual model proposed here has not changed for many of the 'tangible' systems that have been proposed since. It assumes first that there exists a certain 'digital world' (what Ishii & Ullmer call '*cyberspace', ibid*). The design question centers on how the user can access this world. The goal is thus to create *an interface,* to a virtual world, filled with digital information. Framed this way, DRC principles support the idea that suitable tangible props will reduce cognitive load, and therefore result in a more user-friendly interface than most graphical- or command-line interfaces. In other words, Ishii & Ullmer's 'phicons' (physical icons) are expected to outrank graphical icons on usability measures, since they exploit the natural ways in which people use physical objects (including our own body) for representation and computation. Or, as Ishii explains it:

"People have developed sophisticated skills for sensing and manipulating their physical environments. However, most of these skills are not employed in interaction with the digital world today. Tangible User Interfaces (TUIs) are built upon those skills and situate the physically-embodied digital information in physical space. The design challenge is a seamless extension of the physical affordances of the objects into the digital domain.... Tangible User Interfaces (TUIs) aim to take advantage of these haptic interaction skills, which is a significantly different approach from GUI [graphical user interfaces, jvd]. The key idea of TUIs is to give physical forms to digital information. The physical forms serve as both representations and controls for their digital counterparts. TUI makes digital information directly manipulatable with our hands, and perceptible through our peripheral senses by physically embodying it.

(Ishii, 2008, p. x, my emphasis)

Indeed, tangible interfaces, such as transBOARD and metaDESK may provide user friendly interfaces to digital information. This is one way to see the theory of EC at work to help improve interaction design.

3.7. Further discussion of the distributed cognition account

There is however an issue lingering in the background. Consider again this part of the quote above.

"The key idea of TUIs is to give physical forms to digital information. The physical forms serve as both representations and controls for their digital counterparts."

(Ishii, 2008)

The representational flavor in Ishii's interpretation of embodiment is also reflected in the vocabulary being used to describe the design, for example when discussing transBOARD:

"monitored pen-strokes from the whiteboard are virtually "stored" within [a physical] card...The user can then keep the meeting contents within this card..."

(Ishii & Ullmer, 1997, p.7, my emphasis).

The theoretical implication is that the meaning of the embodied interaction (i.e., what a tangible object - or the manipulations that can be performed with it - mean) is grounded in the meaning of the digital objects and processes it connects to. How the digital information itself comes to have meaning is left unexplained. Regardless of what indeed grounds the meaning of this digital information, it is in any case not grounded in the embodied interactions with the TUI, since the digital information is assumed to have already the meaning that it has, and the TUI functions subsequently to give the user access to these digital meanings.

3.7.1. Pre-given digital meanings

As it happens, Ishii's model of tangible interaction actually helps us to understand why, some proponents of more radical forms of EC feel that the DRC version fails to get to the bottom of what it means to say that cognition is truly *embodied* (e.g. Dreyfus, 2002; Chemero, 1998; 2009; Thelen & Smith, 1994; Noe, 2004; Merleau-Ponty, 1962).

In order to see why, we must first realize that DRC conceives of the mapping between meaning and physical form as a *functional* one, even if the functional mapping is 'extended' into the environment (Clark, 2008). *Functional* relations between form and content imply that the particular physical form that implements (represents) the content, is always in some sense *arbitrary*. In other words, however 'tangible' someone's problem solving strategy may be, one *could* in principle conceive of *another* strategy, e.g. a brain process, or another tangible form, that does exactly the same *functional* job. This is what we see in tangible interaction as well: as the meaning of the digital states is predefined, we could in principle create another tangible interface to these same meanings. We could even create a GUI interface to the same 'digital information', without essentially changing the meanings involved. Each interface may result in *different amounts of cognitive load* – but what the interface maps to, would still be the same content.

In fact, Ishii and Ullmer (1997) also mention a web-based GUI, to the same 'cyberspace' that the tangibles connect to. Using a tangible control, rather than a graphical one is, in that sense, essentially a matter of choice. Indeed, Norman argues that we sometimes rely on 'knowledge in the world' and sometimes on 'knowledge in the head', depending on what suits us best under the given circumstances (Norman, 2002). Ironically, this means it is not at all clear whether graphical interfaces couldn't sometimes do just as well as tangibles, when it comes to reducing cognitive load. Indeed, GUI designs have been proposed based on DRC theory as well (e.g. Hollan et al, 2000). If we conceive of the design challenge in terms of DRC, then, it is not so much the tangibility of the interface that matters, rather than the more general question of whether the interface reduces cognitive load.

3.7.2. Metaphorical mappings

A related issue pertains to the fact that intuitive tangible controls such as activeLENS and passiveLENS are essentially metaphorical mappings (Djajadiningrat et al, 2002). They function 'like' a 'real' lens, and in doing so they map onto certain digital operations, which, in the words of their makers, are 'consistent with the ... metaphor' (Ishii & Ullmer, 1997). But why digital objects and processes would be 'consistent' or 'inconsistent' with a metaphor depends on how one interprets and applies the metaphor. As a consequence of DRC's reliance on functional mappings, deciding on what is a suitable metaphor involves degrees of freedom that get fixed by the designer, on beforehand, and not by the user, in the interaction itself. Whether implemented by icons or by 'phicons', this means users must still already *understand* the (designer's) reasoning evoked by the metaphor in order to be able to make sense of the system. Compare this with the *inherent* relations between form and the function of traditional tools, like a hammer, or a bicycle. Here mappings cannot be changed as a matter of choice, without immediately changing the very nature of the artifact. In classical tools, meaning is embodied *in the* interaction, in a way very unlike metaphorical mappings (Djajadiningrat et al, 2002).

3.7.3. Product affordances?

The problematic nature of DRC as basis for design is further reflected in Norman's representational interpretation of the word 'affordance' (ibid). Norman's information-processing interpretation of Gibson's original concept (as put forward in Norman 1987/2002), have lead many designers into believing, incorrectly, that an affordance is a kind of message, inscribed in the physical form of the object, telling the user what action can or should be performed. A *use-cue*, as it is often called, is indeed a representation, and it works very much like the 'tangibles' discussed earlier. In fact, Ishii often uses Norman's original, incorrect interpretation of the term (e.g. Ishii et al, 2012[3]). In contrast, Gibson's aim was precisely to do away with representation and message passing, proposing instead a *direct* coupling between perception and action (Gibson, 1979). I return to Gibson's notion of affordance in sections 5.3 and 6.1.2.

3.7.4. Grounding meaning

All these issues can ultimately be traced back to a critique of DRC not being able to explain the *grounding of the meaning of the representations involved* (Chemero, 2009). This is why the phenomenological philosopher Hubert Dreyfus rejects Andy Clark's 'extended functionalism' (Clark, 2008), stating it does not at all help us get rid of the old Cartesian split between mind and world. As Dreyfus states:

... Clark ... attempt[s] to free us from the Cartesian idea that the mind is essentially inner by pointing out that in thinking we sometimes make use of external artifacts like pencil, paper, and computers. Unfortunately, this argument for the extended mind preserves the Cartesian assumption that our basic way of relating to the world is by using representations... be they in the mind or in notebooks in the world ... While Brooks & Agre [see section 5, jvd] dispense with representations where coping is concerned, all Clark... give[s] us as a supposedly radical new Heideggerian approach to the human way of being in the world is the observation that... thinking bridges the distinction between inner and outer representations.

(Dreyfus, 2007, p. 254)

In the remaining sections, we will see two general directions in which people have sought to find more radical alternatives to the 'Cartesian idea' based on representations and computations. Our concern here is is whether such radical proposals can help us to get beyond the project of creating physical interfaces to predefined, digital meanings, towards designing a way to support the *generation* of meaning in the first place, right within continuous interaction with the system.

The first of these directions is discussed in the next section (section 4), which investigates how cognition is situated in *cultural- and social practices*. Thus, when Ullmer & Ishii state: "the transBOARD is nearly the same as an ordinary whiteboard, and minimally alters the familiar work practice of using a whiteboard" (Ullmer & Ishii, 1997), the question to ask presently is what this 'familiar work practice' is really all about.

After that, section 5 discusses in detail the role of the body itself, framing cognition as first and foremost a form of *sensorimotor coupling*[4].

4. Socially situated practice

A body of research originating in cultural anthropology and social science, with ties to Computer-Supported Cooperative Work (CSCW; Suchman, 2007, p. 276-277; Dourish, 2001) and Participatory Design (Schuler & Namioka, 1993), has investigated the way tools, and aspects of the environment in general, become incorporated in people's socially situated practices. (Suchman, 2007; Dourish, 2001; Clancey, 1997). The general tendency of this work is one that moves away from cognition as detached, rational problem solving, arguing instead for the cognitive value of concrete circumstances and the various opportunities for action that may arise 'in action' (Dourish, 2001).

4.1. Situated plans

As one of the main proponents of this line of research, Lucy Suchman (1987/2007[5]) argues that people do not first internally create a 'plan for action' that is then executed. Instead, a person is found already acting in the face of concrete circumstances in the world, and in doing so, plans evolve, in an ad hoc, improvised manner. As part of this situated action, people create, adapt, re-organize and make use of many kinds of artifacts available in the environment. Suchman introduces her account as follows:

The basic premise is twofold: first, that ... cognitive phenomena have an essential relationship to a publicly available, collaboratively organised world of artefacts and actions, and secondly, that the significance of artefacts and actions, and the methods by which their significance is conveyed, have an essential relationship to their particular, concrete circumstances.

(Suchman, 1987, p. 50)

4.2. Real-world contexts

Like in many distributed cognition studies, the main method is ethnographical observation, acknowledging that cognition 'in the wild' has its own particular structure driven by the details of the locally available context, which cannot be studied in laboratory experiments. David Kirsh, a cognitive scientist, warns his lab-oriented colleagues not to overlook the value of observing behavior 'in situ':

"People do many more task-relevant things than those allowed for in the strict definition of their task or problem. Addressing this issue requires ethnographic attention to the real-world practice of problem solving."

(Kirsh, 2009)

As an example, Ceci and Roazzi (1994) show in their ethnographical work how Brazilian child street vendors display arithmetic skill which evolved in making money deals on the streets, while those same children were unable to solve (formally) the same problems when presented with assignments in a class-room setting. The street-vendors crucially rely on certain local cues available in the particular social- and material context (ibid; See also Lave & Wenger, 1991).

4.3. The use of artifacts in a social context

Socially Situated Practice theory and DRC contain similarities. Both emphasize how physical artifacts *and* social interactions between people ground cognition. Both use ethnographic methods to investigate behavior in the real, everyday contexts. Both lines of research sometimes use the term 'situated cognition'. However, where DRC treats people and physical objects essentially alike *as* computational units in a distributed information-processing network (Hutchins, 1995); Socially Situated Practice research emphasizes how artifacts ‘get taken up’ as meaningful elements within a *social* process between people. As Paul Dourish emphasizes:

‘knowledge is [classically] pictured as something that can be extracted, transferred, exchanged, stored, indexed, retrieved and managed. .... but the real cornerstone of knowledge is people. ... [A]gain ... a distinction [needs to be made]... between the idea that knowledge can be represented and stored and the view that it has to be contextualized and made relevant to the settings in which it has to be applied. Meaning is not inherent to information; information is made meaningful.

(Dourish, 2001, p.185)

In other words, distributed cognition sees social interactions and interactions with physical scaffolds both as forms of information processing, whereas for Socially Situated Practice research, cognitive scaffolds can only exist as part of a social situation. Without social interrelations, roles, norms, culture, politics, and the like, there would be no meaning at all in using physical artifacts (Suchman, 2007, see especially. p 277).

4.4. Representational artifacts

In distributed cognition, physical media like a text on a piece of paper, a picture, or a map, are seen as locally available media for storing knowledge ‘in the world’, relieving the brain of computational load. Socially situated practice research instead emphasizes how such representational artifacts (for example, cardboard ‘flight-strips’ used by air-traffic controllers; Randall, Hughes & Shapiro, 1991) are not used simply as storage media, but function as active components in the way work gets organized between people (Heath & Luff, 2000; Suchman, 2007; Clancey, 1997). In other words, ‘What it takes to be a representation is to be used as a representation in the course of some activity ... in systems of practice’ (Dourish, 2001, p. 208, original emphasis). In this regard, Winograd & Flores (1986) ask that we should focus on ‘what computers do’, rather than ‘how they operate’ (Winograd & Flores, 1986, p. 7). First, it is shown that a representation does not stand apart from the world, but is always a concrete element in the world, an object with which one engages directly (Dourish, 2001). Furthermore, representational artifacts turn out to form much more a kind of bias on ongoing, improvised action, than a direct specification for action:

“The function of abstract representations is not to serve as specifications for the local interactions but rather to orient or position ourselves in a way that will allow us, through local interactions, to exploit some contingencies of our environment and avoid others.”

(Suchman, 2007, p.185)

In this regard, the public availability of descriptive artifacts is considered essential, and makes the whole affair immediately one of a social nature and thereby ‘accountable’, that is, ‘observable and reportable’ by other members of the community of practice (Garfinkel & Sacks, 1970). This accountability is critical for how people make sense of things and are able to act appropriately in response. For example:

“the railway timetable is not just an abstract description of the operation of the service but its public availability meant that it was be used by the controllers to coordinate traffic flow and passenger movement.”

(Heath & Luff, 1991), cited in (Suchman, 2007)

A summary of the Socially Situated Practice perspective is sketched in figure 2.6:

Figure 2.6: The Socially Situated Practice perspective. Cognition is an ongoing achievement of coordination in social interaction. Physical artifacts function as mediating objects in the way people deal with each other in the context of a situated practice.

4.5. The design question based on the Socially Situated Practice account

Compared to the distributed cognition framework, the work in this section turns the design question up its head: Considering that people are always *already* engaged in an embodied, situated practice, it is the computer that needs to connect to these already existing practices somehow, instead of a user that has to access in some way the computer's digital processes, *replacing* what was before an embodied, situated routine[6]. That is, we need to think more carefully about what digital systems may actually *add*, *in* practice, *to* the practice:

Clearly, the digital world can provide advantages. To temper that, we argue that because there is so much benefit in the physical world, we should take great care before unreflectively replacing it. More precisely, from a design perspective, solutions that carefully integrate the physical and digital worlds — leaving the physical world alone to the extent possible — are likely to be more successful by admitting the improvisations of practice that the physical world offers.

(Klemmer et al, 2006, p. 147.)

Socially Situated Practice research emphasizes the social aspect of practice, and relates most readily to areas such as CSCW. The goal is to 'design systems that resonate with, rather than restrict (or, worse, refute) the social organization of action.' (Dourish, 2001). Embodied interaction with physical artifacts is seen as playing a crucial role. For instance, physical space is reconceived as social 'place' or 'locale' in which people coordinate activities (Dourish, 2001, p.92). In contrast with Ishii's tangible interaction framework (see the previous section) interaction with tangible objects, once they are part of social practices, are already meaningful apart from their possible connections to digital information:

[P]hysical interaction means that many of the interface actions become 'offline' and directed to the social ...setting, rather than to the software on the computer [which invites an] integrated view of interaction-in-context, where offline activities are regarded to play as much part in the 'user interaction' as do actions with more immediate effects on the computational system.

(Ferneaus et al, 2008, p 228.)

Again, the main goal for design is not that the tangible interaction should map 'correctly' to the digital information, but instead, going the other direction, that the digital information becomes meaningfully appropriated into the existing embodied practice. To reiterate: 'meaning is not inherent to information, information is made meaningful' (Dourish, 2001, p. 185). New technologies hence become *appropriated* to do their work within the practice. As an example, Dourish discusses a live video-connection on TV-screens that existed between him and a colleague in another office-space, and how both speaker and listener learned over time to adapt their usual embodied routines (for example, pointing at objects), to have the video-system successfully support the communication (ibid). In fact, many ethnographic studies in the design field have concentrated on how products get appropriated within the natural, everyday context of practice (Wakkary & Maestri, 2007).

4.5.1. The danger of automatization

In relation to the foregoing, it has been claimed that situated practices were being threatened once work became 'automatized' by computer software (Schuler & Namioka, 1993). Computer engineers tended to ignore the concrete and situated aspect of traditional representational artifacts like paper notes or physical diagrams on the table. By first abstracting the work process into a formal description and then automating large parts of this process, engineers ignored the fact that the actual experience of working in a concrete social situation of people, engaging with various artifacts, is precisely what grounds people's understanding needed for selecting appropriate further actions:

"automating the controllers' work of actively organizing and monitoring their work environment would change [the controllers'] understanding about what was happening... it is precisely this understanding that enabled the controllers to safely coordinate [their work]"

(Suchman, 2007. p. 203[7])

The underlying problem may be that the concepts used to define computer technology are also used to define the human practices that the technology is supposed to support:

Computers are representational artifacts, and the people who design them often start by constructing representations of the activities that are found in the sites where they will be used. This is the purpose of systems analysis... In this sense computing has been constituted as a kind of imperialism; it aims to reinvent virtually every other site of practice in its own image.

(Agre, 1997, p. 131)

In relation to this, Robertson (2002) sees the public availability of artifacts as conditional to a sense of agency of the user: i.e. it helps the user in being in charge of what is happening:

If the participants in a cooperative process can be aware of what other people are doing, or have done, then the agency for structuring interaction and cooperative processes ... can be claimed and practiced by the people using the technology.

(Robertson, 2002, p. 300)

4.5.2. Reactable: a tool spurring socially stituated, embodied practice

As a concrete example of the differences between a Socially Situated Practice view and a DRC interpretation consider Reactable (Jordà et al, 2007; Figure 2.7). Reactable is an interactive table surface on which tangible objects can be placed that generate, or transform, (by means of the digital system) sound, thus creating a musical instrument.

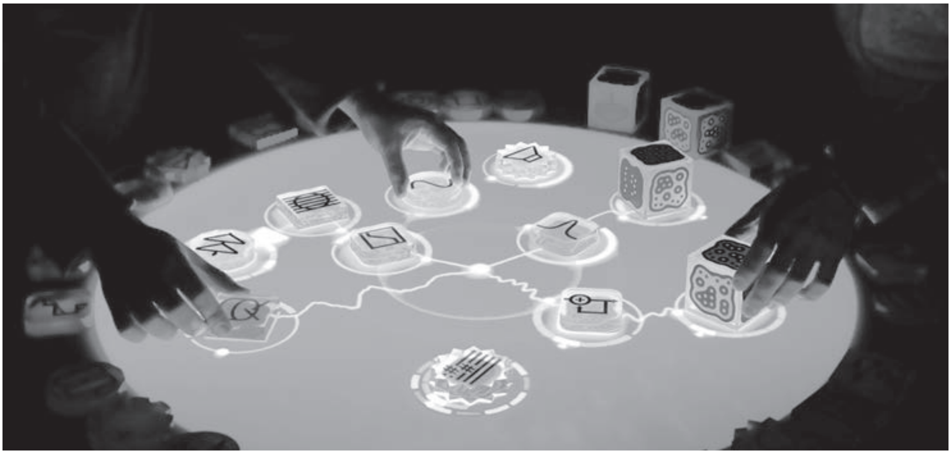


Figure 2.7: Reactable (Picture courtesy of Xavier Sivecas).

Even though Reactable was not designed in explicit reference to Socially Situated Practice theories, we see many of its elements resurfacing. The significance of the musical experience is created 'in situ' as the ongoing action of the participants unfolds. What the system does (not: how it technically works) depends crucially on the social interactions between the musicians (or between the musician and the crowd), who continuously coordinate their actions in real-time, drawing on the public visibility of each other's actions. One could describe Reactable as an application of DRC theory. For example, particular physical objects map to particular digital sounds or manipulations of sound. Yet it would be a mistake to interpret the design purely as an instance of Distributed Representation and Computation. Reactable is not only a new kind of interface; *based on the form of that interface* – it is also a new musical instrument. Its main value lies in the musical experience that people create with it. Musical performance is *socially negotiated* by means of ongoing embodied activities of the participants. And the scaffolding function of the tangible objects only makes sense within the overall social coordinating activity that the system supports.

4.6. Further discussion of the situated practice account in relation to design

Much research has been done to show how artifacts *as a whole* become coupled to practices, explaining how meaningful use of artifacts is therefore a situated affair. Yet, the theory has no detailed advice on how to *design* for interaction between the human body, action, and the form and behavior of an interactive system. So the question is: how to design interactive forms in support of Socially Situated Practices?

4.6.1. What to design from a Socially Situated Practice perspective?

One approach could be to make sure that the system's overall function is meaningfully integrated in the practice, and then think about how to design a user-friendly interface to that functionality. The latter can be done using DRC principles. To some extent this is what we see happening in the Reactable system: the functionality as a whole connects in a situated way to musical practice, while any particular interface element is a tangible control object pretty much in Ishii's sense (Ishii, 2008). Another, related approach would be to literally *copy* an existing practical skill and its associated physical form, and use this as interface element to connect to a digital process. This we see for instance in the *FinalScratc*h digital turntable system (see Klemmer et al, 2006) where a traditional physical turntable is used to control digital music samples. In both cases, the value of evolved practice is recognized, and existing practices are not simply 'replaced' by digital processes.

However, instead of a design that truly *integrates* digital computing and embodied practice, one ends up with at best some form of 'peaceful co-existence' between on the one hand a digital system (made accessible by means of a TUI or otherwise) and on the other hand the human practice in its physical and social context. This does not answer the question of *how* people appropriate digital systems in their practices, nor how the design of the interaction nudges the details of this appropriation in certain desired directions. In a way, Klemmer et al's plea to "leav[e] the physical world alone to the extent possible" (Klemmer, 2006), means that we leave the design question of how to *get into* that world essentially unanswered. The design question of how the digital system is appropriated in the practice is left to the user, which to some extent we also see happening in the Reactable system, as new meaningful moves are being discovered by users themselves. Dourish (2001) seems to argue for just that:

Technological systems ... must be appropriated and incorporated as a part of a specific set of working practices. Because [embodied technologies] can only have meaning through the way in which users incorporate them into working practices, ... the manipulation of meaning and coupling are primarily the responsibility of users, not designers. Coupling, as I use the term here, is an intentional connection that arises in the course of interaction, so while designers may suggest a coupling, they cannot actually make one. Only the user can do that, because coupling only happens in use.

(Dourish, 2001, p.172)

As a designer, however, one wants to make decisions that have impact on the formation of such couplings, even if one acknowledges one cannot prescribe them. And as a researcher of EC, one seeks to understand in as much detail as possible how people make couplings and what factors influence this process.

4.6.2. The role of the body

Perhaps what misses is a strong and detailed account of the role of the human *body* in relation to these socially situated couplings:

[P]articipatory design... ethnomethodology and particularly situated action ...have played a major role in ... CSCW research, [but] ... have not been matched by a consistent rethinking, from the perspective of technology design and use, of related theoretical concepts of human activity, such as perception and awareness.

(Robertson, 2002, p. 302.)

With its history in social science and language research, and its focus on investigating patterns of communication between people, one does not always make a distinction between the 'digital' and the 'actual, physical world': Ethnographic insight about people in real environment is quite easily applied to talk about 'media spaces' such as 'online communities' (e.g. in Dourish, 2001, p 92-93). But in Reactable, an important aspect of the system and how it works hinges on *skillful action*. These skills are based the concrete ways in which the physical structure of the system affords certain tricks and moves in relation to the bodies' position and action possibilities: one really needs the actual physical table and objects, as well as the acoustic feedback, laws of gravity, physical effort, and so on, in order for the routines to arise, just as would be the case with a classical musical instrument such as a violin.

Appropriating Reactable is not just a matter of learning to adjust ones actions so as to be able use the table within some already existing social practice, as was the case in Dourish's 'pointing through a video-screen' above. Like a skateboard, juggler-balls, the play-ground, and so on, skilled users of Reactable learn to do 'tricks' and 'moves' which did not exist on beforehand. This involves the creation of new meaning, which is embodied first in the ability to 'do' the trick and only then in being able to talk about it. These tricks are *also* socially accountable, which is shown by the way users immediately invent new names for new moves, and use these new names to refer to the move, such as to further coordinate action and learn from each other. One may indeed speculate that a 'culture' arises, shared by the community of people that learns to master the instrument. But next to this socially situatedness, or perhaps even prior to it, the actual body and its actions play a grounding role as well. Through a process of skill-formation one develops couplings between ones action possibilities and the physical-digital structure of the system which creates new meanings that would not be possible in any other physical set-up than this particular one.

The design of computers has never really emphasized this involvement of embodied skills, since based an information-processing framework, it tended to ignore the physical aspect of the computer completely. Now that we have endless possibilities in defining how digital computing should be coupled to people's embodied skills we suddenly have a design question: what is the right way to do it? Interestingly, Dourish does seem to acknowledge the importance of these sensorimotor details, for instance when he discusses Gibson's theory of affordances (Dourish, 2001, p. 118). Gibsons' theory did concretely inform interaction design, for example as shown in a video-conferencing concept by Gaver, Smets and Overbeeke (1995; mentioned in Dourish, 2001). This discussion of affordances is however not linked explicitly to the discussion of social practices and appropriation.

In order to *design* for embodied practices, then, we need to have better insight into the details of what happens *during the interaction*, that is, into the *form* of the interactive coupling process. In order to do that, we need to dive into the notion of coupling, or coordination, a bit deeper and relate it more firmly to the body itself. For that, we will leave the social sciences, and discuss another part of EC, starting with robotics.

5. Sensorimotor Coupling & Enactment

A major inspiration for EC has been the 'behavior-based' robot development (or Nouvelle AI as it has been called; Brooks, 1991; Agre & Chapman, 1990; Pfeiffer & Scheier, 1999; Mataric, 1996; Ziemke & Sharkey, 2001; Beer, 2008). By building physical robots that learn to navigate various sorts of real-world environments, it was found that, in accordance with Suchman (2007) internal planning and modeling of the world actually does not compete very well against the interactive creation of functional *couplings* between sensorimotor capacities of the robot and contingent structure in the environment. As Rodney Brooks famously stated:

"When we examine very simple level intelligence we find that explicit representations and models of the world simply get in the way. It turns out to be better to use the world as its own model."

(Brooks, 1991, my emphasis)

The notion of 'coupling' that we already saw in the previous section is used here first and foremost to denote a coupling between perception and action, through the world: as the organism interacts with the environment, gradually a stable coupling between perception and action is formed, where both action influences what will be perceived next, and what is perceived influences the next action, in a cyclic manner (Beer, 2008).

5.1. Dynamics of coupling

It is important to emphasize the *dynamical nature* of couplings being made: a coupling only exists as an aspect of concrete actions by the robot, it is not information stored in the environment (nor in the robot). Sensorimotor couplings are dynamical stabilities created and sustained *over time*: they exist purely as patterns within continuous interaction with the environment. Clark (1997) gives a nice example from human practice describing how a baseball outfielder catches a ball. Instead of calculating first the goal position and running speed in order to catch the ball, the outfielder simply starts running, meanwhile making sure that the ball, in his visual field, maintains a straight horizontal line. By continual adjustments of running speed in order to maintain that straight line, the outfielder is guaranteed to be right at the spot where and when to catch the ball (Clark, 1997). Importantly, Clark concludes that in such sensorimotor couplings, the conception of what the cognitive task needs to be changed. The task is no longer to analyze, offline as it were, on the basis of perceptual input, 'what is out there', rather:

"The task [of a cognitive system] is to maintain ... a kind of co-ordination between the inner and the outer worlds." (Clark, 1997, p. 27)

Ecological psychologists have developed various models in which such couplings are represented as attractors in nonlinear dynamical systems (Thelen & Smith, 1994; Kelso, 1995).

5.2. Coupling towards a stable grip

Moreover, embodied systems like Brooks' robots are successful precisely because they are able to create, by an iterative process of exploratory actions, a gradually stabilizing 'grip' on the environment. In that sense coupling is always also a developmental or learning process (Thelen & Smith, 1994). In other words, the development of a sensorimotor coupling can be seen as the development of a 'skill': a successful way of doing things that is stable enough to pop up each time it is needed. (We will say more about skill in the next section). This developmental aspect is sometimes obscured in robot engineering since it is often the resulting coupling that is first painstakingly engineered (by many trial and error attempts) which is hardwired into the sensor-actuator connections. But even here, in some cases we may see that robots develop, over the course of their interactive activity, couplings that were not designed (Clark, 1997).

5.3. Affordances

The concept of affordance plays an important part in the sensorimotor perspective. Perception psychologist James Gibson was among the first to emphasize that cognition is not just analyzing a pre-given world, but a form of coupling between perception and action. An affordance (Gibson, 1979) can be seen as how the world shows up for a perceiver as directly affording some action on the basis of a temporally stable sensorimotor coupling. So, for instance, while running at a certain speed, a river might show up as 'crossable', depending on both the width of the river, ones jumping capacities *and* the current speed of running (Figure 2.8). The same river could also show up as non-crossable, if one would stand still in front of it, instead of running towards it at great speed. This means how one sees the world depends on how one is acting in it, and action and perception get coupled over time as co-ordinations.

Figure 2.8: At full speed, a river may be perceived as crossable, while that same river, standing in front of it, may not. (Photograph by Krista Travers, taken with kind permission from http://www.whippetsnippets.com/)

The affordance is a heavily debated concept. As an aspect of sensorimotor coupling, we may see it as the way in which one directly 'sees what to do', which is a direct effect of the way action and perception become coupled over time during our continuous interactions with the environment. It is in any case not a message, encoded in the physical form of the artifact, which communicates to the user 'how it should be used' (unlike Norman's early explanations, 2002). (See also section 6.1.2. below).

5.4. Enactment

Related to the notion of affordance is Fransisco Varela's notion of enactment. In 'The embodied mind' (Varela, Thompson & Rosch, 1991), Varela starts his account of cognition with the observation that the main drive of any living organism (and already the single cell), is to maintain itself, by a cyclic process of continuous interaction with the environment. This process is called 'autopoiesis' (Maturana & Varela, 1984). Autopoiesis is the basis for the way an organism finds meaning in the world. Varela calls uses the term 'enactment', which is:

"a process whereby a living being creates and maintains its own domain of meaningfulness, in generating and maintaining its own self-identity as an embodied organism."

(Torrance, 2006, 359)

Enactment underscores how making sense of the world is grounded in sensorimotor coupling:

“Cognition, conceived fundamentally as meaning-generation, arises from the sensorimotor coupling between organism and environment.”

(Ibid, 361)

That is, we perceive the world always in terms of how it fits into the self-sustaining process. As a consequence, things show up in terms of what we can do with them, which is basically the idea of affordances. Or as Ryle put it: knowledge is first and foremost a form of ‘know-how’ (Ryle, 1949).

In the course of continuous self-maintenance, organisms over time come to inhibit appropriate ecological niches, that is, suitable environments, shaped by the organism’s own behavioral and evolutionary history. In other words, the “environment” we inhabit does not exist before we come to inhabit it: each creature, based on its sensory capacities and its behavioral repertoire, brings forth both itself as well as its environment, through its actions: its Umwelt (Von Uexkull, 1934; see also Ziemke & Sharkey, 2001).

For some theorists, this implies that ‘the world’ we come to understand does not pre-exist as a fixed *objective reality:* sensorimotor couplings are *generative*: the process that leads to the sensorimotor coupling brings forth, or *enacts* (co-creates) the world. In a way, the word sense-making should be taken literally:

‘[W]e characterise cognition in general as sense-making’. This means that ‘exchanges with the world are inherently significant for the cogniser and this is the definitional property of a cognitive system: the creation and appreciation of meaning or sense-making in short’.. ....meaning is in the engagements in which an organism builds its world.”

(De Jaegher, 2009, 358, emphasis mine)

As mentioned in the introduction to this chapter, such a relativist conception of ‘the world’ may be hard to digest from within an objective, scientific world-view (e.g. Andy Clark explicitly refuses to go this way, see Clark, 1997, p.172-173). ‘Enacted worlds’ and ‘sense-making’, on the other hand, align quite naturally with a phenomenological perspective. In section 6 I give a short introduction to the phenomenological backdrop of these ideas.

5.5. Reflection-in-action

In a related fashion, drawing on the pragmatic, educational philosophy of Dewey, Donald Schön (1983) shows how professionals create knowledge. They do so through repeated cycles of taking action in response to given circumstances and reflecting on these cycles to form a more detached analysis on the basis of it (see also Clancey, 1997). The external materials that the professional generates through his work are not just the ‘output’ of ones work: it is a medium with which one is in a ‘conversation’. The designer doesn’t so much sketch the idea he already has in mind - he evolves the idea in parallel to the creation of the sketch, and the sketch functions to guide his evolving thoughts (Schön, 1983; Van der Lugt, 2005). What we see emerging is a picture where ‘doing the work’ turns out to be a crucial aspect of how people generate knowledge, and knowledge is thereby fundamentally grounded within the practical work setting.

A summary sketch of the sensorimotor perspective is given in figure 2.9.

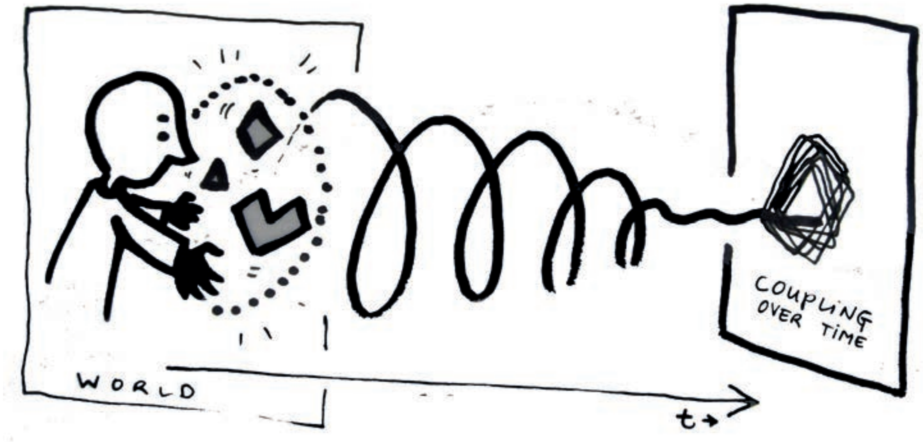


Figure 2.9. The sensorimotor perspective. Cognition is seen as an temporarily stable coupling between action and perception that is created and sustained through continuous interaction with – and through- the environment.

5.6. The design question from a Sensorimotor Coupling & Enactment perspective

Several designers have explored a design vision called rich- or embodied interaction (Djajadiningrat et al, 2004; Wensveen, 2005) which holds close resemblance to a sensorimotor account. In what follows we discuss three examples from the Eindhoven Designing Quality in Interaction group, by Frens (2006), Bruns et al (2008) and Stienstra et al (2011).

5.6.1. Embodied snap-shots

Joep Frens explored various designs for digital photography (Frens, 2006). We will focus here on one particular design exploration based on the form and skills of the body (Figure 2.10).

Figure 2.10. A 'yo-yo' like snap-shot camera concept (Taken with kind permission from Frens, 2006).

Frens reflects on the design as follows:

"The functionality is expressed in the form, but also in the interaction. Images are literally grabbed by throwing the camera towards the object of interest. Moreover, the form begs to be thrown to capture images. Not only are rich actions necessary to capture images, with practice, their expressive qualities can be used to enhance the picture. Information-for-use is given in two ways. First, the form of the camera and how it fits the hand express that it can be thrown. Second, information on 'functioning' is given by the expression of the images on the screen."

(Frens, 2006, p77)

In line with sensorimotor theory, Frens defines the design challenge as the "challenge to fit both form and interaction to the body and perceptual-motor skills of man." (Ibid, p 76). The device supports the formation of sensorimotor couplings by means of the richness of the action that it affords, together with the sensory feedback one gets from manipulating the physical strip. Frens (and with him e.g. Wensveen, see e.g. Overbeeke & Wensveen, 2003) is searching for a more analysis, one that information processing metaphors cannot readily account for (Frens, 2006). This is already implied by phrases such as "the form begs to be thrown to..." which is not so much about *information for use* as it touches on what makes something *meaningful for a person* (Overbeeke & Wensveen, 2003).

At the same time, we see how Frens struggles to define the special qualities of this body-based device using theoretical concepts drawn from other paradigms, such as DRC. He mentions "information-for-use" (cf. Wensveen, 2005) and argues how the system can be seen as a system of "tokens and constraints" (cf. Ishii & Ullmer, 1997). This representational vocabulary may have the danger of covering up the significance of sensorimotor coupling and the enactment of meaning.

5.6.2. Augmented Speed-skate & Stress-reducing pen

A more explicit attempt at integrating digital information with sensorimotor coupling is taken by Stienstra (Stienstra et al, 2011), who presents a digitally augmented speed-skate that continuously maps skate action to acoustic feedback over headphones:

"The amount of pressure delivered is sonified through the intensity and loudness of the band-pass filter; ranging from the absence of sound while lacking pressure to the intense loudness ... while put on full pressure. ... [Furthermore] Balancing on the backside of each speed-skate translates in a low sound while balancing on the front ... translates in a high sound."

(Stienstra et al, 2011)

In this concept, the digital information is not the end-point of the sensorimotor loop, but instead digital information is fused into the sensorimotor loop, supporting the skill of speed-skating.

A similar effect is found in Bruns' interactive, stress-reducing pen (Bruns et al, 2008). This pen has the conventional properties of a normal pen, but also detects patterns in the way you wiggle and roll it in your hand. The idea is that people will start to 'fiddle around' with things like pens during stressful office-activities (e.g. attending a team-meeting). If the wiggling pattern signals the emergence of stress, the pen detects this and responds by counter-acting with forced feedback, making it more difficult to perform the movements you are making. In this way the system interrupts the existing, stressful, sensorimotor loop and subsequently allow for a more relaxed state to emerge (Bruns et al, 2008).

Both the pen and the skate apply an artificial external feedback loop, connecting behavioral output back to sensory input. In similar vein, Paul Bach-Y-Rita famously coupled vision to touch, vision to sound, and so on, in a paradigm he coined 'sensory substitution' (Bach-Y-Rita, 1972). Such new 'input-output' connections; an artificial synesthesia if you wish, do not need to contain predefined meanings for the user (some 'idea' behind the mapping between what is sensed upon acting). As long as there is a reliable mapping in place, this feedback loop will over time come to be recruited for cognition in a meaningful way. That is, the feedback loop will come to 'make sense', even if people cannot consciously report how. In this regard it is interesting that in the earlier concepts, Bruns envisioned that the system makes one consciously aware of being in a stressful state, such that one could then decide to take action (Miguel Bruns, personal communication). However, in a later study, skin conductance measurements revealed that even when people consciously reported to gain no use from the device, stress-level was nonetheless affected (Bruns et al, 2012). This effect is in line with the Sensorimotor Coupling and Enactment perspective, as such couplings are formed in a self-organizing fashion through action (Hurley & Noë, 2003) and do not necessarily need conscious reflection in order to be acquired (Wegner, 2002).

5.7. Conclusions concerning the sensorimotor account and design

The examples so far hint at a number of preliminary conclusions, if we wish to ground design in sensorimotor perspectives on cognition. First, describing these systems in terms of 'digital data' presented as messages, that is, as representations of something else, to the user, may perhaps be possible, but would not help gaining a better understanding of what these systems do. Instead, these systems support the emergence of sensorimotor couplings, and these couplings enable a person to deal effectively with the world. Secondly, the user does not need conscious, descriptive understandings and decision making, in order to be able to integrate interactive systems into the sensorimotor coupling. Thirdly, the sensorimotor perspective puts great emphasis on the dynamical nature of the process of creating and sustaining a coupling. And finally, a sensorimotor account suggests that the user does not so much create a coupling to the artifact, as well as that she uses the artifact to create a coupling to the world: or rather, we may say that the user 'enacts' a world of meaning by interacting through the artifact.

5.8. Further discussion of the sensorimotor perspective in relation to design

5.8.1. Interface design or system design

In design work that relates to notions of Sensorimotor Coupling and Enactment it is actually not always clear whether the goal is to use sensorimotor principles in order to build an interface to digital information inside the system, or whether the aim is to create a technological support through which one creates sensorimotor couplings to the world. Consider this quote from (Overbeeke & Wensveen, 2003):

“The designer needs to create a context for experience, rather than merely a product. ... It is her task to make the product’s function accessible to the user whilst allowing for interaction with the product in a beautiful way”.

This illustrates both that these designers try to reach beyond the idea of a product as ‘merely a product’ (a context for experience) and that they still suggest the product function is predefined and should be made ‘accessible’ by means of an interaction design.

Likewise, Frens seems to take the function of the digital camera for granted (it creates digital pictures). He does not explore in depth what additional digital objects and processes could be added to system, on the basis of the sensorimotor couplings that the design already affords. That is, based on a yo-yo-style interaction: what new kinds of digital input, new kinds of digital objects, new ways storing and computing, and new ways of feeding output back into the embodied action, can be envisioned? How would these digital processes then change the meaning of what it is one is doing? A sensorimotor, enactivist interpretation may perhaps invite one to think about how a *series of snapshots over time* helps the user further evolve a certain skill in photography. In this case we would not just be talking about the skill of ‘throwing out the yo-yo’ (in order to take the snap-shot), but more something geared towards dealing with the situation at large; in other words, with, say, mastering ‘the art of photography’. Frens actually comes close to this line of thought when he writes: “Skill is needed to operate the camera: it is not easy to snap a picture with it. However, if the ‘art’ is mastered of snapping out the camera and having it hang somewhat stationary in the air at the end of its rolling motion, new opportunities of making pictures become available. Motion blur becomes something that can be played and toyed with, thus giving expressive qualities to the pictures that originate from the users skills with the camera.” (Frens, 2006, p.76-77).

Instead, in Stienstra’s skate and Bruns’ pen, the continuous loop involving digital information is crucial to the formation of the embodied skill of dealing with the world, which means the question of what the digital information brings to this coupling process is immediately relevant (Stienstra et al, 2012). However, in the skate example, the device seems to be geared towards optimizing normative standards that are already defined by existing practice (what is good and bad concerning ‘ice-skating’). In the case of the pen, we do not know until a true practice has evolved around this new artifact. Even so, in principle the digital processes involved may *transform* the meaning generated by creating sensorimotor loops to the world while using these devices: ice-skating may become ‘something completely different’ with the head-phones on, and so may ‘relaxing’, with the interactive pen in hand.

5.8.2. Is sensorimotor coupling addressing the topic of cognition?

Another issue is that a practice such as ice-skating is already itself strongly a ‘bodily skill’ and so the question is whether a sensorimotor view on design can actually be successfully applied to practices that are, on the face of it, ‘more cognitive’. While DRC research is critical of classical cognitive theories, it does still deal primarily with clear-cut ‘cognitive activities’. DRC theorists for example readily speak of the kinds of human activity they are investigating in terms of ‘problem solving’ (Kirsh, 2009). If we want to design systems that support the way people make sense of the world around them, the question is whether sensorimotor couplings are going to be enough, or whether sensorimotor theory is mostly useful when designing for 'bodily phenomena', like sports, or feelings of stress. That is, can sensorimotor theory help us get a grip on the more 'cognitive' activities for which we normally would use words like 'remembering', 'thinking', 'representing', 'deciding', 'creativity', 'communication', and so on?

5.8.3. The interactive system as an extension of the body

In general, the design question from a sensorimotor perspective is how interactive artifacts may *support* the basic ways by which people create sensorimotor couplings to what they are engaged with, *through* the artifact. The artifact becomes part of the system that generates the coupling to the world, not an object in the world that we must 'couple to'. As Dourish states (in contrast to his own explanation of coupling-*to*-the-artifact):

The embodied interaction perspective begins to illuminate not just how we act on technology, but how we act through it.

(Dourish, 2001, p.154)

In the next section we will see that this new way of looking can be understood quite naturally if we take a phenomenological perspective (Merleau-Ponty 1962).

6. Phenomenology

This section gives a brief introduction into the phenomenological position that forms the backdrop of much research on sensorimotor coupling (Dreyfus, 2002) as well as on Socially Situated Practices (Dourish, 2001). I draw mainly on the work of Merleau-Ponty (1962) and that of Martin Heidegger (1927; See also Dreyfus, 1972).

In "Phenomenology of Perception", Maurice Merleau-Ponty (1962) sought out to find a middle way between what he called empiricism and intellectualism. Empiricism states first that there exists an objective reality outside of us, which is then received by our sensory system and finally understood by our mind. Intellectualism, in contrast, assumes first that we have some inner, mental idea, which is then projected onto the outside, 'subsuming' all sensory data 'under it' (ibid, p. 167). Even though these positions have been contrasted with one another throughout the history of science, Merleau-Ponty actually argues that both these perspectives are flawed, since they both leave unexplained how a 'subject' and a 'world' first come into being, even before the one can be related to the other:

"(t)he world is inseparable from the subject, but from a subject which is nothing but a project of the world, and the subject is inseparable from the world, but from a world which the subject itself projects"

(Merleau-Ponty 1962, cited in Varela et al. 1991, p. 4)

According to Merleau-Ponty, the 'subject' and the world co-define each other, and this is something that happens in the basic ways we deal with the world *already*, even before we start to reflect on the world as consisting of a collection of objects apart from us. Phenomenological analysis shows how our most basic, everyday engagements with the world are first and foremost an unconscious *habit*, a form of 'embodied coping' (Dreyfus, 2002). If we describe the perceptual experience of this embodied coping, we see how the flow of experiences evolves towards a stable percept while we are continuously acting at the same time. In light of the previous section we can say that a sensorimotor coupling is formed. Merleau-Ponty (1962) calls this coupling *optimal grip*:

"My body is geared into the world when my perception presents me with a spectacle as varied and as clearly articulated as possible. . I have a visual field in which richness and clarity are in inverse proportion ... [W]hen brought together [they] produce a certain culmination and optimum balance in the perceptual process. What I call experience of the thing ... is my full co-existence with the phenomenon, at the moment when it is in every way at its maximum articulation."

(Merleau-Ponty, 1962, p. 371)

6.8.1. A sailor's perspective

An example may help to get a grip on these ideas[9]. When learning to sail a small boat on a lake, one of the difficulties for the novice is in avoiding collision with other boats, especially since there is no fast brake. To begin with, the way a novice perceives her speed ("going slow") and her distance to other boats ("still far away") is 'off': one easily misjudges how little time is actually left to take appropriate action. Secondly, it is difficult to see which boats will pass before you, which ones will pass on the rear, and which are the 'dangerous' ones that are on collision course. We may say the novice lacks clarity and richness in perception. That is, she experiences a lack of 'grip' on the situation and she does not 'see' relevant meanings in the visual scene. At some point, she may learn from an experienced sailor to categorize boats in terms of the way they move relative to the shore behind it. Boats that move faster than the shore behind it are said to 'eat land'. These boats will cross before you.

Figure 2.11. A sailor's challenge: is this boat on collision-course?

Boats that seem to 'fall back' from the shore behind it (as if slowing down) are said to 'spit land': these will pass you on the rear. Boats that seem to stay put, relative to the shore behind it, are on collision course, which calls for immediate change of ones own course. At the start, one learns these 'rules' as explicit instructions and there is conscious deliberation and overt conversation with the instructor involved in applying them. However, after a while, what happens is *that the whole world simply has* *changed*. Once sailing has become an embodied skill, one is able to act immediately according to ones intentions, *and as a result of* ones skillful coping, one now perceives other boats directly in terms of an intention to act appropriately. That is, boats are perceived *directly* as 'front-crossing', 'rear-passing', or 'collision-course' (Figure 2.11). This is not a judgment as when one first sees the boat and then reasons and decides to which category it belongs: it is what these boats 'are', to you, it is how they 'feel', and this feeling is strongly action-related: one sees-and-starts-to-adjust-ones-course in one unified experience. Thus, if a 'collision course boat' comes into view, one finds oneself already taking action towards an appropriate course adjustment, without so much as a further thought. The world that the novice sailor perceives is a complex and chaotic world in which boats first seem far away and then suddenly pop up as dangerously close, and ones own boat seems unwilling to respond to ones intentions. Once the skill is there, however, it is not as if one has learned to deal with unwilling and pop-up: these 'break-down' objects (Verbeek, 2000, Heidegger, 1927; Robertson, 2002) have simply ceased to exist. In skillful coping, boats are spotted as safe or risky already at large distances. And ones own boat, in fact, has disappeared altogether: one acts on the world 'through the boat', or alternatively: one has become one with ones boat.

6.8.2. Zuhandenheit and transparancy

Dreyfus (2002; 2007), based on the philosophy of Martin Heidegger (1927) points out that in most of our everyday dealing with the world, we are *coping* just like the sailor skillfully copes with the circumstances at the lake. In coping, elements in the environment are taken up and used as 'Zeug' ('equipment'). This is called the 'zuhandenheit' of the world (Verbeek, 2000; Heidegger, 1927). This is usually translated in English as 'ready-to-hand' or 'available'. In using 'Zeug' (tools) in order to cope with the situation at hand, we are not directed *at* the tool-object but instead at the world *through* the tool, which itself disappears to become 'transparent' (ibid). Heidegger goes at length to describe the way the hammer is zuhanden for the carpenter as part of his work-practice (Heidegger, 1927). Another famous example is that of the blind man and his cane, who is said to feel the pavement with the tip of his cane, instead of feeling the cane with the touch of his hand (Merleau-Ponty, 1962). On the other hand, there are also situations in which a tool suddenly shifts back into view, mostly when there is breakdown (Verbeek, 2000), or when one does not have the necessary skill (Dreyfus, 2002). Should the cane become wet and slippery, suddenly the cane itself, and not the pavement, is the object of attention. When we then explicitly start to inspect and reason about this object ('What is wrong with this cane?'), it becomes "vorhanden" (Heidegger, 1927; present-at-hand or 'occurrent' (Dreyfus, 2002), which is a mode of being that is however secondary to the more basic ('primordial') zuhanden mode. Zuhandenheid comes close to Gibson's idea of affordances (Gibson, 1979). As Dreyfus explains (2007)

"Heidegger struggles to describe the special, and he claims, basic, way of being he calls the ready-to-hand [zuhanden]. The Gestaltists would later talk of ''solicitations.'' ... Merleau-Ponty speaks of ''motivations,'' and later, of ''the flesh.'' All these terms point at what is not objectifiable—a situation's way of drawing one into it. ... 'What is first of all ''given'' . . . is the ''for writing,'' the ''for going in and out,'' the ''for illuminating,'' the ''for sitting.'' ... What we know when we ''know our way around'' and what we learn are these ''for-what's''."

(Heidegger, 1976, p. 144) (Dreyfus, 2007, p. 252)

6.8.3. Lived space

Phenomenology presents a subjective perspective of the space that surrounds us, in the sense that, based on the sensorimotor loop, we perceive the world as inherently 'egocentric': we see the world 'from our point of view', which is based on the body's actual position, orientation, and action-possibilities. The space around us is a 'lived space', rather than the scientific idea of space, which is defined from an allocentric point-of-view:

Both perception and action are calibrated in egocentric space, ... [which is in phenomenological terms called] lived space. Since my body is geared towards existing or possible tasks, its spatiality 'is not like that of external objects or like that of "spatial sensations", a spatiality of position, but a spatiality of situation' (Merleau-Ponty, 1962, p.100) ... A frame of reference that applies to the lived body as perceiver and actor. (Gallagher & Zahavi, 2007, p. 142)

This is how it can be that while sailing, in 'my' world, my own boat is transparent, while 'your' boat is immediately seen as, for instance, a 'boat-that-will-pass-me-on-the-rear'.

6.1. Phenomenology and tool-design

In their review of phenomenological thinking, philosophers Gallagher & Zahavi (2007) speculate the following:

"Not only can the body expand its sensorimotor skills by acquiring new skills and habits, it can even extend its capabilities by incorporating artificial organs and parts of its environment." (Leder, 1990, p.30) (Gallagher & Zahavi, p. 137-138) ...This is not unlike the famous blind mans stick. (ibid, p.139) ... Something similar can happen with more complex technologies.

Or, as Merleau-Ponty puts it:

Sometimes, finally, the meaning aimed at cannot be achieved by the body's natural means; it must then build itself an instrument, and it projects thereby around itself a cultural world. At all levels it performs the same function, which is to endow the instantaneous expressions of spontaneity with 'a little renewable action and independent existence.

(Merleau-Ponty, 1962, p. 169)

Yet, concerning the 'complex technologies', the question remains: how? How can complex technologies be 'similar' to what the blind man's stick is to the blind man? More importantly: how will they be *not* similar? What does digital technology *add* to traditional tools? In spirit of the present discussion, I speculate that we cannot answer such questions 'in theory': we must engage in an 'embodied' attempt at building the very systems that we have been talking about, and learn from our experience in doing so.

A sketch of the basic 'first person' perspective in phenomenology is given in figure 2.12.

Figure 2.12. A sketch of the phenomenological, enactivist perspective, providing a first-person perspective on dealing skillfully with circumstances that include both people and things, with new yet-to-be disclosed worlds waiting to be 'enacted' at the 'horizon' (Merleau-Ponty, 1962). The 'double frame' of the photograph is intentional: When looking at the sketch, one may realize one is oneself at that moment 'getting a grip' by interacting through a sketched-artifact.

Phenomenology may seem alien to those brought up in the 'hard' cognitive sciences or in computer engineering, where knowledge is something factual, some-thing, the phenomenological perspective actually comes quite naturally for designers (Djajadiningrat et al, 2004; Frens, 2006; Hengeveld, 2011) and traditional craftsmen (Pye, 1968; Ingold, 2000; Sennett, 2008) for whom knowledge is essentially embodied skill. It is precisely in computer science and industrial engineering, practices rooted in the Cartesian tradition, that this connection to skillful know-how may have been lost (Hayles, 1999; Verbeek, 2000).

7. Conclusions to this chapter

I presented a general introduction to the theory of embodied cognition and I identified and contrasted three variations within it: *Distributed Computation and Representation*; *Socially Situated Practice*, and *Sensorimotor Coupling and Enactment*. One may of course take the three variations as one set of related principles, providing an alternative to the cognitivist, information processing view of cognition (Anderson, 2003; Clark, 1997; Wilson, 2002). Taken together as one whole, the theory of EC can inform and inspire the design of physical-digital interactive systems (Hornecker & Buur, 2006).

However, I also discussed specific benefits and drawbacks of each variation and showed how each variation has different consequences for design. In summary, DRC sees the cognitive function of the external environment, including a designed artifact, as a property inherent to the structure of the environment. This environment scaffolds the cognitive process by offering means for external representation and computation. Socially situated practice research instead emphasizes that designed artifacts are not inherently meaningful but 'takes on meaning' by means of a coupling process in a social context of a situated practice. That is, a process of appropriation by which the artifact comes to mean something for a person using it. The sensorimotor account instead shows that the real significance of a designed artifact is in the way it supports the process of creating a sensorimotor coupling as such. This process may lead to dynamic stabilities, which means that the user brings forth, or enacts, a meaningful world through the artifact.

On the basis of this analysis I propose refinements and some tentative answers to the central research questions. As stated in the introduction, the analysis presented above has been fueled by the actual design and research activities that were undertaken in parallel. This means part of the insights offered below will be encountered again in the discussion and conclusions sections of the design cases. (Final conclusions will however be discussed chapters 7 and 8).

1. How may we design interactive systems in support of embodied cognition?

1.1. How does embodied cognition inform designing the relation between the digital process and physical form of the interactive system?

We have seen in this chapter that digital systems evolved as a cultural artifact strongly tied into Cartesian philosophy, science and engineering. Is it possible to give digital processes a new role, one in which they become part of the embodied process of meaning generation? Can new kinds of interactive systems that mix physical and digital process provide something for embodied cognition that traditional tools cannot? And if so, how do the digital processes in such interactive systems then relate to the embodied cognitive process?

In search of these questions, I place critical remarks at least with respect to theories of distributed computation and representation (Hutchins, 1995; Kirsh, 2010; Clark, 1997). I argued that by implicitly working from within this view, tangible user interfaces like that of

Ishii (2008) create metaphorical mappings of physical form to predefined digital meanings. This, I propose, is only a minor step in the direction of what it means to say that cognition is embodied. It essentially does not get rid of the Cartesian worldview (Dreyfus, 2007).

This is not to say that DRC is not useful for design. I believe the notions of cognitive scaffolding, epistemic action and external memory are relevant and may guide interaction design in fruitful ways (e.g. Hollan et al, 2000). In fact, as will be shown in the chapters that follow, the notion of 'cognitive scaffolding' came to be a central concept for the design projects in this investigation, especially in the first project (NOOT, chapter 4). The problem however emerges when cognition is equated with, and restricted to, DRC. Both principles of social situated practice, as well as principles of sensorimotor enactment, suggest there is more to cognition than just distributed problem solving. In terms of design, then, one question is what it entails to go beyond DRC, and how we can relate interactive systems to notions of embodiment in a more fundamental way than (only) by creating tools for distributed computation and representation.

1.2. How does embodied cognition inform designing for the way in which the interactive system at large connects to people's real-world, embodied and situated practices?

On the basis of the present analysis I suggest that the more challenging approach to EC-design is a combination of social situated practice theory and sensorimotor theory, both of which align most naturally with a phenomenological perspective. Such an approach does not aim at designing a user-friendly interface to digital information. It aims much more fundamentally at creating technological artifacts that form an integrated element within human embodied activity in a social and physical context Through this activity a person enacts a meaningful world. Based on Dreyfus' idea of embodied coping (Dreyfus, 2002; 2007), the very distinction between 'function' and 'interface' of an artifact disappears. It disappears not because the interface form is metaphorically mapped onto a predefined digital function, but, instead, because the embodied ways of coping with the world, through the artifact, in a social situation, are precisely what grounds 'the function' of the system (its meaning) in the first place. Such a vision of EC as applied to design may ground the design-based intuition stating that meaning is not represented but instead arises in the interaction between user and system itself (cf. Overbeeke & Wensveen, 2003).

2. How does (the practical attempt at) designing interactive systems supporting shared insight in creative meetings, inform the theory of embodied cognition?

2.1. What is the role is of 'external representations' in the embodied cognitive process?

This question can be further refined as follows. In Socially Situated Practice research, attention is given to the function of *representational artifacts* as biasing improvised activity by providing a guiding context. In a creative brainstorm meeting, we might think of such artifacts as sticky-notes, flip-charts, models, diagrams, etc. Digital 'media' (e.g. stored text, pictures, movies, audio) mediated by computer technology presents modern variations of such external representations. Based on the design cases, then, we should be able to say something about the role of these representational media. One question is what happens to the role of these kinds of artifacts if we start designing interactive versions of them, based on the notion of sensorimotor enactment, and the idea that people enact meaning *through* the artifact. Will such artifacts function in ways different from more traditional representational artifacts, like text on paper, a picture on the wall, or a street-plan on the table?

2.2. What is the relation between the social situatedness and the physical embodiment of cognition (interacting with the physical environment)?

Given the three variations I proposed, this question can be refined as: What is the relation between Socially Situated Practices, on the one hand, and Sensorimotor Coupling and Enactment, on the other?

As discussed earlier, sensorimotor enactment speaks about artifacts as extension of the body, once they become part of the sensorimotor loop. Situated practice research sees artifacts as mediating social coordination between people. How do these two interpretations relate to one another? Are they part of the same basic process? Can we reconcile these roles within one coherent design concept? In particular: how can these two perspectives be integrated at the concrete level of human-system interaction?

7.1. Looking forward

Some initial insights have now been identified. In order to get beyond this point, the actual design cases need to be introduced. That is, in order to really make the theory work - we need to make it work. The cases are described in chapters 4, 5 and 6. In chapter 3 I first describe my research approach. In chapters 7 and 8 I reflect on the design cases and refer back to the theory, and present final conclusions regarding the research questions.

1 What I call 'information processing perspective' would in the philosophy of mind be called a functionalist perspective (e.g. Clark, 2010). Functionalism – in this context - states that the relation between cognitive states and the physical world are representational, whereby a physical form implements the cognitive content, in the same way that software is ultimately implemented in hardware. See also note 3, 4 and 9.

2 One complexity is that whether or not one chooses sides with objectivist science or phenomenology does of course not necessarily imply whether or not one endorses an information-processing model of mind – although most people that reject an objectivist, scientific approach seem to also reject information processing models (e.g. Dreyfus, 1972).

3 "Material has to inform users of its transformational capabilities (affordance). In 1977 Gibson proposed that we perceive the objects in our environment through what action objects have to offer, a property he coined as affordance. For example, through evolution we instinctively know that a cup affords storing volumes of liquid. Industrial design in the past decade has established a wide set of design principles to inform the user of an object's affordance—for example, a hammer's handle tells the user where to grip the tool" (Ishii et al, 2012, p. 47, my emphasis).

4 Andy Clark does in fact discuss many forms of sensorimotor coupling (Clark, 1997). Yet even for Clark, the value of the body is ultimately assessed in terms of how well it can perform computations or store information (Clark, 2008). The body is a physical constraint on the selection of action. Strictly speaking, this turns the body into a part of the environment, 'used' by the brain to offload computation.

5 Suchman wrote a revised edition of the (1987) book she called Human-Machine Reconfigurations, which includes new commentary as well as some extra chapters. One relevant comment on her own original text concerns the often cited example of the person that 'plans' to run a canoe down a rapid stream. In the original text it reads " when it really comes down to the details of responding to currents and handling a canoe, you effectively abandon the plan and fall back on whatever embodied skills are available to you". The 2007 comment reads: "...this phrasing is unfortunate, as it suggests ...the plan is jettisoned ... it would be better to say that your ability to act according to the plan ultimately turns on the embodied skills available to you, which are themselves presupposed, rather than specified, by the plan" (Suchman, 2007, p. 72). This latter interpretation, in which the plan works as a plan because it can safely assume embodied skills available, is in accordance with the view proposed by Clancey (1997). Physical artifacts, including interactive systems, are designed structures, comparable to plans (methods, procedures, rules, laws). They may function in actual, practical use on the basis of this same assumption of embodied skills being reliably available.

6 In this light it is rather surprising that Dourish, 2001, who explicitly discusses Gibson's theory, and moreover puts great emphasis on the socially situated nature of cognition in human practices, presents Ishii's tangible media as an application of embodied interaction in design: "Tangible computing gives physical form to digital information. ... [B]ecause we have highly developed skills for physical interaction ... make interaction easier by building interfaces that exploit these skills. (Dourish, 2001, p.205)".

7 There is also a political (ethical) aspect to this historical process as the formal descriptions of the work that guided the software designs were mostly defined by board members and strategic consultants in the firms, not by the workers themselves. In terms of what software 'does', then, we can say that it is often a materialized form of control by management over its employees (Suchman, 2007, esp. p. 277).

8 Clark is an explicit proponent of a computational-representational view of EC (Clark, 2010), based on his commitment to what he calls 'extended functionalism' (Clark, 2008). (See also note i). In this quote at least he seems to come close to letting go of functionalist discourse. One question is whether one is a realist about computation and representation (the physical nature of the brain is that it performs computations on representations) or whether one just finds it a convenient language to use in talking about the research topic (as e.g. Kirsh, in personal communication). However, even if one is just pragmatically using the vocabulary, computational talk, in a rhetorical sense, 1) may neglect or downplay some of the interesting dynamical and developmental effects of coupling, which are at the hart of both sensorimotor and phenomenological acccounts and 2) may seduce computer engineers into believing that their (digital) computational models can be simply 'plugged in' to the computations that human minds perform by creating the right kind of interface, on account of both being defined in the same language (Agre, 1997, Clancey, 1997). Clark's discussion of for example the parity principle (e.g. Clark, 2008), in which external devices should be considered candidate components of the extended mind if they perform a function that could also have been performed using brain processing, can be questioned: it obscures the idea that brain internal mechanisms are complementary to (and therefore presumably very different from) external structures (i.e. not exchangeable as plugin modules in a software). See (Myin & Hutto, 2013) for extensive discussion on this point. Regardless of ones personal views on this, a warning is in order that it would be a category error to think that one may connect the mind to artificial, digital environments by just finding the right kind of cable-plugs.

9 Phenomenological writings are often hard to grasp at first reading. The phenomena themselves should however always be understandable and they are, according to Dreyfus, also what makes the theory accountable between people since it is ultimately on the basis of reflecting on our own raw experience that this philosophical analysis is built (Dreyfus, online lectures in audio, http://www.learnoutloud.com/Podcast-Directory/Philosophy/Modern Philosophy/Heidegger/24272, last visited Feb, 17, 2013),

3.

Constructing a Research Approach

Everywhere science is enriched by unscientific methods and unscientific results, ... the separation of science and non-science is not only artificial but also detrimental to the advancement of knowledge. If we want to understand nature, if we want to master our physical surroundings, then we must use all ideas, all methods, and not just a small selection of them.

(Feyerabend, 1975, p. 306-307)

Every human tool relies on, and materializes some underlying conception of the activity that it is designed to support. As a consequence, one way to view the artifact is as a test on the limits of the underlying conception.

(Suchman, 2007, p. 31)

Joke: A drunk searches for his car keys under the light pole. His friend shouts to him: "Why are you looking for your keys over here, if you know you've lost them way over there?" "Because here at least I've got some light", the man shouts back: "over there it's all dark!"

1. Introduction

Chapter 1 presented the overall background and main questions for this investigation, while Chapter 2 reviewed relevant literature on EC theory, and made a first pass at mapping theory to design. In this chapter I describe my research approach. Some of the details concerning specific design phases, user-studies and (co-)design activities are found in the corresponding chapters (chapters 4, 5 and 6).

The general framework within which to position my approach is called Research-through-Design (RtD; Archer, 1995; Van der Lugt & Stappers, 2006; Stappers; 2007; Overbeeke et al, 2006; Cross, 2007; Koskinen et al, 2011). My approach also shares a general commitment to a Human Centered Design (Schuler & Namioka, 1993; Steen, 2012), meaning that design takes place in close contact to - and with full respect for - the people and context that the system is designed for. In relation to this, although it is not the core approach taken, my research contains *co-design activities*, in which both end-users as well as other stakeholders actively contribute in the design process itself (Schuler & Namioka, 1993; Sanders, 2000)[1].
I intend not only to answer questions about how to design, but also to find out about the

ways Embodied Cognition shows up in human practices as such, and what all of this may learn us about EC as a theory of human cognition. (See section 6, below). As explained below, this dual interest has shaped my approach and choice of techniques.

1.1. Research-through-Design

A growing number of people have been advocating 'constructive', design-based forms of inquiry (Koskinen et al, 2011). "Design-based" may refer either to doing research constrained by the practicalities of a design project situated in a real-world context, or to the skills and tools by means of which a certain phenomenon is investigated in a 'designerly way'. The present investigation contains both these elements. RtD is a relatively young research framework as compared to, for instance, empirical methods of hypothesis testing, the standard approach in experimental psychology. RtD can be seen as a form of Action Research (AR, Archer, 1995, Lewin, 1951), where the researcher does not observe and analyze the phenomenon of interest 'from behind the glass wall', but actively intervenes in the situation in a collaborative attempt to transform it for the better. This approach is a direct consequence of the type of context, and consequently the kinds of questions, that AR is concerned with:

"There are circumstances where the best or only way to shed light on a proposition, a principle, a material, a process or a function is to attempt to construct something, or to enact something, calculated to explore, embody or test it. ... Such explorations are called Action Research, which I defined earlier as 'systematic enquiry conducted through the medium of practical action; ... to devise or test new, or newly imported, information, ideas, forms or procedures and generate communicable knowledge'".

(Archer, 1995, p. 11)

In deviation of the classical empirical method, the Action Researcher is herself involved in what she is investigating, and she is investigating not so much *what is the case*, rather than *how can we understand better how to change things*. Even though this may seen miles apart from what conventional science tries to do, and how it tries to do it, it can be argued that classical science and research-through-design 'are fundamentally not so different, [as] both are characterized by an iterative process of generating ideas about the world and confronting them with the world. What can be different is the form of these ideas and consequently how their confrontation with the world takes place' (Hengeveld, 2011, drawing on Stappers, 2007)[2]. The iterative, contextual nature of RtD relates to the kind of knowing-in-action (Schön, 1983) that a designer naturally brings into her work, in order to deal effectively with the complexities involved:

"Inquiry is interactive, a coordinated process that goes on in our behavior over time, aswe reperceive, reshape, and reinterpret, material forms by which we model the world and our actions."

(Clancey, 1993, p. 99)

Therefore, in RtD, the *process* of designing, and not (just) the post hoc testing of a particular design *result*, already generates insight. Stolterman (2008) explains how "dealing with a design task in an unknown or only partially known situation, with demanding and stressed clients and users, with insufficient information, with new technology and new materials, with limited time and resources, with limited knowledge and skill, and with inappropriate tools, ... dealing with such messy and "wicked" situations' means that the designer has to act 'designerly'". To act designerly 'requires a designer to be fully immersed in the context of the case and to make sense of that context based on an understanding of the particular situation, and then to create an appropriate approach for the specific design task at hand' (Hengeveld, 2011). Zimmerman et al (2007) refer to this as the ability of designers to deal effectively with *underconstrained* problems.

Research that is part of a design project is always geared towards the question of how to *move on*. To the degree that asking research questions and undertaking studies in order to answer them is part of this, it will always be about reaching the specific sort of understanding that allows one to decide on *what to do next*. As Schön (1983), based on Dewey (Dewey & Bentley, 1949), has shown, this creates 'know-how' (as opposed to *know-that*; Ryle, 1949). The process of RtD includes the creativity, inventiveness and skills a designer brings into the process (Hummels & Frens, 2008). At the same time, in order for such creative and imaginative dealing with complexity (the know-how), to become part of *research*, one needs some structured means of reflecting on and expressing it in a form that is communicable to others. That is, RtD needs to involve systematic inquiry, reported in a way that is accessible to others (Allison et al, 1996). RtD has therefore also been called a process of 'disciplined imagination' (Koskinen et al, 2011).

"Designers ... explore new materials and actively participate in intentionally constructing the future, in the form of disciplined imagination, instead of limiting their research to an analysis of the present and the past."

(Zimmerman et al, 2007, p 4)3.

As said earlier, the design activities in this project take place in close contact to the human context of practice. This contact shapes the (re)formulation of the design challenge, the kinds of design activities (e.g. part of co-design activities) and thereby the resulting design, as well as the way we come to understand that design in our reflection. We may say that the human context of practice is a special kind of empirical touchstone, which 'talks back' (cf. Schön, 1983) to the ideas developed by the researcher: one cannot develop just any design, as the reality of human practice bites back, it selects, biases and all in all co-determines the final outcome. With Stappers (2007) we can say that confronting ideas with the world through designing products for people is not unlike a conventional empirical investigation. This is why, as will be argued further below, RtD has 'empirical quality' and can be used as a form of inquiry for the human phenomena that interest us, in our case, phenomena having to do with embodied cognition in creative meeting situations.

In order to explain the particular form of RtD taken here, I describe first what I actually did[4]. After that I will give some background on the three fields of interest that this investigation tries to connect (see chapter 1). These fields of interest each have their own associated research traditions and principles, all of which influenced my particular approach. Based on this background I then position my approach in the RtD framework. I end by discussing how the approach enables answering the research questions.

2. What I actually did

I now present an overview of the two design cases, the number of iterations within them, and the various user studies, workshops and design reflections that made up these iterations. I have chosen to present ‘the facts first’: what I actually did. In spirit of the very themes being investigated, this reflects more truthfully the iterative, explorative way that my research developed, as much of it was in fact not planned, set and decided on completely on beforehand[5]. Another reason for this ordering is that having a concrete idea of what was actually done may help to digest some of the methodological concerns that will be discussed in some detail later on.

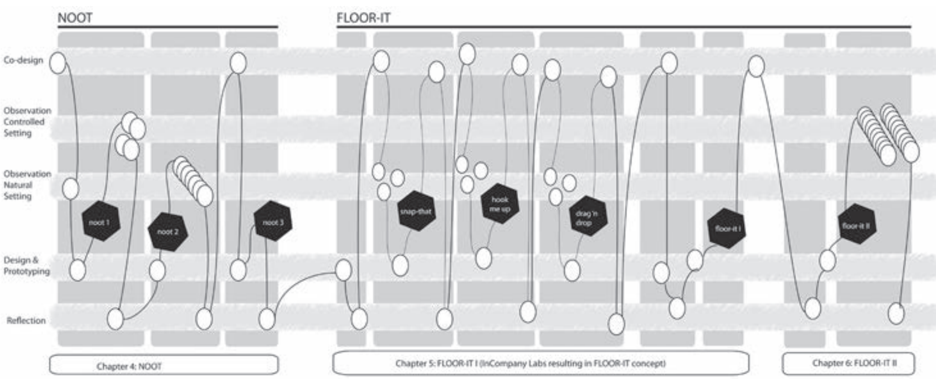


Figure 3.1. A graph presenting in historical order all RtD activities, divided into five kinds (further explained in table 3.1). These activities were part of iterations (grey vertical bars). The iterations were part of 2 design cases. The first case is called NOOT (chapter 4) and the second is called FLOOR-IT (chapter 5 and chapter 6). The first part of FLOOR-IT (FLOOR-IT I, chapter 5) centered on collaboration with three companies by means of so-called In Company Labs. It resulted in the FLOOR-IT concept. The second part, FLOOR-IT II, focused on a use study in a controlled setting, for which two new prototypes were designed and built. In actuality, FLOOR-IT I overlapped in time with the final iteration of NOOT (‘noot 3’). Hexacons represent prototypes resulting from the iteration. Circles represent activities. In practice there were some smaller sub-iterations, these are not shown. In case of observational studies, the number and clustering of circles represent the research design. E.g. the use study of FLOOR-IT II (final two bars) involved observations of people in 20 separate ‘creative sessions’, divided over 2 prototype conditions (10 x 10 design). Further details can be found in the corresponding chapters.

As can be seen in figure 3.1, the project can be divided up into two case-studies: NOOT and FLOOR-IT. Each case consisted of a number of *RtD* iterations. The first three iterations in figure 3.1 are of an interactive system concept called NOOT, further discussed in chapter 4. The subsequent iterations are of a project called FLOOR-IT, spanning chapters 5 and 6. Critically, the last iteration of NOOT was executed in parallel to the first iteration of FLOOR-IT, and FLOOR-IT can be seen as a follow-up of NOOT, as it partly builds further on the insights gained in NOOT.

The horizontal bars in figure 3.1 represent different kinds of research activities. These activities are summarized in table 3.1:

RtD activities
1) participatory design workshops with practitioners & situated interviews
2) observation of interaction with a prototype in a controlled setting
3) observing human practice in natural setting (with our without prototype)
4) designing an interactive system (including a prototype) in answer to the challenge posed
5) theoretical reflection: interpreting findings from activities 1-4 in light of EC theory, with implications for: *1. How to design for EC* *2. Revisiting EC theory*

Table 3.1: Research activities, a selection of which used in each iteration

We see that each iteration included design activities that resulted in a prototype. The iteration further contained either co-design workshops, situated interviews, observational studies, either in a controlled setting or in a natural setting, either with our without prototypes; or combinations of these. Each iteration ended with a theoretical reflection, reflecting on design implications as well as theoretical implications (the two research questions).

Three further notes are in order. First, design action and theoretical reflection were at times closely tied into each other, evolving in iterative fashion within iterations (instead of reflection only happening at the end). Secondly, introducing a prototype into a real-world practice can be seen as creating in some sense a 'controlled' setting. I have chosen to reserve the term 'observation in controlled setting' for an experimental-like situation that specifically compares two or more designed situations, assessing the user's differential response. Introducing one prototype in a natural setting and observing how people behave in its context I call 'observation in natural setting'. Finally, situated interviews in this project were always part of an overall co-design setting. This is why I position them as part of co-design. Of course such interviews also give insight into people's everyday practices in a more general sense, not necessarily directly impacting on design, so they could also be seen as part of 'investigating human practice in natural setting', with interview and observation as two different techniques.

Taken together, the two design cases with the various research activities in it provided a rich set of practice-based insights that, together with the accompanying theoretical reflection, provided the ground for answering the research questions.

3. Connecting three fields of interest

3.1. How to design interactive systems

My research takes place not in the academic context of the social sciences, but in the context of industrial design engineering at a technical university. Within that context, the concern is to know more about *how to design interactive systems*. That is, the objective is to find out how to design these technological artifacts that have some physical form, contain digital process, and have some means (e.g. knobs, dials, sensors, actuators, displays, projection, etc.) which enable a form of interaction with the user that supports Embodied Cognition. The RtD approach forms the basic framework for this research and throughout this thesis the design question returns, resulting in concrete design proposals in the form of prototypes.

Yet even though RtD forms the basis, I am not purely a designer studying how to do design. All studies were conducted in *teams* of which I was only one member. Sometimes my role in that team was more that of a social scientist or psychologist, simply trying to understand what people are doing (both designers as well as the users for which to design). In particular, I was concerned with finding out how cognition emerges in action, in concrete practices. However I did not just take the role of a social scientist, involved in observing and analyzing. I actively contributed in relating growing insights into EC back to design, making concrete decisions as to how the interactive system should be designed (or contributing to it in the team), in both of the studies.

For a designer, both the actual context of practice and the theory she uses is in the end secondary to the main research goal: how to design (Hengeveld, 2011). For an anthropologist, in contrast, the main goal is to understand the practice itself, and a design project might be a context within which to conduct the investigation (e.g. Suchman, 2007). For the cognitive scientist interested in EC, the main goal would be to improve EC theory, and applying the theory to a design project could be one approach to 'confront' the idea of EC 'with reality' (Stappers, 2007). Although *RtD* is my basic framework, and the technical university is where I drink my coffee, I do not choose any one of these particular viewpoints as the central one. Instead, my goal is much more broadly defined as finding out how these worlds of EC theory and interactive systems design *relate*, and I can only make sense of that question if I consider it in the context of what it means to people in everyday human practice.

3.2. Gaining insight into human practice

Apart from the design context, everything investigated in this thesis is in one way or another related to 'human practice' and may help to understand these practices, in particular, of course, in reference to the 'embodied' ways in which people make sense of the world, using technological artifacts in doing so. Human practices involve the everyday way in which human beings engage in all sorts of activities that make up their lives. There are professional practices, as in what people do at work, and practices in the home environment, as well as in the public space. As explained in chapter 1 I decided to focus on the practice of creative group meetings. Human practices are traditionally studied by the humanities, e.g. anthropology, sociology and philosophy. The traditional approaches in the social sciences are either to observe the practice (Geertz, 1973), interview people about their practice, or to collaborate with practitioners (Archer, 1995). Along those lines, observation, and situated interviewing form an important part of my research, even though it will not meet the requirements that anthropologists demand of a genuine 'ethnography'[6]. Furthermore, I chose to involve potential end-users as partners in a collaborative effort towards improvement of their own practice, and see how I could gain insight from that activity as well (Schuler & Namioka, 1993).

3.3. Gaining insight into Embodied Cognition

The theory investigated is 'Embodied Cognition'. This means I needed a way to say relevant things about how the human *body* and concrete bodily action in the physical environment relates to human cognition. Some have addressed such issues using ethnographic methods (e.g. Goodwin, 2000), but others, mainly from the tradition of experimental psychology, use laboratory experiments (e.g. Van Rooij et al, 2002). In line with that latter tradition I added an experimental manipulation in my project (see chapter 6), with the prototype as a physical hypothesis (Overbeeke et al, 2006). This enabled me to tap into the influence of the designed system on sensorimotor patterns in behavior, results that may be less easily gained from field-notes. At the same time, I avoided a classical laboratory experiment stripped of all context, as I did not want to lose sight of the situation as whole. I looked at sensorimotor patterns in direct relation to the activity of social communication of which these patterns formed part (Goodwin, 2000).

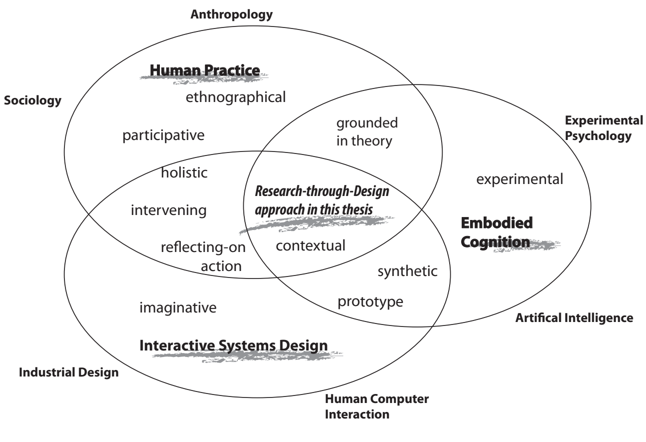


Figure 3.2. A sketch of the various influences that shaped my approach. The design context forms the basis. Embodied Cognition is the theory I wish to apply and investigate. Real-world human practices give meaning to the insights gained from making the theory-design connection. (See also note xii)

Teasing apart these three fields of interest gives some insight into the historical antecedents of the approach taken in this thesis. Since I want to bridge topics that originate from these various traditions, my research approach equally draws from different methodological orientations, associated with these same traditions (see Figure 3.2). The resulting approach is more exploratory and less rigorous than research conducted in the heart of any of the traditional disciplines itself. However, it does enable exploration of cross-connections that any of these disciplines in isolation might not address. This being said, there are actually already a number of relevant *overlaps* between the research traditions that I draw from, which may be worth mentioning (see Figure 3.2, the overlapping areas):

- Interactive systems form an important part of the 'everyday life' that is the human practice – at least todays human practice – as it is studied by ethnographers and sociologists. So, finding out 'how to design interactive systems' is in a way also 'finding out what human practice is', and vice versa (Dourish, 2006). The main overlap in approach, is that both design and e.g. ethnography take a 'holistic' approach to the object of inquiry, trying to get right to the heart of what it is that is being investigated without first breaking up the phenomenon in parts that each have to be studied in isolation. Secondly, both have a tradition of 'action research': making an intervention in practice, and reflecting on its effects (Archer, 1995; Koskinen et al, 2011).
- A methodological connection between EC and the research in interaction design is that both design and EC acknowledge the value of 'research by synthesis', or simply put: one finds out about a phenomenon by trying to build it in the form of working prototypes (In EC, see e.g. Brooks, 1991).
- Both in EC as well as in studies on human practice there is a strong value of *theory* and doing theoretical analysis, over and above reporting on empirical findings as such (e.g. Suchman, 2007).
- Finally, what all three fields have in common is the recognition that the phenomenon of interest is always situated within a larger context. This means that in the approach taken, one needs somehow to take into account the existence and influence of this context – one cannot just strip it away as irrelevant - *and* at the same time one needs to work with the fact that one cannot bring this context completely under ones control (otherwise it would not be 'context'). EC theorists would say the phenomenon is an 'open system', in continuous interaction with the larger environment (Beer, 2000). In line with this idea designers know that '"messy situations" can never be accurately modeled, thus a reductionist approach to addressing them would fail (Hengeveld, 2011)'. Likewise, "[t]he important thing about the anthropologist's findings is their complex specificness, their circumstantiality [involving] long-term, ... qualitative, highly participative, and almost obsessively fine-comb field study in confined contexts (Geertz, 1973). The omnipresence of this open-ended context, in which everything may potentially become relevant at some point, is exactly why I think a RtD approach is valuable. Creating an interactive product, physically realized in a working prototype, both addresses the full richness of in-context interaction *and* provides gives the researcher some grip on this complexity, an 'anchor' as it where, meaning the researcher can focus on what people actually do with the product and how designing the product has effect on what people do as a way of *probing* the complex system dynamics (Overbeeke et al, 2006). This can help the researcher to make sense of what is happening in full appreciation of the holistic nature of the phenomenon under consideration[7].

4. RtD in this thesis

In the projects discussed in the coming chapters, we see a continuous alternation of activities of 'analysis' (observing what is the case) and 'synthesis' (designing something new). This alternation, as visualized in figure 3, forms the heart of my RtD approach.
I set up the projects such that these activities alternated over time, mutually informing each other. A user study would inform design, and a design outcome would be tested in a user study, framing the kinds of questions that needed to be asked in order to be able to move on to the next design phase. The overall research take away is based on the gradually emerging sense of direction that all these cycles point to. This gradual direction was interpreted in, and further shaped by, EC theory, in moments of reflection after each design iteration, and within design iteration often also after the completion of a partial study or design phase. Within each activity of either designing for- or studying humans in action, there is also reflection that may bring partial insight: User study results are interpreted in the light of theory, and just so are particular design problems, and the way we approached them, reflected on and interpreted in light of the theory. Taken together this resulted in an ever more focused understanding of the relations between embodied cognition, the design for interactive systems, and the particular human context of practice.

In figure 3.3 one sees on the vertical axis the alternation between analysis and synthesis. The horizontal axis instead represents the two main *topics* of investigation, with on the left hand 'human (cognitive) practice' and on the right hand '(a prototype of) the interactive system'. The heart of my research consists in finding out how these two ends on the horizontal axis relate, i.e. getting clear about what happens in the interaction between a person (in his embodied practice) and a technological system as seen from the perspective of Embodied Cognition.

We can now map the 5 kinds of research activities from Table 1 into this figure (See figure 3.4). They occupy the four quadrants of the diagram. In addition, 'theoretical reflection' is placed in the center. In my approach, then, I navigate in iterative fashion between these four quadrants and the center. The order of activities in each iteration is not fixed; design can precede an observational study, or vice versa. In each iteration design and theoretical reflection return, most often accompanied by a selection of observational studies and/or co-design activities with users. The process iteratively creates insight into the topic of investigation. Furthermore, by reflecting on my findings both from a designer's experience; on the basis of observational data of users, and from a theoretical perspective, the approach supports a form of triangulation (O'Donoghue and Punch, 2003).

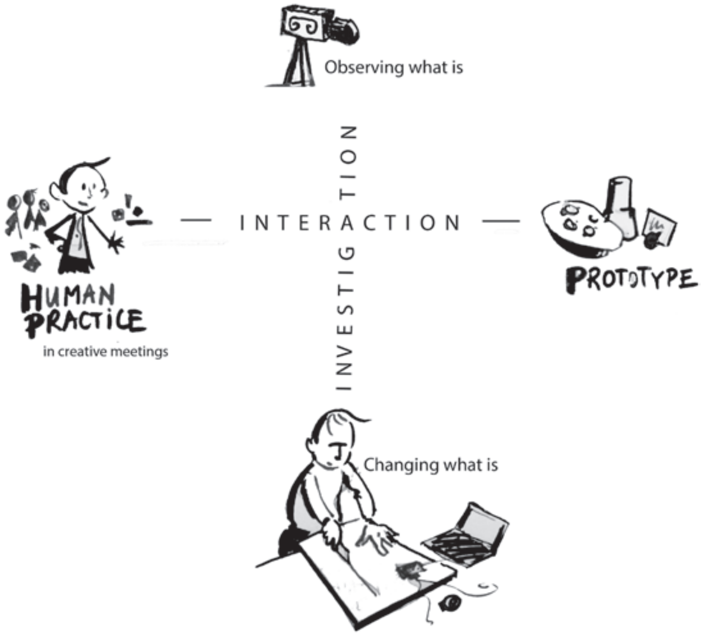


Figure 3.3. Relations between user practice, empirical observation, design action and the evolving design

Figure 3.4. The research activities undertaken in this project positioned within the overall RtD framework for this thesis.

5. The role of the prototype

In RtD, the prototype plays an important role. Prototypes, which may include all kinds of early mock-up forms, sketches, and the like form a conceptual anchor-point for reflection, by means of which we can build relations between EC theory, design, and actual human practices. In this regard, Ylirisku et al state:

"[Prototypes] enabled designers and the workers to discuss new and diverse opportunities that became conceivable in the modified setting. When the action was situated within the real work environment, the relation to the work practice was immediately addressed. In short, exploratory framing [mock-ups] functioned as a platform for divergent thinking, which was grounded in empirical reality."

(Ylirisku et al, 2009, p. 1137)

Note that a prototype in research is different from that in industry, as is emphasized by (Koskinen et al, 2011):

"Prototypes done by researchers typically respond not to commercial definitions, but to definitions and demands rising from research. Then constructive research typically goes back to field studied, studying whether the design work or not, and what it is that works."

(Koskinen et al, 2011, p.180)

5.1. Roles of the prototype

Given this general function, prototypes can play a variety of roles. (Koskinen et al, 2011), drawing on (Stappers, 2007), mention these:

- to test a theory, as embodiment of the theory: a physical hypothesis
- to confront a theory: 'researchers who prototype cannot hide in abstractions'
- to confront the world: 'one cannot hide from the people (via demonstrations, .. criticism...', etc
- they may serve as useful provocations

Furthermore they add the use of a prototype as 'a cultural artifact whose role can be observed in natural practices, in spirit of ethnographical method'. In this case it is not used 'as physical hypothesis, but as a thing to be followed in context' (Koskinen et al, 2011). This latter kind of inquiry however requires that the prototype can be followed in working order for a sufficient amount of time (say, a few weeks). Moreover:

"The prototype should not be thought of as a laboratory experiment. The designer's task is to observe and interpret how people use and explore the technology, not to enforce them to use it in predefined ways." (ibid, p 181)

"And finally, the designing act of creating prototypes is in itself a potential generator of knowledge" (ibid), provided that the insight coming from design action is fed back into the research community and adds to the growth of theory (see also Stappers, 2007). This final role relates to the value of exploring research questions through the process of prototyping (e.g. Hummels & Van der Helm, 2004), in line with what Schön has called a 'conversation with the medium' (Schön, 1983).

5.2. Prototypes in relation to the research activities

In table 3.2 we see how in each of the various research activities introduced earlier (table 3.1), prototypes may play one of these different roles[8]:

Activities	*Role of prototype*
1) co-design	*Conversational anchor that mediates communication between designer and user (Ehn, 2011)*
2) observe interaction in a controlled setting	*A physical hypothesis that can be used to empirically tested the underlying theoretical claim (Overbeeke et al, 2006). Variations of prototypes can implement manipulation of an independent variable in an experiment (Koskinen et al, 2011).*
3) observe practice in a natural setting	*A concrete intervention in a practice, the effect of which can be ethnographically observed (Suchman, 2007), e.g. by studying its appropriation into the practice*
4) designing the prototype	*Scaffold for reflection: the 'medium' in Schön's 'conversation with the medium' that helps the designer to get a better grip on the topic of inquiry by reframing (Schön, 1983)*
5) theoretical reflection	*Concretization, forcing the theorist to be concrete about what it is that the theory claims (Stappers, 2007)*

Table 3.2: The role of prototypes in relation to the various research activities

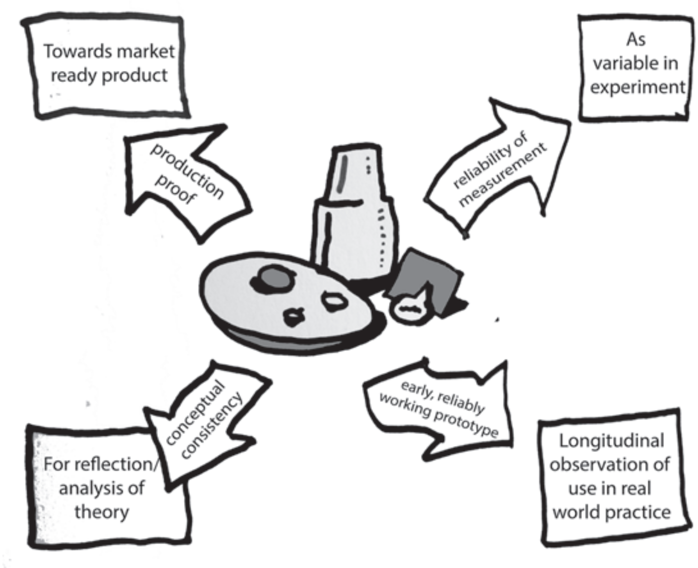


Figure 3.5: Trade-offs for building prototypes.

5.3. Trade-offs in prototyping

I should point out that, as we used our prototypes in these various roles, any particular prototype is in practice always a compromise between various interests (figure 3.5).

First, although the designs in this thesis might potentially become market-ready products at some point, in the present study they function explicitly as research artifacts, and so they are far from production ready.

Yet, even when seen as research artifacts there are still at least three competing interests to deal with in creating prototypes. First, one goal is to create prototypes that are conceptually complete, showing with the greatest clarity exactly how the principles and theory on which it was based shaped the design. This goal however competes with the goal of making a prototype that works autonomously in actual practice, for a significant amount of time, such that one may observe the way the product functions 'in the real world'. To do that, compromises must be made. For example, off-the shelf buttons might be chosen for an interface, where more sophisticated forms of interaction would perhaps have better suited the underlying conceptual principles. The prototypes in this research are constrained both by the aim of getting the 'core' of the concept in the product, and by the aim of creating prototypes that functioned in the real world, and often this means to create at least partially a Wizard of Oz set-up. Furthermore, the desire to create a physical hypothesis that can be tested in a semi-experimental set-up, causes a third set of requirements, competing with the first two. When one choses an experimental set-up (as in chapter 6) - and given that there is only limited time to construct it - the prototype will move into the direction of creating two or more 'conditions' that emphasize the main property of the product one is interested in, not unlike the independent variable in a classical experiment. This however goes at the expense of creating in the full sense all the holistic product experience that was envisioned in the original concept.

Concerning NOOT and FLOOR-IT, many decisions are made that contain such trade-offs, depending on what is seen as fit to the particular design outcome or user study aimed at in that particular iteration. In general, the aim is to build prototypes that can be used to create an 'experience of interacting with the system', as much as possible in a real-world context, both for potential users, as well as for designers. This means in most cases the need to go beyond the earliest technology-free mock-ups or paper-prototypes, and in terms of empirical intervention, it means a more holistic approach than to just vary one single variable or parameter, as in a conventional scientific experiment.

6. *Answering the research questions*

These are my research questions (see chapters 1 and 2):

1. How may we design interactive systems in support of embodied cognition?

1.1. How does embodied cognition inform designing the relation between the digital process and physical form of the interactive system?
1.2. How does embodied cognition inform designing for the way in which the interactive system at large connects to people's real-world, embodied and situated practices?

2. How does (the practical attempt at) designing interactive systems supporting shared insight in creative meetings, inform the theory of embodied cognition?

2.1. What is the role is of 'external representations' in the embodied cognitive process?
2.2. What is the relation between the social situatedness and the physical embodiment of cognition (interacting with the physical environment)?

Based on two case studies I will investigate the way the concrete designs evolved in close interaction with the real-world practice of creative meetings. I use two design examples, two case studies, showing how to design interactive systems in support of embodied cognition. On each iteration I reflect on our attempts to design for EC, linking back the problems and insights that emerged from the practical work to theoretical notions from EC theory. This includes reflecting on what makes it challenging or problematic to do so, and how one may try to overcome the various difficulties involved.

With respect to question 2 I will use both the designer's reconceptualization of the human cognitive practice, and the envisioned role of the prototype in it, as well empirical observations of how prototypes in actuality function within the user's practices, as a basic set of insights 'from practice'. With these insights in hand, I reflect on the theory of Embodied Cognition and propose refinements and improvements of the theory.

The position of the two research questions in relation to my overall approach is visualized in figure 3.6.

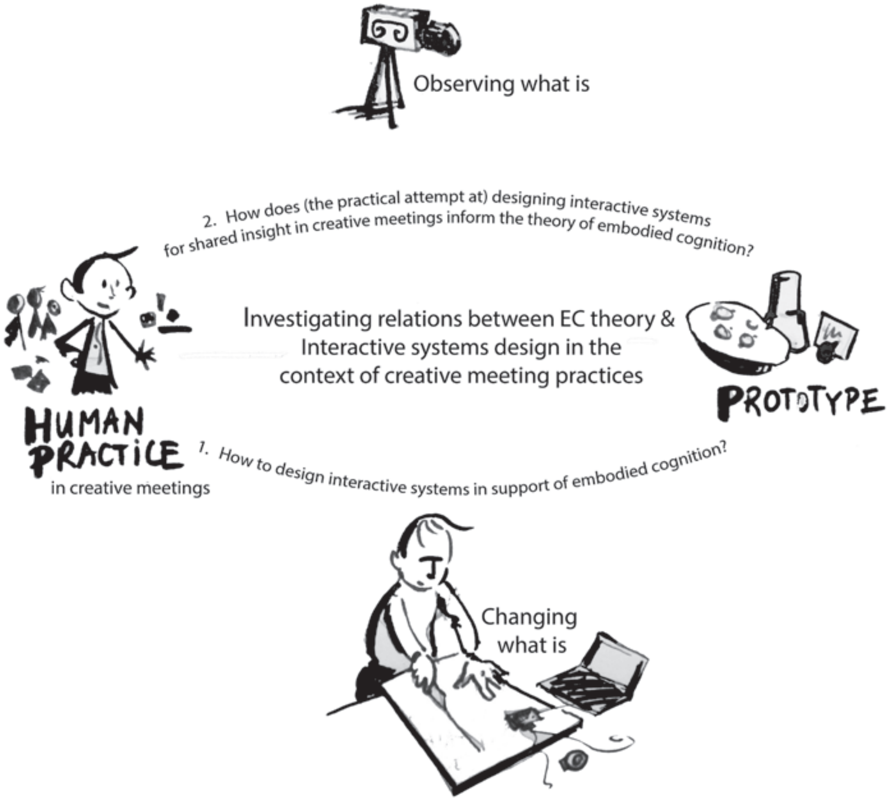


Figure 3.6: the main research questions related to the overall research approach

6.1. How design practice and use context inform EC theory

As said earlier, compared to conventional cognitive science or anthropology, my method for investigating EC theory itself (question 2, figure 3.6.) is less rigorous than would perhaps be expected from established norms in these fields. As Koskinen et al state, my approach is a 'constructive', and 'imaginative' one:

"We are dealing with research that imagines and builds new things and describes and explains these constructions."

(Koskinen et al, 2011, p. 6)

The constructive approach I take towards 'explaining' and 'describing', in this case, the embodiment of cognition, consists of applying EC in concrete design cases, and then critically reflecting on 'what happens in practice'. This gives at least some exploratory insight into the theory itself, and it may inform how the theory may be refined or improved. Using a theory, applying it in a concrete context and reflecting on it, gives one the sort of insight one gets when one is applying an instrument and learning about what it is through use: applying a hammer gives one a 'hands-on' insight into hammers, as well as on how one may improve on the hammer in order for it to better perform its task. There is – in my view – no principled reason why this kind of 'backtalk' from reality (Schön, 1983) in a practical context is less valuable than the more formal ways in which empirical data from an experiment may refute predictions derived from a theory. In either case, the result of the investigation may lead to a revision of the theory, in order that the theory may better withstand a next round of 'confrontation' with the real world (Stappers, 2007; Koskinen, 2011).

In the present project, I see three specific ways in which practice may inform EC theory:

1. Design application makes EC theory more concrete and precise.
We may better understand what certain theoretical claims 'in actuality' mean, because we have to be concrete about them, for instance in the way one has to make concrete design decisions on the form and behavior of the system, but also in the way we give meaning to observations of users interacting with prototypes in real-world settings.

2. Practice shows which aspects of the theory are more relevant than others.
Reflecting on how well the theory could be integrated in design may tell you something about how some aspects of the theory turned out to be more relevant than others, and consequently we may suggest that these useful aspects should perhaps be given a more central position in the theory as a whole. Alternatively we may discover that some aspects of the theory seem to 'hinder' the design process – certain elements of particular interpretations of these elements may actually get in the way of 'moving on' towards getting the main idea of the theory as a whole expressed clearly in a design.

3. Empirically investigating cognition by observing the use of prototypes in real-world practices.
Observing the use of prototypes in actual practice, we actually get quite a bit of 'conventional' empirical data on what people actually do on concrete situations in interaction with their environment, which may further shed light on embodied cognition as a theory of human action. These data are not so rigorously attained as in a formal experiment, but a prototype can function as an experimental manipulation, or as an intervention 'in the field', the response to which can be assessed using observation and interview. An interactive system, built in the concrete and used in an actual, real-world context, taps into the full richness of the unified human experience (Overbeeke et al, 2006). We can thus use data that assess how people use prototypes to get a grip on the phenomena addressed by EC in a holistic manner. This may add to the more fragmental (though also more rigorous) sort of insight we get from formal experiments, where unified human experience is necessarily broken up into into separate sub-processes, each studied in isolation.

In all, I claim this gives the current study an added value that brings new insight, not only as to the question of how to apply a theory in design, but also concerning the theory of cognition itself.

7. *Concluding remarks*

In all the practical activities of designing, making sense of what users were doing in their practice, and getting a grip on the theoretical principles involved, three criteria guide my actions. I state them here as a conclusion to this chapter:

Grounding design action in human practice:
I continuously contrast the design proposals with observations of people in creative meetings, either with- or without prototypes. Part of this contrasting of theory and practice is based on co-creation workshops with stakeholder parties from the context of practice.

Grounding design action in theory:
At each major design decision, it is discussed whether and how the concept fits the theory of embodied situated cognition. The prototype is a 'physical hypothesis' or 'intervention in a cognitive practice': it is the operationalization of the theory as seen within the context of practice.

Observation before opinion:
In the analysis of what people do in interaction with the prototypes, focus is on patterns of embodied, situated action, which may not necessarily be accessible to people consciously and in post hoc reflections. Therefore, the primary focus is on what people actually do (which includes natural talk) rather than what they consciously report about it. Post-hoc responses, e.g. from interviews, are always interpreted against the background of the interaction observed in situ.

In summary, the continuous 'realignment' of design action with EC theory and in close contact with actual user practices, may lead both to a better understanding of how to design for EC (question 1) as well as a revisiting of EC theory itself (question 2)[9].

By adhering to the approach outlined in this chapter, therefore, I have a structured means to address my two research questions.

1 *In this thesis I focused mostly on the involvement of end-users as experts of their own everyday practices and experiences. In the background organization of the two main projects, however, various companies were involved in several stakeholder meetings in which prototypes were evaluated and new concepts were collaboratively designed in creative co-design activities. Detailed analysis of these stakeholder meetings is however beyond the scope of this thesis.*

2 *Perhaps the strength of RtD is on how a series of iterations 'zooms in' on an ever more clear grip on the phenomenon in its entirety, while conventional science can say very precise things about particular details of it on the basis of a single 'confrontation with reality' (e.g. one experiment).*

3 *As we will see later, the present project contains a bit of all of that, i.e.: researching current practice, and evaluating how people interact with a new situation, i.e., the prototype, and reflect on the design process that got us from the former to the latter. But the design project as such remains the primary reference for undertaking all of these partial studies.*

4 *Most often together with team-members, who are mentioned in each of the corresponding sections of the chapters that follow.*

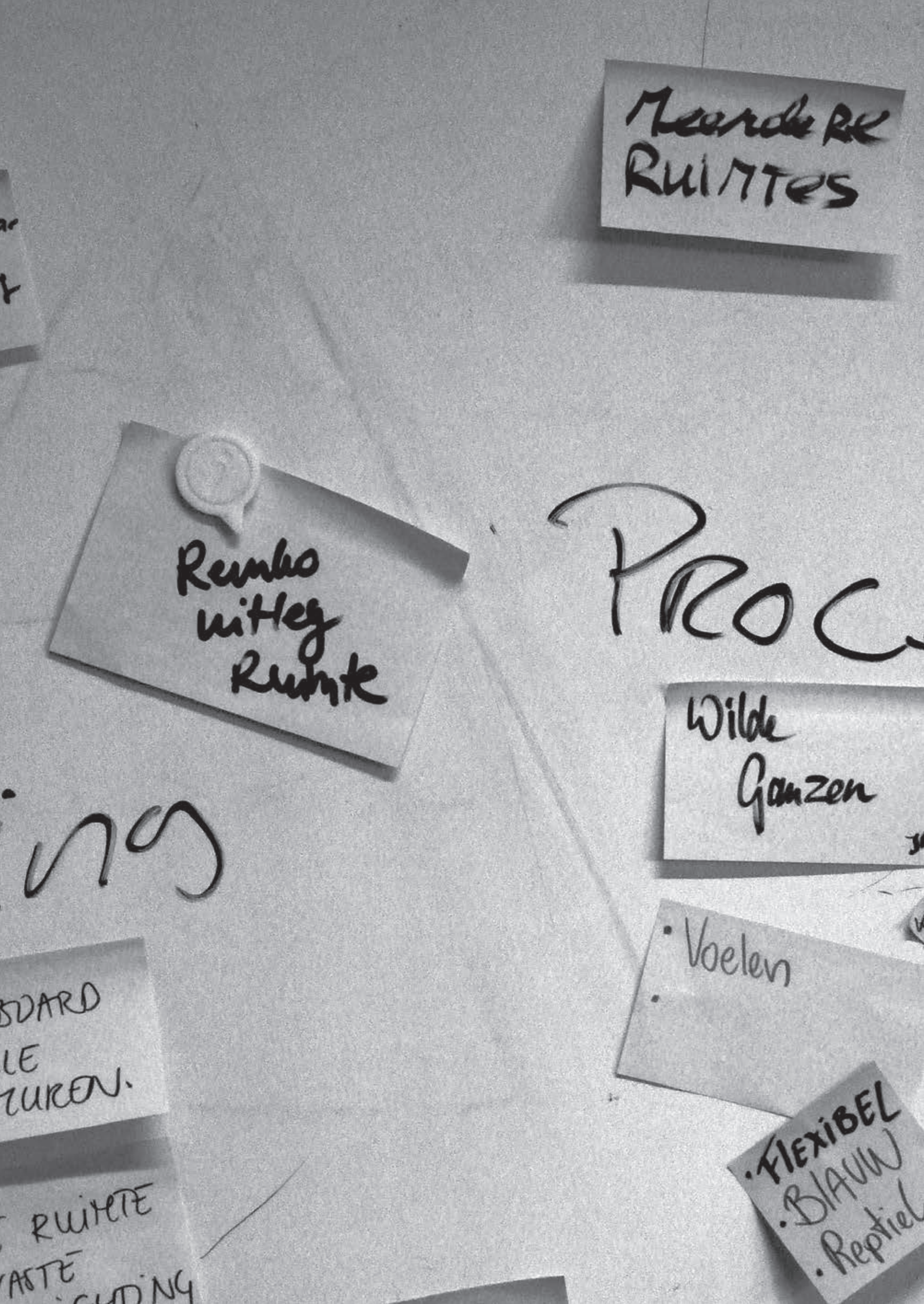
5 *This should not be read as derogative of this research project, rather than as a conscious choice that can said to be, if not a logical conclusion, than at least completely parsimonious with the content of the theory investigated, as well as with the professional design context that situates this investigation: That is, if action is primary in cognition (Varela et al, 1991) and if knowledge in design practice is essentially 'know-how' that is learned-by-doing (Schön, 1983), then one may equally hold there should be primacy of action in research (about embodied cognition for design practice) as well (as do Overbeeke et al, 2006; see also the quote by Ryle, 1949).*

6 *In fact, this goes for all the techniques borrowed, as the mere fact that all of these elements were pragmatically combined and situated in an applied design context under deadline pressure implies already that neither one of them can be executed with the scrutiny that would normally be expected. The strength of my approach then, lies not in the rigor with which any of these methods is applied, rather than in the breadth with which I can relate various themes and principles that lie conceptually far a part, using a variety of research activities 'lightly', instead of applying just one of them 'in depth'.*

7 *It may be compared to the way analysis revolves around a case-studies in the social sciences or to the way a certain ritual can ground an entire ethnography*

8 *Koskinen et al make a distinction between research in the "Lab" tradition, tracing back to experimental psychology, and research in the "Field" tradition, related to ethnography and sociological method. The present study makes no strict distinction and draws from both traditions – but one can see the different traditions in the various research activities undertaken, as is illustrated in figure 2, where 'real world practice' roughly corresponds to "Field" and Embodied Cognition (in particular, the associated tradition of experimental psychology) roughly corresponds to "Lab".*

9 *Strictly speaking it may also lead to a revisiting of the practice, that is, the practitioners (users) involved in these design projects may come to a new understanding of their own practice (either through- or even apart from using the new technological device in question). This 'consequence for practice' is briefly touched upon in the reflections of chapter 5, but it lies beyond the scope of this investigation to explicitly address it. Instead, I focus on the way EC theory informs design and the way design-insight in return informs EC theory.*


RUIMTES
Remko uitleg Ruimte
PROC
Wilde Ganzen
ing
· Voelen
· FLEXIBEL
· BLAUW
· Reptiel

4.

Sticky Ideas or Marked Moments?
Research-through-Design of Tangible Interaction Supporting Shared Reflection

Our names for things and what they mean, our theories, and our conceptions develop in our behavior as we interact with and re-perceive what we and others have previously said and done. ... The processes of looking, perceiving, understanding, and describing are arising together and shaping each other.

(Clancey, 1997, p. 3)

1. Introduction

Suppose some idea or insight comes up in a brainstorm session; would you think is it possible, even in principle, to ‘write down’ the idea on a sticky-note? We certainly talk about it that way: we point at the sticky-note, and we say: ‘this idea here’. But what does it really mean to say ‘this idea’? Is an idea, or insight, something that can be fixed, stored descriptively as the ‘content’ of a sticky-note?

Consider an example, taken from one of our own design meetings. Two of us were brainstorming ideas on the current project. We were both making notes and sketches on a centrally placed flipchart (figure 4.1.)[1]. We were quite enthusiastic about the results. After the meeting, I took the flip-chart home with me. Two busy weeks later, we met again. This is what I wrote down of that moment:

“Staring at the flipchart, we couldn’t remember what was supposed to have been so great about ‘the ideas’. They seemed superficial, or just not interesting, and for some of the sketches we didn’t even remember what they meant. Struggling to recount how the first meeting had evolved, we managed to reconstruct part of our line of thought. 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 wasting time, having to redo most of last session.”

(Taken from Van Dijk et al, 2009, slightly rephrased)

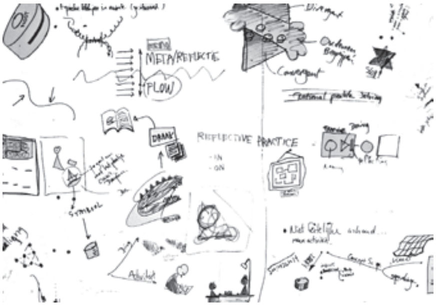


Figure 4.1

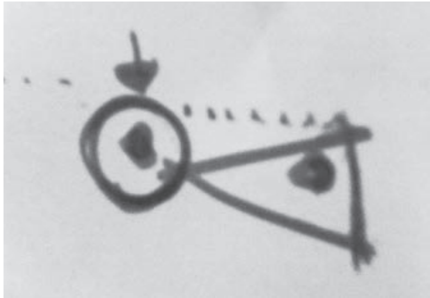


Figure 4.2

Figure 4.1. The flip-chart that didn't ring a bell

Figure 4.2. A meaningful sticky-note?

Let's take another example of such an 'expressive artifact', as I will call these on the fly created sketches, sticky-notes, personal annotations, white-board diagrams and the like. Consider the sticky-note in figure 4.2. This artifact was collected from a brainstorm session, where several company representatives were discussing innovation opportunities in the creative sector. During this session, not once did anyone ask questions about what the picture meant, although each person readily used the picture to explain, discuss and ask questions of each other. If you weren't part of the session you do know what this picture means. In fact, the picture doesn't even refer to a specific 'idea' at all. People created and used this drawing as part of the unfolding conversation. They pointed to it, turned it around, added bits and pieces as they were talking, and so on. Even though it played a crucial role as a 'working ground' for the conversation, as a picture in and of itself, it did not refer to anything in particular[tt].

In the design case presented in this chapter, expressive artifacts such as these are important conceptual carriers for the research. Various attempts are made to 'hook on' to the role that such artifacts play in a creative session, in the design of interactive technology.

1.1. Initial design questions for this case study

One of the starting points for design was exactly the problem described in the examples above: how come these artifacts seem to lose their meaning once outside of their original context of use? Can we respond to this in a sensible way by augmenting such artifacts with interactive technology?

Below I describe in detail how a design concept emerged and transformed over several iterations starting from this basic question. This, in turn, transformed also my understanding of the role of expressive artifacts in embodied cognition in general, and the possible added value of interactive technology, thereby transforming the design question itself. Taken together, reflecting on the design process enabled me to address my main research questions.

1.2. The structure of this chapter

The chapter is structured as follows. After introducing the context of practice and related design work, I briefly describe my approach for this case study (section 4). After that, three design iterations are presented (section 5, 6 and 7). In each iteration I discuss the design process, the resulting design, and a reflection on the findings, which may include results from user studies. At the same time each iteration has its own 'signature'. In iteration 1 (section 5), emphasis is on getting familiar with the context of practice and creating the first concept. In iteration 2 (section 6), emphasis is on a detailed observational study of using a fully working prototype in practice. Iteration 3 (section 7) concentrates on translating insights from iteration 2 into a final design concept, materialized in a working prototype. I then discuss and refine my main research questions in light of this case study (section 8), ending with conclusions (section 9) that form basis for a second design case discussed in chapter 5 and 6.

2. Context of practice

Given our focus on embodied action and situated activity we wanted to give the actual physical environment a prominent place in our search for design opportunities right from the start. Let me therefore spend a few words on the physical space in which creative meetings take place, including various props and tools. In dedicated 'creative spaces', one typically finds several familiar tools and materials in service of guiding the creative process, such as: whiteboard surfaces, magnetic walls, flip-charts on standards, sticky-notes, felt-markers, magnets, (sketching) paper, furniture, such as meeting-tables, some free space to navigate and to enable sub-group activities, and perhaps dedicated interior design (color, texture, etc.) aimed at inducing the right kind of 'creative atmosphere' (McCoy & Evans, 2002). The use context for the present study was based on two sites of external stakeholders (see 4.2) and our own in-house creative space. One of the sites contains a large meeting table and magnetic walls on both sides, as well as free space for moving about, and comfortable chairs. Another site had a more conventional meeting space with whiteboard, flip chart, magnetic wall and large meeting table. Our own creative space is a physical space enriched with several tools for stimulating creativity and co-design (see figure 4.3). Several slightly less conventional tools – at least according to business standards – are part of this space, such as boxes with scrap-materials, clay and LEGO's, wall-size whiteboard surfaces and wall-sized video projection surfaces. Furthermore, several interactive prototype systems supporting the creative meeting are being developed and tested in in this environment (Figure 4.4).

Figure 4.3. The context of practice: 'Conceptspace'

3. Related design work

To provide some context for the design project now discuss a number of related design proposals that all have tried to combine physical space and digital process in service of collaborative insight formation or shared memory.

3.1. Creative group collaboration

Several proposals have been made for enriching physical creative spaces with interactive technology. Ianus Keller's *Cabinet* (Keller, 2005) merges interaction with digital and physical inspiration materials during design. However the goal here is to support the individual designer, and focus is on merging the designer's everyday life with his digital collection of inspiration materials. Inspired by Keller, Arjan Klinkenberg developed an interactive screen for our own *Conceptspace*, to be used in a creative meeting. Snapping a digital picture of a physical sketch or sticky-note with a camera causes the image to be instantly displayed on the interactive screen, ready for further manipulation using an infrared-pen (Figure 4.4).

Figure 4.4

Figure 4.5

Figure 4.4. Klinkenberg's interactive wall prototype in Conceptspace

Figure 4.5 LiveScribe pens used in a contextual interview

A holistic approach is seen in the *dialogue labs* of Lucero (Lucero et al, 2011) in which physical props, interactive surfaces such as a multi-touch 'moodboarding tool' and the space as a whole spur dialogue in co-design sessions. Another concept figuring table-top interactivity is the *EDC environment*, supporting shared understanding and collaboration between various stakeholder representatives in large-scale engineering projects (Arias et al; 2000). The table here critically functions as a physical space where knowledge and perspectives can be shared and negotiated. Recently, Geyer et al (2012) developed a comparable system specifically aimed at brainstorm settings in which digital versions of sticky-notes can be created and physically manipulated by means of interactive table and wall-surfaces (Geyer & Reiterer, 2012). This system aims at creating added value of digital function to interacting in physical and social space, instead of replacing the physical with the digital (ibid; see also Klemmer et al, 2006).

In all these examples we see how information is put out in the environment, ready to be picked up and manipulated, reducing cognitive load and facilitating communication between people (See chapter 2).

3.2. Tangible interaction and memory

A number of interactive systems in which physical aspects of the environment are combined with digital processing are aimed at supporting memory, many of which reviewed by van der Hoven & Eggen (2008). As an example, their own system, the *Digital Photo Browser*, utilizes people's use of personal souvenirs as memory cues. The system associates these souvenirs with digital photographs, thus enhancing memory (Van der Hoven & Eggen, 2008). 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 (Helmes et al, 2006). *Experience Clip* (Isomursu et al, 2004) 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. A related tangible interaction system out on the consumer market is the interactive pen by *Livescribe*, which makes use of the *Anoto technology*[3] (Figure 4.5). Combining memo-recorder and physical notebook, the *Livescribe* pen automatically links written text to audio-recordings, synchronized in time. The notebook writings can then be 'tapped' by the pen in order to replay the audio over headphones. Focus is on individual use, e.g. for recording an interview or a lecture[4].

Comparable to the augmented creative spaces above, these examples already differ from traditional information processing tools because they are not aimed at the storage of complete, explicit descriptions of that what needs to be remembered, but combine 'knowledge in the head' with 'knowledge in the world', to use Norman's terminology (Norman, 2002).

4. Approach

The evolution of the design spans three (main) design iterations, each resulting in a working prototype to be used as intervention in real-world practice. Figure 4.6 shows the overall design history, with alternating phases of use-research and prototyping. Throughout the project both the designs, as well as the underlying design challenge changed. This process was driven by 'top down' theoretical reflection using EC theory, and by 'bottom up' ethnographical insights from use studies. This means each prototype is both a physical expression of my understanding of EC theory, as well as ready for use as an intervention as part of a use study (See also chapter 3).

4.1. Team roles

Each iteration was carried out by a design team that included, next to myself, students of design & engineering schools both in Utrecht and Eindhoven (bachelor and masters' level)[3] and in iteration 3 professional designers from the external stakeholder (see 4.2). The students did part of the design work, including the actual construction and programming of the prototypes. My role was either that of an involved designer contributing as a team member, or one of observing and reflecting on the design process as a participant observer. Students mostly focused on creating a 'good' design (that is, a useful tool for the external client and use context), my own focus was on applying EC theory and to reflect on the process and its outcomes in this regard.

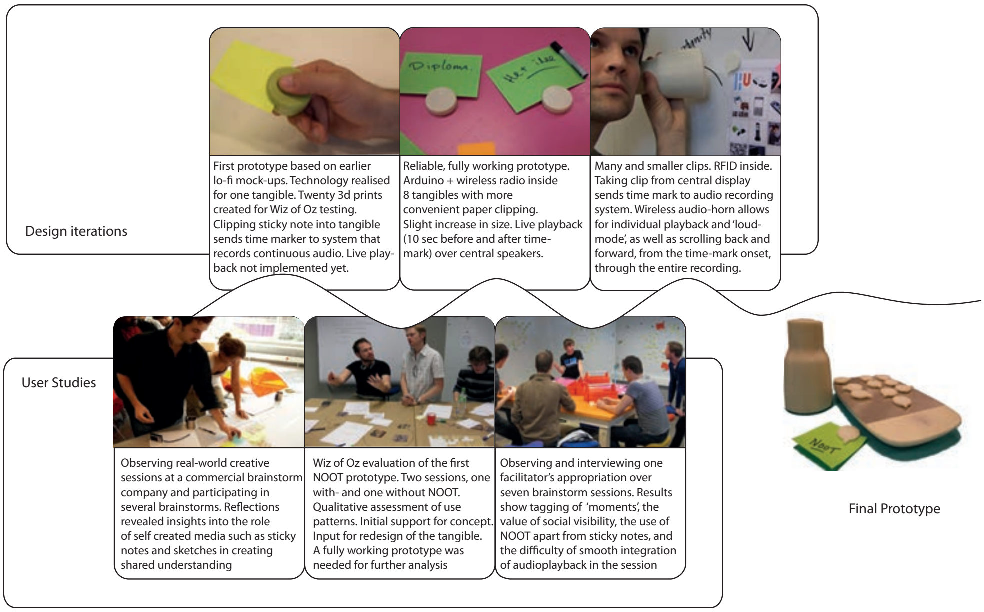


Figure 4.6. The design evolution of NOOT. Further details in text. A video showing the final, fully functional prototype can be found at: www.youtube.com/watch?v=XzZoq-5dJnE

Study	***Iter.***	***Key-word***	***Description***
A	*1*	*Orientation*	*First initial co-design brainstorm exploring the topic with 5 designers. Open question: with the theory of embodied cognition as a background, can we design a tangible interactive tool supporting cognitive tasks during creative sessions? Use of physical tinker materials in order to bias ideation towards tangible interaction.*
B	*1*	*Observing practice*	*Analyzing existing video material of real-world brainstorm session at commercial company & 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.*
C	*1*	*Evaluation of NOOT 1.0 (mock-up)*	*8 design students engaged in 2 creative sessions at the university, and 7 participants (mixed backgrounds) engaged in 2 creative sessions located at a brainstorm company. Each session lasted 2 hours and figures a realistic business case. First session is without NOOT; second session with NOOT. (Wizard of Oz set-up regarding the audio recording and mock-up versions of the NOOT clips). Participants commented on the basic experience and usability of the product. Speech-length was also analyzed. Two weeks later the design students received via email a selection of ideas on sticky-note (digital image), either with or without the associated audio-sample. They were asked free-recall of what they still remembered.*
D.1	*2*	*Studying appropriation in practice using NOOT 2.0*	*Seven sessions with groups of students figuring one and the same facilitator, interspersed with situated interviews with the facilitator. Observing patterns of use and the evolution of appropriation of NOOT by the facilitator. For more details, see main text.*
D.2	*2*	*Investigating the practice of using sticky-notes*	*Conversation analysis of 10 minute video sample from recordings made in E focusing on the way sticky-notes mediate meaning making in the ongoing conversation between participants (Brouwer & Van Dijk, 2011 and Van Dijk & Brouwer, 2011)*

Table 4.1. Activities, part of iterations, specifically organized to study and/or involve end-users.

4.2. Work process

Each iteration followed the cycle depicted in figure 4.7. A first understanding of the design challenge spurred design explorations and research into the user practice. This growing body of design information then was synthesized into one, concrete design proposal in the form of a prototype (either lo-, mid or hi-fi depending on the stage of the project). This prototype was then evaluated by design reflections and empirical user research (using the latest available prototype as an intervention in the practice). This growing body of reflective/evaluative information was summarized into a new design challenge, after which the cycle would repeat. What we thus see is the alternation of project activities that generate data (observing, searching and creating), with the activities that reduce data (a process of synthesizing, selecting and summarizing). Activities classically associated with 'research' and with 'design' can both be generative and reductive (e.g. 'synthesizing research data' into a new problem definition, or 'analyzing the problem by design explorations' (see chapter 3).

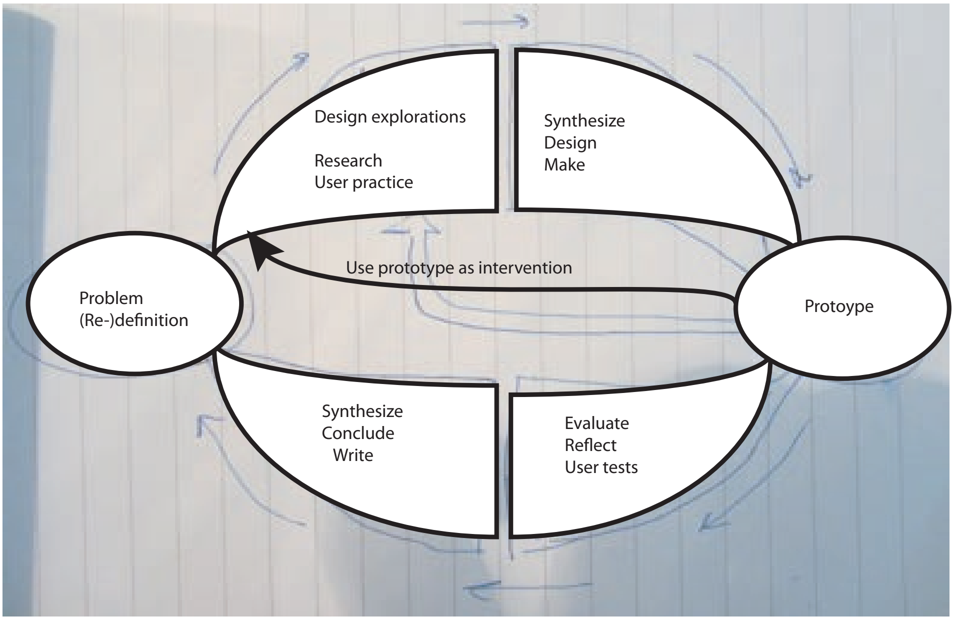


Figure 4.7. The Research-through-Design cycle for this study.

4.3. In touch with the practice

Next to our own Conceptspace, the context of practice was provided by two external stakeholders: Creativity Company and Van Berlo Design[6]. Over the course of the 2-year design period, we had regular contact with 2 facilitators of Creativity Company (iteration 1), a facilitator of ConceptSpace (iteration 2) and with 2 designers at Van Berlo (iteration 3). Furthermore, a number of observational studies of situated practices in the creative space were conducted. Table 1 lists the main activities specifically organized for investigating the context of practice.

4.4. Guiding principles for analysis

As said before, the design process was continuously grounded both 'in theory' and 'in practice' (see also chapter 3 of this thesis). This means the goal of user research was not to gather user wishes, requirements or generally 'what the user thinks of the system'. The aim was instead to get insight into embodied practice and how the technological system becomes part of this through appropriation.

People's conscious verbal accounts of their own practice – e.g. in co-design workshops - are themselves treated as empirical data – as verbal behavior - that needs to be interpreted in light of the theory and behavioral observations. To give one example: participants often stated the wish to 'easily store all ideas for later'. Instead of readily accepting this and making it a design objective, we started looking for underlying reasons why people express this wish, especially since it seemed inconsistent with their behavior. That is: people were seen to photograph all 'ideas' resulting from a brainstorm, but never looked at the photo's again. This tension between what people say and what they do is precisely what lead to new insights during this study (cf. Holzblatt & Jones, 1993).

5. First RTD iteration

5.1. Exploring the context of practice

Initial design explorations started with the idea that sticky-notes, flip-charts and whiteboard are familiar and important elements in most brainstorm spaces, used to develop and discuss ideas and insights. One of the earliest ideas (from study A), involved a technologically enhanced sticky-note, that could be 'thrown' unto an interactive wall, to immediately display the contents of the sticky-note in digital form. This idea seemed intuitively appealing; 'shy' participants could for instance use it to catch attention. At the same time, however, the reason complex digital technology should be used remained unclear. We initiated a student project based in this initial idea. While a first design concept was being explored, observations were made of actual brainstorms both at the stakeholder site and in our own space (table 4.1. study B). A first analysis of this observation material shed light on the main activities and artifacts used within such sessions. It revealed that the larger part of a brainstorm involves verbal conversation, while much less time is spent on expression in physical materials, such as writing notes or sketching, even though brainstorm instructions explicitly call attention to the need to annotate. In short: people talk and interact a lot with one another, but write down only very little of it. On the basis of this analysis we concluded that a digital version of the current function of physical sticky-notes essentially misses the core of the embodied activity, as the main process of interest is the ongoing conversation between people. In fact, what gets written on a sticky-note is a poor residual of the rich and subtle expressions of an idea or insight as it is discussed between people. People may have heated discussions and excited flows of ideas, present rich anecdotes from personal experience, and so on. In such rich conversation, we speculated, shared insight into the task at hand emerges. But little of that richness is recorded in the written note, which is often mostly a kind of 'label', a pointer, referring to the shared experience of a rich conversational episode.

Our guiding question, then, became why physical residuals like sticky-notes are such poor memory triggers later on. We started thinking about how to connect the system in some way to the richness of the conversation, precisely because this richness seemed to get lost in the sticky-notes (Figure 4.10). This resulted in a shift in focus from trying to make interactive versions of existing artifacts for expression, towards an attempt to couple digital technology more directly to the insight generating activity itself.

Figure 4.8


Figure 4.9


Figure 4.10

Figure 4.8. First explorations for NOOT 1.0

Figure 4.9. Brainstorming in action: the use of sticky-notes to guide a conversation

Figure 4.10. Much of the rich detail of conversation is not captured by the contents of a sticky-note

5.2. The first concept: NOOT 1.0

The first prototype of NOOT[7] is a system of 20 small, wireless tangible disks (Figure 4.11 and 4.12), connected via embedded RF-radio and PIC unit to a digital audio-recording and playback facility. The basic idea is as follows (see figure 4.12): The audio system continuously records audio of the brainstorm conversation. When a participant has an idea or insight and writes something on a sticky-note, she immediately attaches a NOOT to it and is then free to place the combined object in whatever suitable location in the space. NOOT functions as a handy placeholder, with a magnet inside for connecting to e.g. the whiteboard. When NOOT gets attached to the physical artifact (the sticky-note, the sketch), a wireless signal is send to the central system that places a time-marker in an audio recording of the entire brainstorm session. Pressing the play button on a NOOT plays back 20 seconds of the recording centered on the associated time marker. That is, NOOT plays a segment of conversation that took place at the moment NOOT was attached to the paper, including the 10 seconds leading up to it.

The basic idea behind this first version of NOOT is that it provides an auditory context to sticky-notes. We had seen that sticky-notes by themselves are poor memory stores. Instead of focusing on a system that would create better representations of the idea, e.g. more accurate text on the sticky-note, in order to remedy that problem, our idea was to use see the sticky as a scaffold that played its part within a larger, situated activity. That is, we speculated that ad hoc texts and sketches are used primarily as cognitive scaffolds (Clark, 1997, Mascolo, 2005) enabling creative thought, and guiding the conversation between participants towards shared insight. Sticky-notes and sketches, on this view, function so as to guide and sustain satisfactory interactive couplings between the various participants and the emerging idea in situ (Suchman, 2007; Lave, 1988, Goodwin, 2003).

For example: we had seen that in cases where two participants would be confused with respect to some idea, one of them might walk over to the whiteboard and draw a sketch, after which the sketch would function as an external 'anchor' to which both participants can relate their talk, guiding the conversation towards shared insight. This is very different from cases where participants deliberately take notes with the aim of 'storing' the idea for later use. In the latter case one need as good as possible to describe "the idea" that just emerged. Texts or sketches created as scaffolding aspects of conversational flow generally do not function well as such "offline" descriptions even though people talk about them as such and also attempt to use them as such. It is only later on that one realizes the sparse text on the sticky-note is not enough to revoke the idea. The conversation itself is needed as a context in order to keep active what the sticky-note refers to. Adding that conversation to the sticky-note such that not only the artifact but also the situated context is retained for later use, was assumed to enhance the way people remember the idea later on.

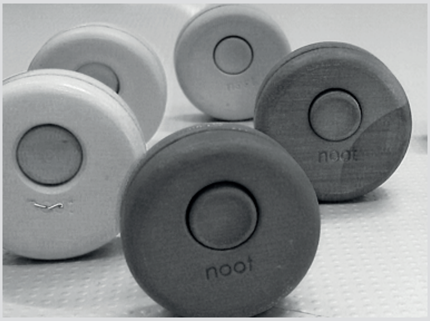


Figure 4.11

Figure 4.12

Figure 4.11 The tangible clips of NOOT 1.0

Figure 4.12: The first NOOT prototype in context-of-use

5.3. Reflections on the first iteration

5.3.1. Main findings

NOOT's function

One of the main steps in this iteration was to abandon the idea of creating a kind of digital sticky-note, that is, to try and digitalize a process that up to know was supported by 'analogue tools'. In order to stay close to existing 'embodied practice' (Dourish, 2001) and investigate what a technological system could do within such a practice, we decided to try and add something to the existing routine of using sticky-notes and whiteboard, and see how digital processing could provide added value without having first to replace these conventional tools completely (Klemmer, 2006). This lead to NOOT: a system that enhances the memory function of sticky-notes. However, this also changed our understanding of what it means to 'store ideas for later use'. Even though we were still speaking in terms of memory, we can perhaps better view NOOT's function as one of making directly available in the here and now part of the original conversation from which the idea first emerged. This means that NOOT functions not so much as a storage device for ideas rather than as a 'bridge' from moments in the past to the current conversation, creating an ongoing feedback loop that fuses sound-bites from the past directly into what goes on now (Figure 4.13).

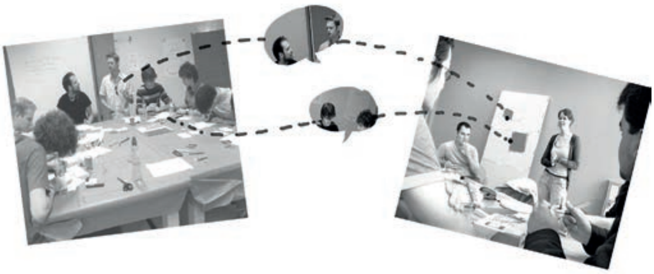


Figure 4.13. NOOT bridges parts of conversation in the past to the conversation that is happening now.

Figure 4.14. In terms of physical form, NOOT gets meaning not from its own form but from the context in which it is placed, and this context is created in use.

NOOT's form

One design issue centered on the form of the clips. In early discussions we thought about representing in the form of a clip different kinds of ideas, such as selected ideas, discarded ideas, ideas from John, and so on, to be symbolized by e.g. by different color, form, etc. Later on, a vision emerged in which NOOT clips themselves actually have no particular meaning at all, they would instead be little 'dots' that could be attached to the existing forms and patterns in the physical environment. The clips became 'linking pins' between the already present, physical world of objects, people and activities, and the digitally stored audio samples. We decided there would be no predefined mappings of meaning to function: by positioning a NOOT at a personally meaningful place in the space, the user creates own meaning, its own' scaffolding structure' (Figure 4.13). This design direction is in contrast to e.g. the Token & Constraint model (Ullmer, Ishii & Jacob, 2005; see chapter 2).

User feedback

We conducted an evaluation study comparing creative sessions with a mock-up version of NOOT to a version with no prototype (Figure 4.15; More info can be found in table 4.1. study C). Time-marking was performed in Wiz-of-Oz fashion using a remote control operated by a researcher. Analysis of speech-length showed that the mean length of an utterance in which a person 'explains an idea' is 15 seconds, and that a default sample size of 20 seconds should suffice to store the necessary conversation for a NOOT-clip. Using NOOT does not by itself put a large burden on people's cognitive demand, as clips were readily attached to sticky-notes as part of the creative process.

Figure 4.15. Observing creative session practices, either with- or without mock-up NOOT system (Clothing pins with magnets and a Wiz of Oz recording of audio samples by remote control). Table 3.1., study C.

However, it was noted that people would stop speaking while performing the clipping action, which indicated that the action was not completely unobtrusive. ("My idea is ... ehrr [clipping action] ... well my idea is..."). This was confirmed in the post-interviews. Participants indicated it would take some time to get NOOT into their normal routine. In the student session, NOOT was used throughout, but it was still experienced as an 'extra step' to take in comparison to the conventional situation. In the commercial session, NOOT was hardly used at all. People indicated they had forgotten about the NOOT clips, being immersed in the flow of the session. Two further themes surfaced: what part of the conversation a user would want to tag (User quote: 'the ability to go back in time is important, as you don't yet know whether you are doing to say something important upfront') and who is tagging it (User quotes: 'For me it was not a success, first talking or explaining and then tagging'; 'I think the person for which this input [i.e. the idea as verbally expressed] is meant, should tag that idea'). When we inspected the free-recall accounts of what people remembered of the ideas two weeks later, it turned out that in some cases participants indicated audio was helpful, while in other cases they responded that audio, quote: 'did not add much'. In particular, audio seemed to relate more than isolated sticky-notes to remembering the origin of the idea (who had first proposed it and within what context), as well as evoking the feeling of 'being back' in the session itself: User quote: "Because of the fragments I could place myself back into the creative space and this helped me in recalling the ideas".

5.3.2. Challenges for iteration 2

The interaction with NOOT: who, when, with what and in which order?

The concrete scenario of interacting with NOOT, i.e. which actions a NOOT clip affords, in which order they should be carried out, and under what concrete circumstances one would activate a NOOT, was not clear. For instance, we didn't quite know whether first writing a sticky-note and then putting it into a NOOT would be unobtrusive enough so as not to block the flow of the conversation. In the user studies we noticed two possible entry-points in the conversation for using a NOOT: one could shout out ones own idea and clip a NOOT so as to record it, but we also observed people clipping a NOOT as a listener to someone else speaking.

Can ideas be recorded?

Much discussion in the design team was on the length of the samples for a NOOT clip. We measured how long it takes for a person to 'explain his idea' and designed it so that the audio-sample would also contain ten seconds prior to the activation of the NOOT, all to make sure that the sample would contain the expressed idea. In our design discussions there remained this tendency to think about how to get 'the right content' in the audio recording. However, over the course of iteration 1 we realized that ultimately this leads to a requirement that the system should 'know' when someone starts talking about an idea and when he is finished with it. But that would quickly lead us into fundamental problems of building an artificial intelligence, which was a direction we didn't want to pursue (Haselager, 1997). What began as a practical problem, revealed the more fundamental questions of 1) what it was exactly that should be stored in the audio in order for it to be supportive, and 2) what it was exactly that this audio should then be supportive of. We spoke about providing 'context', but the user feedback showed that not all audio-context is useful for recall. An embodied perspective suggests that the NOOT clip should be one element in a distributed system of people and other props, and the memory for any idea is to emerge from the interplay between all these factors. As Van der Hoven & Eggen (2008) state correctly: "augmented systems cannot [by themselves] store memories". But what, exactly, should the augmented system do, and what should be left over to the physical and social environment (cf Klemmer, 2006)? This was still an issue that warranted further investigation.

5.4. Conclusions to iteration 1

Iteration 1 is the first step towards the recognition that an 'idea', for example as generated in a brainstorm session, is not 'in' an expressive artifact, such as a sticky-note, even though in everyday practice we point to the sticky-note and refer to it as 'the idea'. Ultimately this move proves to be first step towards distinguishing between the distributed representation principle stating that 'insights' can be 'offloaded to the environment' (as in Norman, 2002) and a socially situated practice account, in which external representational artifacts do not store insights but instead help to coordinate the way insight emerges 'in action' as part of the a continuous process of interaction between people (Suchman, 2007; Heath & Luff, 2000; see chapters 2 and 7 for further theoretical analysis).

At this point in the design process the assumption was still that digital samples, when listening to them, provided missing information that helped one remembering the idea associated with the sticky-note. There was a bias into thinking primarily about how the digital audio could be a form of memory storage that could be used after the session, as an extra context to sticky-notes. Sticky-notes, seen as bad memory devices, were 'augmented' to help the reader to reconstruct the idea more easily. At the same time it was not at all clear that NOOT did in fact improve recall that way. Furthermore, in our discussions, a different line of thought was emerging: perhaps neither sticky-notes nor NOOT clips are storing ideas: perhaps all of these external artifacts in some way help to 'scaffold' the emergence of insight in the conversation itself. This concerned the question of how NOOT functions within the session: how creating and using a NOOT clip, perhaps in combination with sticky-notes or other conventional artifacts, would help the group in gaining insight.

Part of the continued focus on 'storing insights for later' was biased by practical constraints. Although the concept figured the possibility of live playback during the session, this function was not operational in the user study. The Wiz-of-Oz only allowed the possibility to store an audio sample, not listen to it immediately afterwards. Our evaluation study focused on whether people could still remember ideas two weeks later, while listening to the audio-samples sitting behind their pc or laptop. This meant it was hard to assess whether or how audio playback be useful within a session, or in any case within the same physical space that the session took place, with the actual NOOT clips still present in the room in their original configuration.

In summary, we still struggling between two scenario's of use: 1) using NOOT recordings 'later on', after the session had ended, providing a context that spurs recall 2) using NOOT as support for gaining insight into the design challenge, 'in' the session itself, a part of the concrete environmental structure that scaffolds the group's activity. Actually, these scenario's reflect two conceptualizations of what the audio-recordings, or any physical residual of a brainstorm, mean, namely: 1) 'the audio recordings contain the result – the end-point of a creative process, its 'outcome', versus 2) audio-recordings form an active, mediating object, situated in physical space by means of the tangible objects, which functions as new input, to the design process.

We decided that, if we want NOOT to be an explicit application of EC, the more promising direction would be to pursue the second scenario. This scenario challenged us more to find out how digital information could really become 'embodied', while the first scenario lies quite closely to a conventional information-processing model. The second scenario builds on the idea presented earlier of NOOT as a scaffold that 'bridges' past activities to current activities by means of technological mediation, rather than by 'representing' past insights in a digital format that can then be accessed later on. It would focus more on dynamics of interaction and how digital information becomes a meaningful element within situated activity in real-time. In order to focus most strongly on these topics, we decided for the next iteration to address primarily how NOOT would be used as a scaffold for insight within the session. For that, we needed a fully working prototype.

6. Second RTD iteration

6.1. Design of NOOT 2.0

Instead of first conducting further user-research and then ending this iteration with a second prototype, we started this iteration with design activities with the goal of creating a prototype that we could use to conduct a detailed qualitative observational study. The aim of that study was to investigate the appropriation of NOOT as part of how insight evolves within a session. Our interest was not so much in 'first-contact' experience, but rather in how NOOT, over time, becomes part of participants' embodied routine within the creative practice. All in all this meant the prototype had to afford live playback of audio in parallel to the recording functionality.

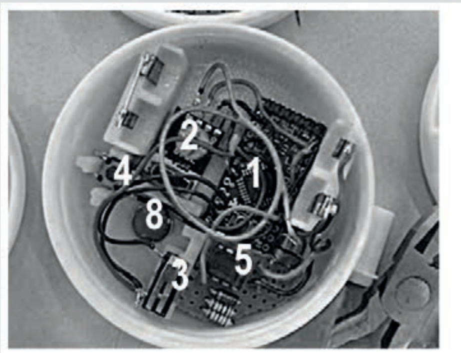


Figure 4.16. Technology of NOOT 2.0. [1] Arduino Mini (Arduino Mini [http://arduino.cc] [2] RF Link transmitter [3] Microswitch [4] Push button [5] Step-up circuit 1-3V to 3.5V [6] 2 AAA batteries [7] 3 Rapidly Prototyped ABS parts [7] Magnet [8]. Not shown: Central microphone hanging from the ceiling, centrally placed speakers, 1 unobtrusively placed PC.

In order to conduct the study, several practical adjustments first had to be made to the prototype in order to get audio playback to actually work in combination with a set of physical clips. The result, NOOT 2.0 (Figure 4.16), consists of a set of eight handy disks (d=10cm) that can be attached as clips to sticky-notes or paper sketches. We call these disks 'clips' from now on. Time markers are sent at the moment the paper is inserted into a special purpose slot to the side of the clip. Only one other interface element connecting to the digital system remained on the clip which was a button that, when pressed evoked playback of audio samples distributed over the built-in speaker system of Conceptspace.

Figure 4.17

Figure 4.18

Figure 4.17. RTD team member contextually interviewing the facilitator F.
Figure 4.18. NOOT clips used in context.

6.2. Studying the use of NOOT in practice

Using the new prototype we were able to conduct a qualitative study in order to study more in detail how NOOT clips can become part of an ongoing activity of developing insight during a creative session (Figure 4.18; Table 4.1. Study D1-2).

6.2.1. The data-set

The dataset consists of video of seven one-hour brainstorms figuring the prototype (sessions were not organized especially for this study) recorded with two unobtrusively placed remotely controlled cameras and microphone in Conceptspace, in May and June 2010. Five out of seven sessions figured one and the same student design project (with different design teams in each session). In this project, students of an interactive media course were asked to come up with a new online game concept for children between the ages of 6 and 12, in order to promote a visit to a nature park. In the analysis below these sessions will be referred to as 'the game sessions'. One session figured professionals in the media-business, and one session figured three product design students discussing a graduation project.

6.2.2. The participant-informant

Over the course of all sessions we observed and analyzed the behavior of the brainstorm participants and the facilitator. Apart from our observations, there was one key-figure that provided a first-person perspective on the practice in a way comparable to a participant informant in ethnographical research (Spradley, 1979). This was one of the facilitators in Conceptspace, who agreed to try out the new prototype in seven sessions lead by him. We held contextual interviews with the facilitator in between sessions (Figure 4.17). We were able to follow his own evolving relation with the tool for a significant amount of time, that is, over all sessions. The transformation of experiences and behavioral routines of this one facilitator over all seven session forms the main source of information for analyzing how NOOT becomes appropriated, beyond its 'first contact' effect, in a real-world context of practice. Being in close contact with the facilitator enabled us to investigate the practice 'from within', as seen through the eyes of a key-participant. The drawback of course is that the insights gained cannot be easily generalized. In the analysis we compared and related the facilitator's personal perspectives and ideas with our own, 'design-oriented' observations of the group's behavior.

6.2.3. Data analysis method

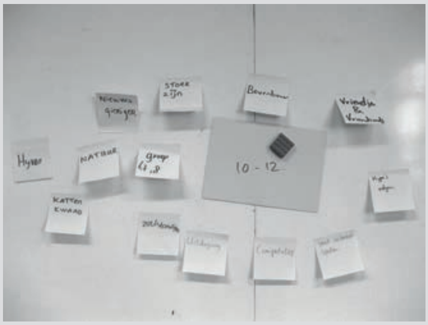
After each session two investigators each analyzed the video recording, the expressive artifacts created in the session, and the contextual interview, searching inductively for common patterns and themes. In three synthesizing sessions the two researchers discussed their findings and in each of these sessions iteratively refined a growing set of themes and relations emerging from the data as summarized in a mind-map. Many meaningful patterns were discerned in behavior (routines, problems, strategies, significant events). Some patterns dealt with the way NOOT was used. Other patterns dealt with meaningful aspects of the brainstorm while NOOT was not used (but perhaps could have been)[8]. We contrasted our behavioral observations with both the facilitators' own verbal account, as well as with our original design concept. After session 4 we made an explicit intervention by discussing part of our analysis with the facilitator himself. More on this intervention is explained in section 6.3.1 below.

6.3. Findings

We first discuss our findings regarding the role of conventional sticky-notes in brainstorms. Against the background of these findings we will then discuss what we observed regarding the use of NOOT.

6.3.1. Distributed representation scaffolding understanding

We saw evidence for the idea that external artifacts like sticky-notes provide cognitive scaffolds (Clark, 1997) used as an aid for developing a shared understanding of the design challenge (Heineman & Mitchel, 2010). For example, in one of the game sessions two colored cards were placed on the whiteboard, one with the text '6-9' on the left-side of the wall, and one with the text '10-12', on the right side (See figures 4.19 and 4.20). These cards represented two potential age groups of users. The facilitator points at each card in turn while saying:



Figures 4.19 (left) and 4.20 (right): clusters of sticky-notes. Details of analysis in text.

Episode 1

F "On the right {point} you have grade seven and eight [According to the Dutch primary school system], on the left {point, hanging arm} you have grade ..."

[Several participants together fill in]

PP "...group 2,3 and 4" {muddled talk}.

F "That's about lower half {point} upper half {point} one could say, right?" [referring to the first half and second half of the primary school period].

F puts forward a distinction between two relevant age groups, and understanding this distinction is scaffolded by the spatial separation of, and F's pointing at, the two cards. Next, the space surrounding the cards become two collection 'zones' for sticky-notes associated with these age-groups. But these zones also continue to function as physical scaffolds representing the two groups whenever people talk about the groups and the distinction between them. Participants routinely point or wave to either zone using deictic terms like 'them' or 'they' in speaking about the age-groups.

6.3.2. Meaning is created in a social negotiation

As we can already see in the example above, external representations do not simply mean what they mean based on their form alone. The meaning of the two age-group cards is co-constructed by the group, in talk and action. In other words, fixing meaning of a scaffold is the outcome of a social negotiation between users. This often involves asking and answering questions, while physically dealing with the scaffold (holding it, pointing at it, writing on it, and so on). A question about what to write down, even if one is already quite sure about the answer to the question, is an implicit check on whether the other agrees that this item should be written. For example, in the episode below participant P has a sticky-note before him on a table and hovers his pen, ready to start writing, when he asks:

Figure 4.21. Negotiating what should be written on a sticky-note

Episode 2 (Figure 4.21)

P: *"which grades are those again you know (this) right?"*

A: *"grade six [ehm...]"*

P *"grade six"*

....[P starts writing]

By giving the answer that P was expecting, A confirms that this should be written. The initial question can also be more open-ended and then participants subsequently negotiate whether the answer should be written. Nonverbal interaction and social norms influence the outcome of this process. For example, in this episode a question was asked about what one did as a kid. Participant D says:

Episode 3

D: "kattekwaad uithalen"

doing monkey business

[several people laugh]

F: "ja goeie schrijf op"

yes good one write down

D provides his idea after a long stretch of silence and structures his answer as something not really serious, in a low pitch and volume. The non-seriousness is confirmed by laughter. However, overlapping this laughter, the facilitator overrules the implicit suggestion by the group to discard the answer by saying: 'yes, good one, write down'.

6.3.3. Sticky-notes do not themselves carry intended meaning

Often enough, a sticky-note that is already written, may still be subject to different interpretations. As we have already seen, this is a direct result of the fact that sticky-notes are by themselves unable to completely and accurately represent the socially situated meanings they support. Consider this episode:

Episode 4

W: "Little children like animals more than the older ones do"

F: "Good. Write that down"

[Some reaction ('protest') by other members of the group]

S: "Perhaps 10-12 year olds also"?

Follows a discussion where finally the group settles on a difference between 'liking family farm animals' (associated with the 6-9 age group) and 'being a nature fan such as in the boy-scouts' (associated with the 10-12 age-group). By way of conclusion, W puts a sticky-note with 'nature' in the 10-12 space, while B writes one with 'animal farm' and puts it in the 6-9 space. Then G, apparently having missed asks of W:

Episode 4 (continued)

G: "Huh? Now you put it the wrong way around" {surprised, People laugh}

W: "No. He (points at B) is doing 'animal farm'".

G: "O. But what about 'nature' then?"

W: "That was, like 'animal farm', and the other one, like, 'forest'."

W's phrasing of words, especially in the last sentence, implicitly assumes that G is able to 'fill in' the short-hand talk based on the two sticky-notes referred to, but since G missed the discussion, the sticky-notes make no sense to him and W's explanation only causes more confusion.
Potential misunderstanding 'covered up' by the external representation. Consider this example:

Episode 5

P: "It seems to me that those children of 10 to 12 would also be interested in information,

that is, they want to know why things happen and how things ... that is, they want explanations."

O: "They are more curious?"

P: "Yes, they are more curious"

F: "Good point, write it down"

P [writes down 'curious' on a sticky-note]

We see how P explains something in his own words, which gets relabeled by O and affirmed strongly by F. The tone of voice of P in affirming O's suggestion, however, is hesitant, and it is unclear what each member in this conversation thinks the resulting sticky-note means. In such cases, the sticky-note does not help people to align with one another towards a shared meaning, but instead it potentially 'covers up' an unsettled dispute. It now 'seems' as if shared understanding is accomplished (the 'physical evidence' is on the wall) where in fact, it isn't.

6.3.4. Situated meaning that does not necessarily involve sticky-notes

On many occasions the writing of a sticky-note is preceded by, or followed by, a long stretch of rich, insightful discussion, involving meaning that has little or no relation with using the sticky note. For example, the writing of the word 'monkey-business' (Episode 3), spurred further associations of participants' own childhood, during which no visible reference or action towards the sticky-note is made. Personal memories are recalled, jokes are made and the group proceeds to discuss children's emotions, and whether children are sensitive to 'trends' and 'hypes'. The phrase 'feelings of anxiety' is uttered – but not written down. In the context of the design challenge (design a children's game) this is meaningful talk, as the game-designers seem to connect to the target group on a personal, experiential level. But precisely because the conversation has lost its artificial 'shout-out the next idea' format, nothing of it gets written down. People are so engaged that they forget to make notes or perhaps they even believe it would be inappropriate to do so.

The conclusion of this detailed analysis of the role of sticky-notes in brainstorm sessions is that what gets written on the sticky-note is only meaningful relative to in situ social interactions between people. Moreover, not everything that is meaningful or useful ends up on a sticky-note. This analysis provided the background against which we revisited the NOOT design concept.

6.3.5. Using NOOT: The basic routine

Over the course of seven sessions, a certain routine of using NOOT emerged as displayed by facilitator F (Figure 4.22). The basic interaction with the tangible object did not present difficulties. F evolved a smoothly executed routine. The two main phases are Marking the Moment and Playback, each with their own sub-routines:

Marking the Moment (Figure 4.22)

Opportunity for marking.	F steps back from the process and observes (listens to) the conversation. An opportunity for using NOOT arises.
Prepare to mark.	F walks over to where clips are located, grabs one and a sheet of empty paper (A5). F waits with both items in hand and listens, or walks back to the group activity and waits there.
Marking the moment.	F puts the paper in the clip at a carefully chosen moment.

Playback (See Figure 4.25, below)

Playback opportunity.	F approaches used clips when participants are involved in activity.
Activating playback.	F presses the replay button. (there seems to be no relation with the current conversation of the participants)
Listening.	Participants listen to the playback as a group, or they would continue with their (own) conversation while the audio is played.
Acknowledgement.	After playback ends, the group acknowledges this with a reaction. Sometimes one refers to the content. Sometimes only acknowledgement, such as “Hey, I heard Bob”.

Figure 4.22. The basic routine making a mark (details in text)

Importantly, F does not attach a clip to an existing sticky but uses a NOOT directly to 'catch' a piece of conversation, using an empty paper purely to activate NOOT. Inserting a paper involves some conscious attention: F would always for a brief moment look down to what he was doing (figure 4.22, 'mark'). Only in second instance is the paper used for writing a text functioning as a label to distinguish one clip from the others. That is: in contrast to our original design concept, paper labels provide an additional context to the audio-trace, instead of the other way around. F would always be actively listening to what people were saying in order to sense an upcoming opportunity for marking, while standing outside of the immediate action. F placed NOOTs either on the whiteboard, together with existing sticky-notes, or in egocentrically in reference to his own position, for example in a lay-out before him on the table. In later sessions he became quite creative in that latter form of positioning, creating his own 'interface' of clips before him (figure 4.23).

6.4. Reflections on iteration 2

6.4.1. The appropriation process

It is important to emphasize here that the final NOOT routine did not evolve all by itself, but was in fact mediated by an explicit intervention by de design team, during the situated interviews. In particular 'what' it was that F tried to 'grab' with the NOOT interaction, changed after our intervention. The intervention was itself informed by our observations of what we saw happening in the practice. That is: we saw particular patterns in use, which we labeled and then presented back to F as inspiration. In that sense the final conception of NOOT is neither something we as designers 'envisioned' and defined NOOT to be, nor something we passively observed as being the case, in terms of 'what users apparently were using the thing for' (cf. Dourish, 2001). Instead, it was a co-constructed mix of both. We now turn to discussing how the final conception of NOOT emerged as mediated by the conversations we had with F.

In the first briefing we asked F to reflect on how to use NOOT. His verbal response in this initial briefing was in line with our explanation, i.e. as an 'extra context' to sticky-notes or sketches, so he appeared to have understood the instruction. However, F explained NOOT to participants as something to store 'an idea' in. That conceptual shift is perhaps understandable given that such an interpretation maps quite easily onto known technologies, such as memo-recorders. Yet, F would not use NOOT literally as a memo-recorder, (i.e. he would not ask people to literally 'tell the idea in the NOOT'. He did try to catch, as he said, the 'core of an idea' from a participant's natural speech. This proved to be a challenge, costing effort and also frustration. Especially the 20 seconds time-frame cause him to be afraid that 'the right information' would be missed:

F: "You're constantly thinking about the timing, that 10 seconds before and after [marking], it sounds really short but it really is quite a long sample, but you are wondering, did I record it or not?"

Apparently, the current prototype, regardless of our briefing, still causes the interpretation we cared to avoid: a kind of memo-recorder in which to 'store' ideas.

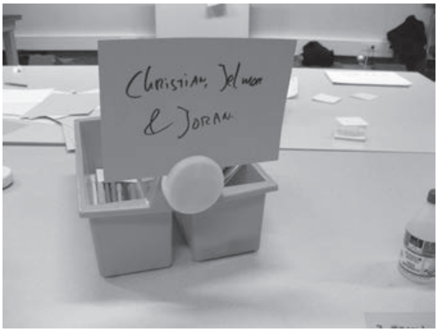


Figure 4.23

Figure 4.24

Figure 4.23. Creative forms of 'positioning'

Figure 4.24. Physical materials used in the confrontation interview (Translation: "atmosphere, core, chaos, inspiration, reminder, phases, role of NOOT in process, who uses NOOT, timing use")

This meant, for us, something needed to change in the design. We wanted NOOT to become meaningfully coupled to what really goes on in actual user practices – but we also wanted to avoid the information-processing interpretation of the tool, which is also a part of how people currently think and act in such practices. So we needed to find a way to go beyond a storage-device interpretation and look of elements within the practice that connected to principles of EC. As a start we tried to understand a bit more in detail why the facilitator has a different view than we, as designers had. F had some explicit ideas on what NOOT was. He stayed pretty much focused on trying to get the device to do something that it actually wasn't very suitable for: recording specific episodes of talk in which 'an idea' was uttered. From his point of view, this meant that the device was actually not working 'properly'. We see various reasons why this mismatch arose and continued to exist:

1. The fact that something could be recorded already evokes metaphorical associations at the conscious level concerning related devices like the memo-recorder. That is: current society is laden with 'storage' metaphors and the technology to support it. It is hard to break through this 'cultural bias'. Perhaps there an explicit training phase could have counter-acted these implicit assumptions based on the cultural bias, although this would have created an artificial situation rather than the naturally occurring brainstorms we had chosen to observe.
2. The design concept stating that NOOT couples to existing sticky-notes may be troublesome: since people consciously speak about sticky-notes as 'storage media' for ideas (even if they in actuality function more as cognitive scaffolds for interpersonal communication), this conception will carry over to a device that is presented as an 'extension' of the sticky-note.
3. F's main focus, as a brainstorm facilitator, is on what are called 'the results', which are the ideas created and represented in some format (e.g. a sticky-note). Ideas are seen as objects that need to be created and then saved for later use. Available media are readily used for that purpose, be it sticky-notes, or NOOT-clips.
4. As facilitator, F's immediate concern is always time: how much time do we have left and what to do with it. This made him particularly conscious of the existence of a 20 seconds sample and what one 'could catch' within this time span.

This collection of biases, I suggest, leads F to conceive of NOOT within a more 'classical', information-processing interpretation. After session four, it seemed that this situation was not going to change. F expressed worries about the usefulness of the tool as it was so difficult for him to 'catch ideas', which means his interaction with the device was not satisfactory in his own experience. At the same time just using the device did not lead him to explore completely new opportunities for use. So, to try and move beyond this status quo, we decided to make an intervention to see whether we could seduce F into going beyond the current, not-satisfactory routine of use.

As researchers observing actual in situ behavior, we had seen various situations in actual brainstorm sessions that could potentially be supported by the use of NOOT, but in fact weren't. We confronted F with his interpretation of NOOT and offered in response a number of these situations we had observed in his own practice, that might contain potential for using NOOT in different ways that to 'catch ideas'. (See figure 4.24). We took care not to fix on a particular theme, nor did we already interpret the situations into 'desired functions' for NOOT: we just presented F with situations of his own brainstorm sessions, and suggested NOOT might be useful in it in some way. After this confrontation, F changed gears. In the following sessions, he evolved a smooth routine as discussed above (Figure 4.22).

6.4.2. The final role of NOOT within the practice

In the final brainstorm sessions, the facilitator used NOOT to 'mark interesting moments of conversation', rather than to capture the 'an idea as verbally expressed'. This change (relative to the early sessions) can is actually reflected in the way F introduces NOOT to the participants. This explanation involved a subtle shift towards 'marking a moment' instead of 'recording and idea'. E.g. in session 2, F said:

F: "At the moment you say something very interesting, you don't want to lose that point, so you can call it back. You're able to say, hey, I just said something brilliant we need to get that back for a moment, and so you grab the NOOT, if you really don't want to forget something, you grab one"

In the final session he introduced NOOT as follows:

F: "So it records everything we say, and whenever we mark a moment it catches the moment 10 seconds back in time. So if you say I want to record what we say here because this is really some insight we could use or this is something I just want to listen to again later on, put the paper in, and the fragment gets stored".

In the first explanation, focus is on 'something brilliant' that needs to be stored for later. 'You don't want to lose 'it''. Also F speaks about an individual person using NOOT, and the framing is in terms of memory. In the second explanation, F more openly describes what the system does, focus is more on that one may want to use the recording later on, and the framing is in terms of the group value, not the individual memory function: "I want to record what we say here". This shift in NOOT's function was reflected in his behavior more clearly than in his talk. A typical Opportunity for Marking in the first brainstorm session was this:

Setting: Three participants brainstorm about their new to-be-created company that will sell a special kind of bikes. They are in search of a particular kind of market and brand identity for the bikes.

F *[standing at the whiteboard asks S3, pointing at a sticky-note]*

"And that market, would you like to focus on all markets, or only the housing market, and why that one in particular?"

S1, *[interrupting] "I think it would be cool to..."*

F *[quickly takes a NOOT and a piece of paper]*

S1 *"...look a bit into that market"*

F *[clips a paper into NOOT and walks back to the table with the participants]*

S1 *"... well, you have now the public-transport bike and some companies have their own bikes"*

F *[writes down words on the post-it while P1 is talking]*

S1 *"...that you can borrow when you have an appointment"*

Here F creates a 'conversational slot' for a NOOT recording by asking a question and then attempts to grasp the concrete idea that is offered in response ("I think it would be cool to..."). In contrast, in session six a typical Opportunity for Marking would be quite different. In this episode a group discusses kinds of games they liked as kids. The age difference between the two target groups is further marked out using certain games as a reference point.

W *First marbles came, then Flippo's*

P *I never did Flippo's*

W *Not? O come on! Well, you took secondary education, so that figures*

[Implying P is younger than W, who went through a longer route of technical education]

P *Yeah, you guy's are Generation Flippo! [Laughs]*

F *"What did you do yourself when you were at that age?"*

S *"I played with marbles"*

[Laughing]

G *"I was really the Flippo guy*

[More laughing]

After this, the group gets into an associative flow. The general theme is on kinds of play they used to like as kids. As the conversation starts to fly, F grabs a NOOT-clip, listens for a bit, and then 'marks a moment' in the middle of the lively conversation.

6.4.3. Who uses NOOT?

Even though F explained in each session to the participants what NOOT was and that they were free to use it, most of them didn't. In every session there was at least one participant creating a NOOT marking or activating playback one or two times. Apparently it takes time – more than one single session – to get used to using NOOT. A new tool like NOOT may be just 'too much' to handle if one is also fully concerned with the design case and the brainstorm activity (which for many of the participants involved lot's of new information as well). In the short interviews we had with participants after each session it was stated that they liked the idea, but also that it was a 'strange new thing' that they didn't feel like just picking up and trying it in the middle of a session. Meanwhile, we found that F was experimenting with the tool in various ways, but by trying it out mostly for himself. This suggests that for F, NOOT is seen first as a personal annotation tool.

6.4.4. What is the immediate effect of using NOOT?

In relation to the foregoing, we have observed at least three different roles that people implicitly and informally adopt in a brainstorm conversation: one can be a speaker, an active listener (the addressee), and one can be a third party listener or by-stander. Speaker and listener are engaged in a conversation that involves turn taking, such as asking and answering questions (Schegloff, 1991). However, there are also participants that temporarily take the role of a bystander. In this position one tries to make sense of what other people are discussing but is not actively involved in it. The facilitator, based on his formal role and task, often took on this role. But from time to time other participants switch between any of the three roles, and F also on numerous occasions took active part in the conversation (perhaps somewhat against the usual convention in brainstorm facilitation). We may expect this mixing of roles to apply even stronger to ad hoc sessions that involve no formal structure and roles at all, such as informal design meetings with professionals. Now what we observed is that F would come to use NOOT precisely in conjunction with moving into the bystander mode, stepping outside of the conversation. This is different from our original idea of NOOT.

Based on the observations, I suggest that by taking a clip in hand, one becomes a reflective listener, a by-stander, rather than an active contributor. Taking the clip in hand creates a reflective focus. One becomes sensitive to upcoming opportunities for making a 'good mark'. Marking the moment effectively means stepping out of the process 'for a moment', and making a reflective statement about what one experiences is going on. This also means that our initial idea of creating a time-mark in an unobtrusive way, activated automatically as a kind of 'by-effect' of writing a regular sticky-note, is false. Preparing to mark (by taking a clip in hand) creates a conscious, intentional awareness. This awareness, moreover, involves anticipation towards the upcoming moment worthwhile of marking, rather than that one grabbing the clip only after something 'important' has already happened[9].

6.4.5. Playback

F tried out playback several times in each session, but much less so than creating markings. F decided at 'sudden' moments, during the ongoing conversation, to activate playback. The audio coming over the central speakers caused curiosity and some excitement by the participants, and most participants stopped whatever they were doing to listen to the audio. However, the audio also seemed to intrude rather than connect to the ongoing activity. Sometimes it even caused annoyance, and we observed people 'waiting', silently, until the sample was done, so as to be able to continue their own conversation. Clearly, audio-playback is presently not usefully integrated with the practice, other than as an element of 'surprise'.

Figure 4.25. Playback

6.4.6. Shared reflection

The ego-centric positioning of NOOT clips further supports the view that a NOOT in the space is not simply an audio version of a sticky-note containing general information for all members, but functions instead as a personal scaffold that belongs to somebody: The clip refers not just to the conversation time-tagged in the audio, but also to the person that created the mark: it says "I find this relevant". Yet while NOOT clips are initially personal objects, people also see each other activating a clip, and so this action becomes socially accountable: I see you 'marking this moment', which may trigger in me a reflective thought as well ('what do I think 'this moment' is really all about?). In session seven, the facilitator accidently made something of this accountability visible to us. He had first given NOOTs to participants, asking them to try them out. Immediately when the session proper started, a participant grabbed a NOOT clipped a piece of paper in it. F reacted a bit surprised, saying:

F: "Aha, you already know the important moments?"

[F now sees what the participant is writing and apparently understands the participant's line of thought, as he then says:]

F: "Aha, now I see...yes".

6.5. Challenges for iteration 3

Although the observations of NOOT revealed important insights, there were also numerous problems that turned up. These issues posed further design questions, which were taken up in the third and final iteration.

6.5.1. Audio playback

The most serious problem we saw in the present prototype involved audio-playback. The activity of marking, we saw, presents a moment of personal reflection on ongoing activity, socially accountable for others. This may be useful in its own right, creating a shared sense of awareness. But this leaves unsettled whether and how actual playback of the digital audio is useful as well. Fusing in audio-playback into the conversation proved no trivial task. Playback was not strongly integrated in the further activities of the participants, or even inhibiting. As the facilitator states, it takes time to appreciate what audio can do:

F: *"The learning process of NOOT takes some time, only after three sessions I understood what clever moments [for playback] were. You need to know the effect of your recording."*

We offer two reasons why audio-playback remains troublesome. Firstly, the system did not invite 'experimenting with'. Apart from the design of the NOOT clip discussed earlier, audio was centrally played from the speakers. Activating playback quickly becomes an obtrusive act people will hesitate in performing, not wanting to disturb other participants. There was no way to play around with the audio without directly disturbing others as well. This is important especially since the function of NOOT is not readily appreciated just by explaining it: one needs to have some first-hand experience into what the effect of listening to the samples is and what it may bring you. Secondly, an audio-sample is not simply 'information', ready for pick-up by anyone exposed to it. Any particular speech-sample is an object that may be used as part of a conversational structure, but without this structure it is meaningless. For instance, 'turn taking' is a very important pattern people use to stay tuned to what's going on. Just activating audio-playback in the middle of an ongoing conversation means one is effectively breaking into the conversation rather than joining it – people cannot listen to two speakers at once. Likewise, there are certain suitable moments that a listener can 'hook on to' talk, e.g. at the beginning of a sentence, or when the topic changes. However, playback of audio starts 10 seconds before the time-tag, regardless of the audio-content, and it can be that this onset happens to be very confusing. In such cases it takes considerable time in order to be able to 'tune into' what is actually being said. The current design of NOOT enforces these almost random clashes of past and present speech much more than that it enables people to use the clips of past moments to join in and have it impact the present conversation in a smooth way. This is why playback is the aspect of the product that we think most strongly needs attention in the next iteration.

6.5.2. How to get people experimenting with NOOT and learning it's effect through using it

We saw many occasions where one or two participants for a moment stepped back from the immediate action, listening to the others. These provide potential moments for using NOOT, and using NOOT in turn may help people to become more aware of these implicit moments of reflection, and help them to share these moments with others. Presently however, there are only eight NOOT clips available, and each of them was fairly large, which causes them to be perceived as a special kind of object that one does not readily take up and use. This inhibited participants to just try out and explore the tool, in order to experience 'what it is like to mark a moment'. One of the goals for the next iteration became to redesign the system such that the set of NOOT clips would become much more 'approachable', inviting exploration and playing around with. NOOT clips should be approached in the same way as sticky-notes and whiteboard markers: cheap, discardable objects one picks up for use within the flow of whatever it is one is doing. A related issue is the sense of ownership: since NOOT turned out to be supporting personal scaffolds ("my moments"), the clips lying around on the central table in the space may not have been perceived by participants as 'free for use' (even though F had told them they were).

7. Third RTD iteration

7.1. Design orientation

We decided to disconnect the time-marking action from the action of linking the clip to a sticky-note. The focus should be on marking a moment, which is not intrinsically connected to other physical elements, such as sticky-notes, other than the person doing it. Marking the moment consists of three phases: anticipating a marking (stepping outside of the process and taking a reflective stance) the marking, and only then, the positioning in a physical context. Apart from clipping it to a sticky-note or sketch, one should be able to attach NOOT to anything, anywhere in the space, as long as it seems meaningful to the user.

This biggest challenge, as said, is playback. We wanted to encourage people to experiment actively with the system and find out its value through experience. So playback should perhaps be local, such that every person can experiment with playback for himself without disturbing others. Playback could be on the NOOT, or via a separate tangible (an 'ear'), or perhaps in a particular corner of the space. At the same time it would be interesting to have at least the possibility of central playback, whenever the situation asks for it. In this way we aim for playback to become a naturally integrated act, or sequence of acts, in a conversation between people.

People will playback audio from earlier moments within the situation of 'the current' moment of the session. We wanted to support a process of being able to 'tune into' the audio recording and provide some control over the playback function, in order to enable them to give meaning the audio, relative to what is going on in the current situation.

In sum, we decided to make substantial changes based on the following premises:

1. Taking a clip means 'marking a moment'. The clip functions as a physical link, not to a 'sample', but to one time-point in the entire audio recording.
2. Marking a moment is a short moment of reflection created by a passive listener to an ongoing conversation.
3. The system provides a large amount of small clips available at all times (comparable to whiteboard magnets or markers or sticky-notes), inviting use.
4. It should be possible for individuals to 'experiment' with playback in unobtrusively, that is, without others being disturbed, just as one can gloss over the writings on the wall wit hout disturbing other people.

7.2. The final concept: NOOT 3.0[10]

Figure 4.26. The final NOOT system. From left to right: the playback horn, a clip attached to a sticky-note, clips presented on a dispenser, laptop with NOOT software and wireless connection to dispenser and horn. Physical product design in collaboration with Van Berlo.

In the previous prototype, clips were very large and expensive due to the technology inside. We decided to take out all technology, leaving only a small RFID tag for identification, and a magnet. This way we could create many clips for a low price. This however meant we had to create two new devices: a 'dispenser tray' which provided the 'audio time tagging' functionality and an audio-playback device, both connected wirelessly to the central computer (Figure 4.26). Taking a clip from the tray causes the time-tag to be placed in the audio (Figure 4.27). The linkage to time-points instead of samples means each tangible clip is no longer connected to one specific audio sample. Instead, each clip is now but one of several tangible 'entry-points' to the complete audio stream. The user may enter the stream through each physical clip (each 'marked moment') and go through the audio as needed with respect to the current situation. Holding the playback horn close to a clip causes it to start playing the audio from the time-tag onwards, in 'individual listening mode' (figure 4.28).

To encourage exploring the audio and getting a feel for it, the playback device has a large wheel on top that allows scrolling back and forth. When one has found 'that one bit' one was looking for (or any other interesting bit that makes sense), one may ask the attention of other participants and push a button, which activates a 'play out loud' mode. When one scrolls to a certain point, after one stops playback (with the large button on top of the horn) the clip will remain linked to the new timepoint (while the software also stores all old time-points as well).

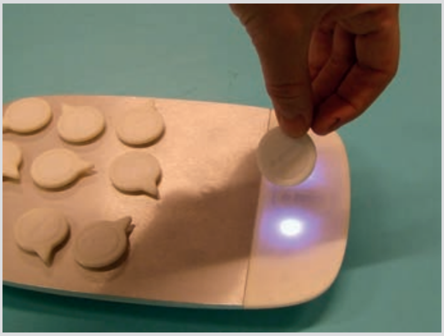


Figure 4.27

Figure 4.28

Figure 4.27. Activating a time-mark by taking a clip of the dispenser (RFID detection).

Figure 4.28. Activating playback via horn (RFID detection inside horn)

In effect, the network of tangible clips connects the present situation (i.e. a group people in the creative space engaged in a brainstorm now) to the history of all earlier instances of that same session, in the form of a recorded audio. Participants are therefore able to share and compare various instances of the conversation across the time dimension, providing reflective insight into the way the brainstorm evolved, how each of them found meaning in particular moments of the session, and thereby creating a deeper, shared insight into the design challenge.

The publicly available clips make individual, short-lived moments of reflection (ones that would normally pass by unrecorded) 'actionable' as scaffolds in the physical environment, just as sticky-notes do for concrete 'ideas'. One may say "listen to this", activate an interesting part of the earlier conversation, and say: "I thought was an interesting part, perhaps we should do something with it", even without being explicit about what it is that is interesting about it: that latter question now becomes part of the socially negotiated meaning in the conversation itself, and thereby a group insight shared by the participants. This makes individual reflective moments accountable and open to social sharing.

7.3. Reflection on the third iteration

The third iteration was focused on translating as best as possible the conceptualization that had emerged from the second iteration into a final design, which also formed the end-point of this case-study. A full evaluation of the final prototype in user actual practice awaits further investigation. However, we did present the prototype as a demo on a conference and we explored its use in several brainstorm sessions in an ad hoc fashion (Figure 4.29). I now give some final reflections on the third prototype before we go on to the final discussion of the NOOT study as a whole.

7.3.1. The influence of the prototype

The large physical objects of the first and second iteration got in the way of a conceptualization of NOOT as a system of dispersed small 'entry-points' in the physical space. Once we had solved the problem of how to create many small clips that had an omnipresent, 'dispensable' character (comparable to, say, whiteboard magnets or felt-markers) we could really start implementing the vision that had been arising in the reflections on iteration 2.

7.3.2. Making a mark and the dispenser tray

Activating a time-marker by taking a clip from the tray was not a direct translation of the routine that F had displayed in the second iteration, which was first to take a clip in hand, then to step back and only then 'make a good mark'. The tray itself is perhaps not the ideal form: it hosts only a limited number of clips, and once these are used the tray has to be refilled with 'fresh clips'. Earlier design explorations considered also a 'bowl' form from which clips could be taken. We were not able to prototype such a bowl but it may be a good alternative. Furthermore, the effect of using a 'grab from tray' action depends on where one places the tray. In our ad hoc evaluations the tray was placed centrally on the main table, also in order to elicit the use of the device by all participants. The result is that 'making a mark' is even more a publicly visible event than it was in the second iteration: This public event elicits questioning and conversation: why did you just make a mark? However, it can also be perceived as obtrusive: not every participant may be up for such a confrontation at all times.

Figure 4.29. Top left: Noot 3.0 in action, with dispenser and tray placed centrally in the creative space. Top right: NOOT clip used to annotate a whiteboard mind-map. Top left, Clip used to annotate a physical mock-up. Bottom right, two clips attached to the same paper artifact. As one can see the artifact is modified to 'label' the clip on the left with text and arrow.

7.3.3. Flexible positioning

Secondly, according to the vision put forward at the end of the second iteration, it the clips afforded quite naturally to be placed not only on sticky-notes or other annotated materials, but also in various other contexts in the space, such as on physical mock-ups (see figure 3.29). One further aspect of this flexibility in use was that multiple clips could be placed in association with one physical object (figure 3.29, bottom right) which means that one 'tagged moment' is not reserved for one particular physical trace, such as one particular sticky-note.

7.3.4. Relistening has its own value apart from making the mark

A final aspect worthwhile mentioning is that listening back to audio has a separate function from making the mark itself. Listening back to the audio, scrolling through it, and finding a bit of audio that 'makes sense' in the context of what one is doing now, is a new reflective, sense-making process in its own right. It has some relation to the reflective process that caused one to make the initial mark for that clip, because one hears the audio of that previous event. But the mapping is not a straightforward 'going back to the earlier moment': it depends very much on the current circumstances how that 'moment from the past' gives meaning to the sense-making effort of the 'current moment'.

8. General discussion

The present design exercise provided a first exploration of ways of applying EMBODIED COGNITION THEORY to the design of interactive systems. In this discussion I describe how the evolution of NOOT informs a re-conceptualization of the role of interactive systems in the embodied cognitive process of creating shared insight in creative meetings.

The evolution of NOOT over three iterations touched upon all the three variations of EC theory discussed in chapter 2: we have seen aspects of *distributed representation and computation*, of *socially situated practices*, and of *sensorimotor coupling*. In fact, the NOOT project ran in parallel with the emerging insight *that* these three variations of EC can be distinguished. Furthermore, the evolution of NOOT coincides with a gradual move away from a distributed representation and computation perspective, towards a stronger focus on social situatedness and sensorimotor coupling instead.

8.1. Discussion of the design-oriented research questions

RQ 1. How may we design interactive systems in support of embodied cognition?

RQ 1.1. How does embodied cognition inform designing the relation between the digital process and physical form of the interactive system?

A number of aspects of NOOT illustrate how the meaning of the designed forms of the system arises in the interaction, and is not predefined by the designer.

8.1.1. No predefined form-to-meaning mapping

First of all, the clips had no physical form with predefined 'meanings'. NOOT clips evolved to become just 'dots', linking pins between moments of audio and practically anything suitable of the physical structure in the space. Instead of the designer defining how the physical form of this dot links to digital meaning, people create their own meaning for the digital audio in relation to how the physical clips are used in action, as part of the conversation. What we therefore spent time on instead is thinking how recording and playback of digital audio could become a meaningful aspect of the temporal patterns of sensorimotor interaction of the participants in the meeting space. For instance, playing audio over central speakers if someone pressed a NOOT-clip turned out to disturb rather than add to the conversation, as it did not fit the natural way a conversation unfolds in a group. The audio-horn, with a private and public mode, enabled the recorded speech to become more naturally integrated with the way people were interacting. In all, the physical form of the NOOT system is based primarily on what one can do with it, and not on a symbolic mapping from a form to digital 'content'.

8.1.2. Manipulation of tangibles is not a representation of a digital process

Secondly, the way people then create spatial organizations of clips in the space is not, at least not necessarily, meant to be an explicit representation of anything. Of course one could, if one wanted, use NOOT clips create an explicit 'representation' of e.g. a timeline, positioning all clips from left to right on the wall 'in order of appearance'. In general the system offers much more freedom; all kinds of ad hoc, local, idiosyncratic ways of spatially organizing clips are possible. Users can therefore create their own particular ways of using the system in much more ambiguous ways that are not always easily mapped on clearly definable representational content. For example, one may position audio-moments (by way of the physical clip) on a prototype that was being discussed at that moment, or on the sketch that was referred to at that moment, 'somewhere' in a mind-map drawn on the whiteboard, in front of oneself on the table ("here are my moments"), or in the physical corner of the room where people where having the discussion that the clip connects to, or even right onto the person that was speaking (see figure 4.29).

8.1.3. Digital content only attains meaning in subsequent use

Thirdly, the digital content, that is, the audio recording, is also not a clearly defined 'something' that is digitally stored and linked to the physical clip. Taking a NOOT means creating a mini-moment of reflection, in which one acknowledges: 'I find this moment interesting, I might want to revisit it later and think some more about it.' Yet, at the moment that one makes the mark, one is not yet able to explicitly describe what it is one is actually 'marking', only that it seems worthwhile to do so. During playback, the clip provides just one entry-point to the entire session. It is assumed that one needs a bit of scrolling back and forth in order for (re)making sense of what one is listening to. This involves not so much 'finding the right part' but rather creating some 'feel' of what it is one is listening to, that is, attuning to the audio such that one forms a sensorimotor coupling to it. Finally, the audio will be played back within a new context that is the current conversation: apparently somebody said something that made somebody decide to play from a certain clip. This context implies that in some sense it can never be defined on beforehand what sense people will make out of listening to a NOOT-clip of past talk, as this will be determined in reference to what they are presently talking about in the here and now[11].

8.1.4. Beyond the storage device: rejecting the external representation bias

RQ 1.2. How does embodied cognition inform designing for the way in which the interactive system at large connects to people's real-world, embodied and situated practices?

From the start, we intended to augment, rather than replace, the physical and social space and its capacity for scaffolding cognitive processes (Klemmer et al, 2006). We cared to avoid a situation in which working with the digital tool would mean to become experientially 'detached' from the actual physical and social interactions as they unfold in the physical space. In general, we cared to avoid system designs that would immediately block the existing creative flow and group motivation. In the first iteration, the fact that so little of what was being said got 'stored' in the physical record of sticky-notes quickly lead us to abandon ideas like a "digital sticky-note" or "interactive whiteboards". The first concept however still retained something of a 'storage device': saving 'important bits' of the conversation for later, which was also how users and facilitators will usually talk about NOOT. When introduced to the concept, it is easy to think of NOOT as a kind of memo-recorder, in which to 'store good ideas'.

At that point, we could have pursued such a direction explicitly, in which one would try to find out how the external environment could better function as an external memory then it does now. We could have asked questions like: what makes for a reliable external memory? How may people search and retrieve in an external memory? How can a technological system help people to store, search and retrieve in an external memory? This would be a direction quite in line with a conventional usage of information systems, and it would also correspond to principles of distributed representation and computation.

8.2. Discussing the theory-oriented research questions

RQ 2. How does (the practical attempt at) designing interactive systems supporting shared insight in creative meetings, inform the theory of embodied cognition?

RQ 2.1. What is the role is of 'external representations' in the embodied cognitive process?

8.2.1. How observations of practice informed conceptualization

However, in our observations of how the prototype of NOOT was used in practice we saw different things happening. We saw many moments in the session that were not annotated at all: moments of heated discussion or enthusiastic creative flow. We saw how grabbing a physical NOOT clip in hand is a sensorimotor reorientation that changes the way a person listens to the conversation, and how inserting a piece of paper became a reflective statement that says "I find this part of the conversation interesting". This was a line of thought that puts the cognitive process right where it should be, according to more radical variations of EC theory: in the concrete and in action. It was the option that more strongly positioned NOOT as a concept based on embodied cognition.

8.2.2. How properties of the system informed conceptualization

Thinking about live playback during a session, instead of afterwards, was our next step away from seeing digital technology as a means for the 'storage' of the 'results' of the thought process in a session, towards thinking about how recording technology could actually support the ongoing cognitive process as it was happening. And the step after that was to acknowledge that NOOT functions as its own kind of scaffold, instead of enhancing the scaffolding power of existing sticky-notes. We turned to principles of socially situated practices, in which a cognitive scaffold is not so much an external storage of an individual insight, but can only take on meaning in the way it functionally mediates the negotiation of meaning between people. With regard to audio playback, people need to 'tune into' what it is they are listening to, and let the speech sample of the past become meaningfully coupled to what it is they are engaged with in the here and now. Merleau-Ponty's notion of 'optimal grip' (Merleau-Ponty, 1963; Dreyfus, 2002) may be an apt way of describing precisely this attunement.

8.2.3. Reconceptualization of cognitive practice and the role of NOOT in it

In all, the design challenge evolved from thinking about ways to 'store brainstorm ideas in the physical structure of the environment', towards creating ways by which digital audio-traces of past events could become integrated into current events, both in terms of the social interaction as well as in terms of the sensorimotor loops involved.

As we saw in iteration 2, in his final routine, facilitator F did not try to capture one particular 'idea' in audio but instead 'a rich moment' of conversation. This 'moment' is not just the content of what is being said, but the whole moment: it is 'whatever is happening right here right now', and how that is experienced by the participant as 'something I should hold on to', even if one cannot precisely put into words what is meaningful about it. These moments largely go by unnoticed for the group as a whole, unless someone immediately breaks into the conversation, stops the talk, and share his experience with the group. Even then, the people that were actively engaged in the conversation would not be able to listen back to their own talk as it just happened in the way that the reflective listener experienced it. NOOT offers a way of sharing that reflective moment with the group, mapping individual 'reflection-in-action' moments to a shared process of 'reflection-on-action' by the group as a whole (cf. Schon, 1983).

Reflection-in-action: Taking a clip in hand helps the participant in a session to start listening reflectively to what is being said, in search of a 'good mark'.
Reflection-on-action: at a later moment, when the situation affords it, the visible availability of existing NOOT-clips in the space invites one to take up the audio-playback device and share his moment with the team.

8.2.4. The difference between sticky ideas and marked moments

One of the main insights that emerged from this study is that there is a difference between either using artifacts like sticky-notes to literally 'store' a full-blown insight in a representational format, or to use them as scaffolds that 'keep active' an emergent insight within the ongoing interaction between people in the space. Instead of trying to find ways to more accurately describe and store insights in external representations, we tried to provide for an 'embodied' and 'situated' form of memory by expanding the scaffolding capacity of the creative space in 'keeping active' important 'moments' within the conversation itself.

The physical NOOT clips map the temporal domain of recorded audio (the history of what has been discussed so far) onto the spatial scene in the here-and-now (the environment that can be perceived and acted upon; Figure 4.29). This can be seen as a form of memory, but it is not a description of 'something' that can then be retrieved, rather than being a direct 'link' to a particular moment in the past, which enables feeding back past moments into the current conversation that is taking place in the here and now.

Furthermore, because marked moments are 'actionable' in the shared, scaffolding space, they become taken up in the way that people collaboratively form insight. The idea of the final concept is that people first go back to one of their moments, relive it by scrolling back and forth until it makes sense *in the current context*, then share it with others, explaining what they were thinking, asking questions of others about it, and so on, all in the context of the discussion that is taking place in the here and now.

The theory of DRC, in which both sticky-notes as NOOT's audio-clips would be seen as a way of 'storing insights' into the environment as physical, 'external representations', is therefore too narrow a theory to fully explain how these external artifacts help to create insight in the creative session. Instead, NOOT-clips, and likewise, conventional sticky-notes or sketches, are perhaps better seen first and foremost as 'traces of an insight generating activity'. Such traces may then come to be taken up as 'scaffolding' elements in further insight generating *activities* that are both driven by sensorimotor couplings as well as being socially situated. Although we need to explore further how this works out exactly, the present study indicates that such 'scaffolding traces' are not *purely* 'external representations' of full-blown insights generated earlier and then 'stored' into the artifact (see also Clancey, 1997; Suchman, 2007; Goodwin, 2000).

RQ 2.2. What is the relation between the social situatedness and the physical embodiment of cognition (interacting with the physical environment)?

Building on the previous section we can say that on the one hand, the idea of 'scaffolding traces' corresponds to a Socially Situated Practice view (chapter 2) in which artifacts mediate collaborative sensemaking between people. On the other hand, there is also a relation to sensorimotor coupling that is however not always explicitly addressed in comparable 'collaborative work' systems. For example, consider again Geyer et al's (2012) multi-touch system or the Arias' EDC environment (Arias et al, 2000; see section 3). In these systems it is acknowledged and emphasized that the system functions within a *social context* where people interact with each other face to face and create meaning collaboratively. This makes these designers already rethink the role of computational systems in terms of socially situated forms of cognition. (Geyer et al, 2012; Arias et al, 2000). However, if we then look at what the interactive tool actually supports in action, we see that *the system as such* essentially it is still an information system storing intermediary outcomes of the creative process as external representations. The information system functions as situated in a social context, but in terms of its interactive properties it still remains a fairly conventional information system for storage and display10.

Instead, in NOOT, a series of bodily interactions: marking the moment, positioning the clip in space, listening privately to the audio, offering it to other participants, creates an individual *sensorimotor loop* that grounds a moment of reflection 'in action' (Schön, 1983). At the same time this loop is publicly visible to the other members of the group, since it involves interactions with hand-sized objects (the dispenser, the tray, the clips) in a shared space. This means that the individual reflection-in-action becomes socially accountable as well (Dourish, 2001, p.79): I see you 'marking this moment', which may cause me to have a moment of reflection as well: 'What might be interesting about this moment?' Even if I have forgotten about one of 'my clips', someone else holding the playback device may stumble upon it, play it, and then ask who tagged that clip and why.

9. Concluding remarks: towards scaffolding traces

NOOT provides a first indication of how concrete bodily interaction with the system can be inherently part of the way the system grounds reflection-in-action and furthermore how this initial sensorimotor coupling then further relates to socially situated practices. In terms of EC theory this hints towards a more radical conception of EC that goes beyond the information-processing interpretation of DRC.

Two outcomes of the present study will resurface in a second design case, which will be the topic of the next two chapters (chapters 5 and 6). The first element involves the cyclic nature of using 'scaffolding traces' as part of sensorimotor coupling: people both create external artifacts and later on use these same external artifacts, often in series of interactions, adapting, elaborating and recombining them on each occasion, in service of 'getting a grip' on the situation (Schön, 1983, Dreyfus, 2002). In the next chapter, we explicitly call these artifacts *'traces'* to guide the design in this direction.

NOOT presents also first indication of how principles of socially situated practices (Suchman, 2007; Dourish, 2001) might be connected to this sensorimotor coupling, as scaffolded by traces. NOOT displays one way in which individual reflection moments become part of the socially situated negotiation of meaning (DeJaegher & DiPaolo, 2007)[13]. In my embodied interactions with the NOOT clips, I show that I am experiencing a moment of reflection, and later on we can all literally 'point to' that 'moment of reflection' together (i.e. by pointing to the physical clip), and use this shared action to further align our mutual perspectives.

These two themes: how one couplings in cycles of interaction to external traces, and how these couplings are part of a larger social setting, are explored further in a second design project that takes the insights of NOOT as a starting point.

As NOOT focused mostly on *the creation* of an 'actionable', physical trace of a reflection moment, in the following chapter focus will be on what actually happens with these 'traces', once they are created and become part of further activities of people in the space. One further goal is to ground even more firmly the ideas that have emerged so far in actual, real-world 'creative meeting' practices, 'outside the lab'. Theoretically, the goal is to find out how principles of sensorimotor coupling and those of Socially Situated Practices can be understood even more explicitly and fully as one phenomenon in terms of the concrete interactions between the user and an interactive system.

1 This sketch was taken from one of our own design meetings, figuring myself and colleague R. van der Lugt. In the figure one can see that at that point, the concept of NOOT had already emerged and was being discussed in relation to theory and the PhD project. The flip-chart was full of crucial, important insights relating to the project, but we couldn't make much sense of it the next time around. Apart from the disappointment, it turned out to be an illustration supporting the very idea of NOOT.

2 These two visual examples may lead one to wonder whether the problem described only holds for images and not for text. It is clear that important differences exist between the representational capacity and structure of images and those of text, investigated at length in the cognitive science literature and various theories on language and semantics (See e.g. Van der Lugt, 2005, comparing text and sketch in the context of design meetings). However, even concerning written statements, e.g. on sticky-notes, which are usually single words or short catch phrases, the problem addressed here may occur: i.e., that the meaning of a physical representation is lost or transformed once taken outside the physical and social context in which (and for which) it was first created: "the significance of artefacts and actions, and the methods by which their significance is conveyed, have an essential relationship to their particular, concrete circumstances." (Suchman, 2007). Contrasting the specific semantic and mnemonic differences between text and images are beyond the scope of the present study.

3 www.livescribe.com, www.anoto.com

4 In relation to the present design concept, we became aware of the existence of the Livescribe pen only when we had presented our first concept (NOOT 1.0). The idea behind the pen contains many commonalities with the initial NOOT concept. NOOT however has always been designed to be an integrated part of a physical space in which a group of people collaborates, while the Livescribe pen is geared towards individual annotation.

5 Iteration 1 lasted one year: the first six months included a student project by a multidisciplinary team of 7 bachelor students from various design/engineering fields. Of this team Janneke Sluijs remained collaborating with me in the context of a bachelor's thesis in Human Technology. Iteration 2 lasted six months. The team consisted of masters' student Marnick Menting, Industrial Design Eindhoven, and myself. Iteration 3 lasted six months: The team consisted of bachelor student human technology Jirka van der Roest and masters student Edouard Messager (Design, University of Compiegne), situated as an intern at Van Berlo design company, and myself.

6 External stakeholders involved in the development of NOOT were:
Iteration 1 and 2: Creativity Company. A company that organizes and facilitates brainstorms for commercial clients Iteration 3: Van Berlo design, a large Dutch product design company: http://www.vanberlo.nl/ I further thank Martijn van de Wiel, Arjan Klinkenberg, Jens Gijbels and Rineke Brouwer, for valuable contributions to the ideas and insights developed in this chapter.

7 NOOT in Dutch means 'note', as well as 'nut', as in 'in a nutshell'.

8 Part of the analysis below is based on a conversation analysis (Schegloff, 1991) of a raw 10-minute cut from one of the videos (Brouwer & Van Dijk, 2011; Table 4.1., D2). With thanks to Rineke Brouwer.

9 It is the case that the facilitator grabs a clip in reaction to something someone is saying, but that particular part is not itself 'marked', F waits for a 'good moment' and then presses the button. So the initial conversational trigger that leads him to grab a NOOT is not the same event as the subsequent part of the conversation that is experienced as 'the moment' that needs to be marked.

10 A scenario of NOOT figuring the fully functional prototype is found here: http://www.youtube.com/watch?v=XzZoq-5dJnE

11 Interestingly, the way people make sense of past moments within the current context, using NOOT, has similarities to theories on brain and memory, which propose that memory for events is never truly 'stored in' and then 'retrieved from' the brain. Rather, memory is always in someway 'reconstructed' on every occasion that it resurfaces in consciousness, subject to change and reinterpretation in the light of current circumstances, while at the same time the very the activity of remembering itself immediately transforms the memory trace in the brain as well (Loftus & Hoffman, 1989)

12 It can for instance be argued that the main 'social' function of the multi-touch tables in both these systems is that they are tables around which people can stand and collaborate, as with normal tables. Outcomes of earlier activities are publicly available on that table. These outcomes as such are still pretty much conceived of as digital representations of an outcome what people have understood together. Moreover, the interactivity of the system itself is not designed in explicit reference to the process of sensorimotor coupling, sustained through continuous bodily interaction with the world. In that sense these systems stay within the interpretation of EC as primarily a Socially Situated Practice.

13 In fact, the NOOT study was responsible for highlighting once again the idea that embodied cognition needs both sensorimotor coupling and social situatedness, which tends to be obscured if both these processes are reduced to forms of distributed computation and representation (as in Clark, 1997).

5.

In the Middle of Things
Co-Designing Interactive Traces Supporting Shared Insight

"I stand, therefore I am. Without a 'standpoint', one is nowhere." [1]

(Jules Deelder)

1. Introduction

1.1. Traces for shared insight

Moving into the third iteration of NOOT (see chapter 4), our guiding question had transformed from designing a distributed form of memory, into asking how interaction with the system supports publicly visible individual reflection moments. Furthermore, the audio-traces associated with individual moments of reflection could be fused back as 'scaffolds' into the conversation at a later point in time. Conceptually, NOOT connects to Schön's idea of reflection-in-action (Schön, 1983), which relates to cognition through sensorimotor coupling[2]. It also relates to principles of Socially Situated Practices, describing how people use publicly available scaffolds to coordinate shared insight in action (Suchman, 2007, Heath & Luff, 2000).

The notion of 'traces' proved to be particularly helpful. That is, in the later phases of the NOOT project, we had started to talk about NOOT as a system by means of which people leave traces of their ongoing sense-making processes in the environment. These traces were the time-points in the audio-recording associated with a physical clip in the space. By means of the physical trace, a 'moment of reflection' that had happened in the past, could re-enter the conversation at a later point in time, as the physical clips would become part of the overall environment that coordinates the collaborative activity of people involved in a practice.

1.2. Using traces

The first of the theory-oriented Research Question was this:

RQ 2.1. What is the role is of 'external representations' in the embodied cognitive process?

Proposing to move beyond a distributed representation and computation perspective, I introduced the notion of 'scaffolding traces' at the end of chapter 4, to replace that of 'external representations'.

The NOOT study can be seen as an implementation of this idea of 'scaffolding traces'. However, it did not reveal in much detail how such traces, when first created, would later be actively used again further on in the session. Most of the analysis of NOOT focused on how a trace is *created* (activating a NOOT-clip and positioning it in the space). Chapter 4 showed that the creation of a trace (marking a moment) is *already* a sense-making event in its own right, as taking a clip in hand puts the user into a 'reflective mode' (cf Schön, 1983) and marking a moment is public and thereby 'accountable' in the social context (Dourish, 2001).

The present study, however, investigates more thoroughly what 'happens next': what happens with traces once they are created and become part of the creative space, and how are these traces then used as scaffolds in embodied cognitive interactions in a creative meeting, in support of shared insight? With this orientation in mind I formulate the following general design question as a starting point for this case-study:

"How can we use *traces* in the environment to stimulate *shared insight*"?

In answering this question I also intend to shed further light on the second theory-oriented Research Question:

RQ 2.2. What is the relation between the Socially Situated Practices and Sensorimotor Coupling?

1.3. Connecting EC theory to real-world practices

One reason that NOOT did not give all the information we needed in regard to the question of how 'traces' (the NOOT clips) are used subsequently in the session is that it proved hard to get NOOT appropriated in the actual, real-world practice of people engaged in a creative meeting, it took a number of sessions to evolve a workable routine, and many participants hesitated exploring the system to the fullest (See chapter 4). A further aim of the present study is therefore to ground even more firmly the design process in close contact with actual, real-world 'creative meeting' practices, 'outside the lab', connecting as good as possible to existing work routines, the physical setting and the props used in todays' practice, while at the same time making sure that the concepts of EC theory are applied. In this we try to get more clear on the following research question:

RQ 1.2. How does embodied cognition inform designing for the way in which the interactive system at large connects to people's real-world, embodied and situated practices?

1.4. Exploring the visual domain

A second reason that NOOT did not fully integrate with people's practices may have to do with the special characteristics of audio, which is an interaction modality that demands full attention, especially concerning speech (see chapter 4). Although the idea was to connect NOOT clips to visual artifacts like sketches and sticky-notes, we had not really explored the question of how the visual modality itself could be made more interactive using technology. That is why we decided to explore the visual domain in relation to people's sensorimotor couplings processes. The aim here is to give further insight into research question 2.2:

2.2. How does embodied cognition inform designing the relation between the digital process and physical form of the interactive system?

By way of further introduction to the present study I first discuss in some more detail the idea of 'scaffolding traces', both in terms of EC theory and as a first design exploration.

2. Exploring the idea of 'scaffolding traces'

2.1. Inspiration from EC theory: stigmergy

The notion of traces is partly inspired by a biological phenomenon called *stigmergy* (Theraulaz & Bonnabeau, 1999). Stigmergy describes how animals leave physical markers in the environment as a natural consequence of their actions, upon which these same markers come to play a crucial role in the further coordination of the very same behaviors that produce them[4]. On the basis of this feedback relation with the physical environment, eve 'simple' animals like insects may collectively develop highly structured, functional behavior in complex environments (e.g. developing a trail from the nest to a food source), while the neural resources of each individual animal would not be capable of dealing with such complexity. Andy Clark discusses stigmergy as an embodied cognitive strategy, not only for ants, but also for humans, enabling coordinated, goal-directed behavior without the need for heavy 'internal processing' (Clark, 1997).

The idea relates to what Kirsh called 'epistemic actions': actions that reorganize the environment such that subsequent coordination of action becomes less cognitively demanding (Kirsh & Maglio, 1994). However, while Kirsh distinguishes between epistemic- and purely goal-directed actions, stigmergic traces seem to hold aspects of both: the trail formed by an animal walking in the forest may at first be purely a by-effect of a goal-directed action (accidently breaking a leaf, flattening the grass in walking) *and* at the same time later on come to function as a coordinating, 'epistemic' structure *for* action (animals following the path formed by the broken leaves). One way we may conceive of it is that stigmergic traces create 'physical history': In a case where two actions taken by a person would be disconnected from each other in time such that the first event does not directly influence the second, the first action taken may in fact influence the second action if it would leave a trace that functions as a bias on the second action even when the first action itself has long since ended. Traces make this happen without the need for internal memory of past events: Actions taken in the past come to guide actions taken later, with physical traces in the environment as a mediating structure. Most importantly, over time, this process may display self-organizing properties: once a second animal follows the trail of the first, it will also break leaves, which causes the path to widen, which will invite even more animals to follow the path, and so on. The self-organizing property of the feedback loop relates closely to the idea of *sensorimotor couplings* that behavioral systems may form in continuous interaction with the environment (Beer, 2000; Kelso, 1995). In fact, robots based on sensorimotor coupling theory sometimes quite operate by leaving and picking up on stigmergic traces (Holland and Melhuish, 2000)

2.1.1. Socially situated artifacts

At first sight, it may appear awkward to map the idea of stigmergic traces to the kinds of artifacts we have been investigating so far, namely, representational artifacts such as the sticky-notes. Representational artifacts are usually seen as media that may carry 'content' which can be send from one person to another person as part of human communication in a language. At the same time, we have already seen that being physical objects in the space, they also play a role in the way people directly and 'in the situation' may coordinate their social interactions (Suchman, 2007; Heath & Luff, 2000, see chapter 2)[5]. It is to this aspect of artifacts that we may connect the idea of traces. In the context of a creative session, such artifacts can be seen to play less of a role as explicit representations of generated insights. Instead, the physical traces that people produce in action play an active part as an element present in the environment that scaffolds the way people interact with one another. As we saw in NOOT this means it is not so much the digital content stored in the system (the audio content), which determines what 'the insight' is and how it develops. Instead, the clip and its associated time-point enable a 'sense-making activity', i.e., a conversation between people, which in this case creates a meaningful connection between what one of the team-members had experienced at an earlier moment, and how this may then be understood as relevant for the group as a whole, in the present context. It is in that reflective activity that the shared insight is to be found, as an aspect of the conversation itself, and not *in* the digital recording.

2.1.2. Shared insight

What do we mean with shared insight? A body of literature in the field of *design communication* investigates so-called barriers and enablers of *shared understanding* in creative teams (Kleinsmann et al, 2008; Maier et al, 2009; Sleeswijk-Visser et al, 2007; Bucciarelli, 1996). In general this work does not explicitly endorse an embodied cognition perspective. 'Sharing understanding' is ultimately seen as the information process of transferring some understanding in the head of one participant, either verbally or by means of external media, to that of another participant[6]. As a result less attention is paid to the role of the local physical setting, embodied activity, and the creation and use of traces as *part of the insight generating process itself*. Even so, there is some sympathy for the recognition that design artifacts may actively help to created shared understanding *'in action'*, connecting to (Schön, 1983). For instance, Crilly et al (2008) describe 1) the process of 'reflective representation', whereby designers get a grip on their design task by iteratively reflecting on the design representations they construct, and 2) the process of 'interactive interpretation', which describes the way users develop an understanding of a product through the experience of using it. Closely related to EC theory is the Scandinavian tradition of participatory design, which emphasized early on the contribution of collaborative activities and the influence of concrete circumstances and context on the development of a mutual understanding between designer and user (Schuler & Namioka, 1993; Ehn, 2011). Participatory design is by and large grounded in principles of social situatedness and action-centeredness (Koskinen et al, 2011; Binder, 2007; Ehn, 2011; Arias et al, 2000; Kaptelinin & Nardi, 2006). To conclude, in the present project, the term 'shared insight' refers not to an insight that someone first 'has' and then 'shares', but instead to the idea that insight is always an emergent property of a *shared activity.* People collaboratively 'make sense'. The interactive system, on that view, should is seen as an integrated element within that process.

In the remainder of this chapter I will first describe my research-through-design approach. After that the main findings are presented in a series of iterations. Each iteration ends with a round of reflection: how may we understand these findings, and what direction do we seem to be heading? After that the final prototype *FLOOR-IT* is discussed, along with user feedback on a Wizard of Oz prototype. I end with a general reflection concerning my research questions.

2.2. Design inspiration for traces

Next to a theoretical study we[7] also did a first design exploration of the notion of traces. This exploration revealed nine initial ideas (See appendix A for all nine ideas). To give one example, Thought Juggler, illustrated in figure 5.1, shows how sketches and text put on the whiteboard, the traces of a creative session will remain visible only if participants keep physically interacting with them. Unused traces will slowly disappear from view, or become smaller, etc. This idea shows how interactive technology may 'enhance' a sensorimotor coupling otherwise conventional traces on a whiteboard by demanding of the user an emphasis on the *action*-aspect of the coupling: one needs to actively *act* on the trace in order to keep it *visible*. This may then put a focus at the group-level to the traces that are most meaningful to the process, that is, the stuff that is really 'used' in the creative activities.

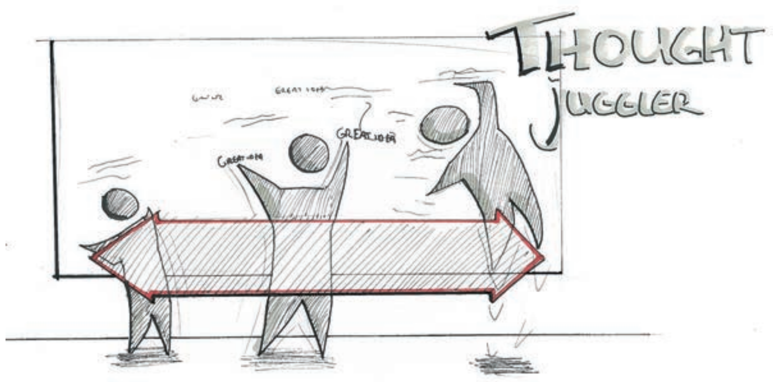


Figure 5.1 One of nine initial ideas, called "Thought Juggler", sketched by Gerrit Willem Vos. In this concept, sketches and text on the interactive whiteboard need active, physical engagement of the user in order to stay visible. Traces that are not 'cared for' by means of continued effort will slowly fade from view.

3. Approach

The general RTD approach taken here is explained in detail in chapter 3. As explained in that chapter, it aims to integrate top-down theoretical reflections, based on EC, and bottom-up insights concerning embodied action of people, as observed in the actual context of practice, through design. In the reflection sections below I discuss on how the design of the final concept, called FLOOR-IT, evolved, and how users and stakeholders interact with this and earlier prototypes leading up to it, and how these findings relate to EC theory.

3.1. Connecting to real-world practices

As said above we intended more strongly than in NOOT to design in close reference to actual practices as found in the real world, outside the laboratory. The opportunity to take part in an innovation project enabled us to involve a number of external companies and organizations into the design process, using a *co-design* approach[8] (Schuler & Namioka, 1993; Sleeswijk-Visser et al, 2007; Buur & Matthews, 2008; Ehn, 2008; 2011).

Of the twelve involved parties, three stakeholders collaborated most closely with us (See Appendix B). In these companies, creative sessions are either part of everyday work-routine (e.g. a product design company) or it provided their core business (e.g. a company that offered dedicated physical spaces and facilitation of creative sessions external clients)[9].

3.2. In Company Labs

These three stakeholders provided access to their own work-sites, where the to-be designed system was envisioned to become installed as part of the physical creative space. At these three sites we conducted one-week lasting co-design workshops we called *In Company Labs*. In each of these weeks, we actively involved company-employees in the design process, in their role as potential end-users of the system. In effect, the In Company Labs enabled us to develop concepts informed and inspired by 1) the physical setting of the work-site 2) the artifacts and materials used by people in their daily practice 3) organizational and cultural aspects of the work-site and 4) the behavioral routines and personal experiences and of the potential end-users (more on the details of these labs below).

3.3. Integration session

A strong focus on actual practices creates, at least for the time being, less focus on the theoretically inspired research questions. In the sessions at the site of practice, we intended to take an open, ethnographical perspective towards what ‘is really going on’ at these sites of practice, how people experience their own work, and what their ideas are for the use of interactive technology, refraining from a strong pre-conception based on theory (Holtzblatt & Jones, 1993). In the end, of course, the ideas coming from each of these three weeks needed be linked back to my research goals, in particular, to EC theory. To this end I organized a one-day design session involving expert designers and theorists. The concrete assignment in that session was to integrate three concepts resulting from the In Company Weeks into one coherent proposal. The underlying goal of that session was to integrate the practice-based ideas firmly to EC theory.

The resulting final concept is thus grounded in 1) collaborative activities at the site of practice involving users 2) design skills and 3) embodied cognition theory.

3.4. Overall process

The overall structure of the RTD process for this study visualized in figure 5.3. In the analysis we will focus on the three In Company Labs, the Integration session with experts, and an evaluation workshop where external stakeholders could reflect on the final concept by trying out and discussing a prototype. A full description of the procedure in the In Company Weeks is given in Appendix B.

3.5. Gathering and processing research-data

During all of the activities described above we made photographs of the general setting and context, of people's actions and interactions, and of the various artifacts created and used, either by users as part of their own work routines, or those created by ourselves (and/or users) as part of the (co-)design activities.

We took field-notes throughout the whole process, primarily using the Livescribe[10] pen to create notes and record audio at the same time, for example during interviews but also during casual events taking place at the work-site. These notes (Figure 5.2) were revisited and discussed between members of the design team over the course of the various activities and insights or ideas spurring from such reflections were immediately processed into new design explorations or decisions. This means we did not wait to start interpreting or summarizing our fieldnotes only after the whole process but directly fused them back into design action.

The analysis focuses on the way the design, and our understanding of it as designers, transformed from one phase to the next (see also chapter 3).

Figure 5.2. Fieldnotes made during the InCompany Labs coupled to audio-recordings.

3.6. Structure of this chapter

In what follows I describe in turn the three InCompany Labs, the expert design session and the evaluation workshop with stakeholders and the prototype of the final concept, called FLOOR-IT. For each In Company Week I first how we came to understand this work-sites' practice, combining insights coming from observations, personal interviews, as well as insights emerging from the co-design session on the first day . In some cases I will discuss a particular observation in more detail. After that, I discuss the evolution of the design concept for that week. I then discuss acting out the mock-up with users and how an artist generated from that a final concept scenario, which ends the section. After each design phase I briefly reflect on the insights gained so far. After that I present a general discussion relating the outcomes of this study back to the main Research Questions. Note that in the next chapter, an observational study is discussed separately, in which a follow-up prototype was created, implemented physically in Future Centre LEF (see In Company Lab 3, below) and based on the concept FLOOR-IT that resulted from the present study.

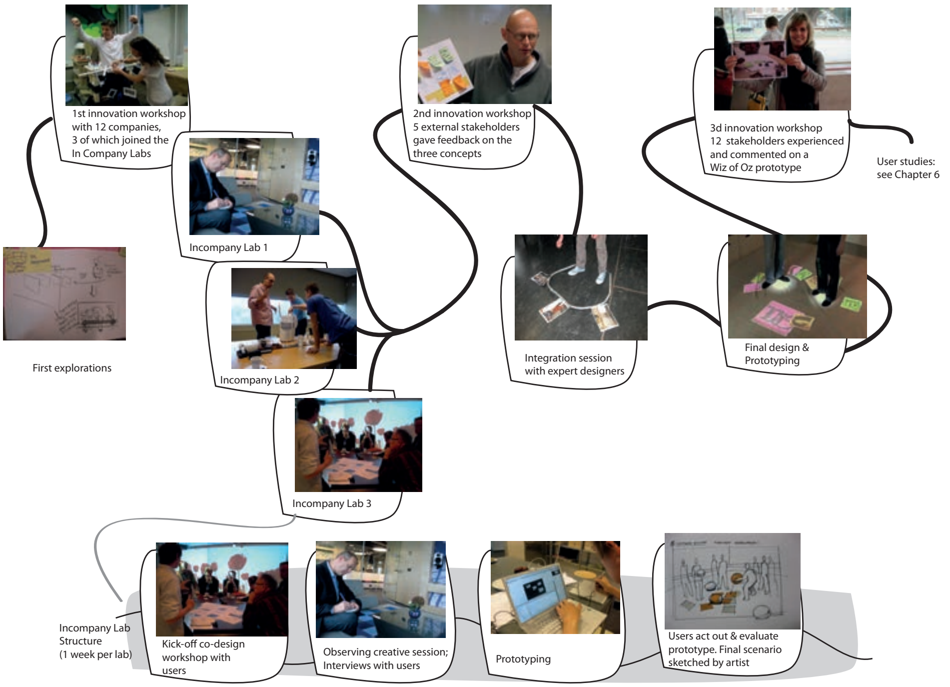


Figure 5.3. The overall research-through-design process for this study, with the structure of the In Company Week visualized in the bottom row

4. First In Company Lab. YOUMEET: A brainstorm facility

4.1. Physical and organizational context

YOUMEET is a brainstorm facility containing five dedicated spaces called catering the creative process. The company offers the physical space and facilitators if needed. It caters sessions up to thirty people. Each space has a dominant color and spatial organization which explicitly represents one phase a brainstorm process. For example, there is a space for introducing the problem, a space for idea generation, a space for selection and integration, and so on. Situated in a business park, the commercial context is clearly visible. Employees wear suits, the atmosphere reveals a strong vision on client-centered hospitality.

Figure 5.4. The central space at YOUMEET, catering plenary meetings as part of the creative session.

The central space at YOUMEET contain a large space for plenary meetings with large movable whiteboards (See Figure 5.4), flip-charts, sticky-notes, and poufs to sit on. Situated around this space we find other spaces containing such items as projection-screens, video- and audio facilities, work-tables, arts & crafts materials, whiteboard walls, desktop computers, interactive 'smart-boards', classical meeting tables and areas with comfortable chairs and coffee tables.

4.2. Observed activities and participant experiences

Facilitators explained to us that during group conversations they would often create on the fly models, for example a model describing the structure of a certain business process, drawn on the whiteboard or a flip-chart. This practice, involves pens and a physical surface, and ignores the use of interactive technology. In Figure 5.5 (Top Left) it can be seen that a large iMac is actually quite literally obstructs the routine, which was recognized and commented on as such by the facilitator himself. In Figure 5.5, bottom, one sees as well that sticky-notes are used separately from digital media like smart-board and iMacs. Traces of the session are found purely in the physical materials, not in the digital tools, the latter of which used primarily to search information on the web

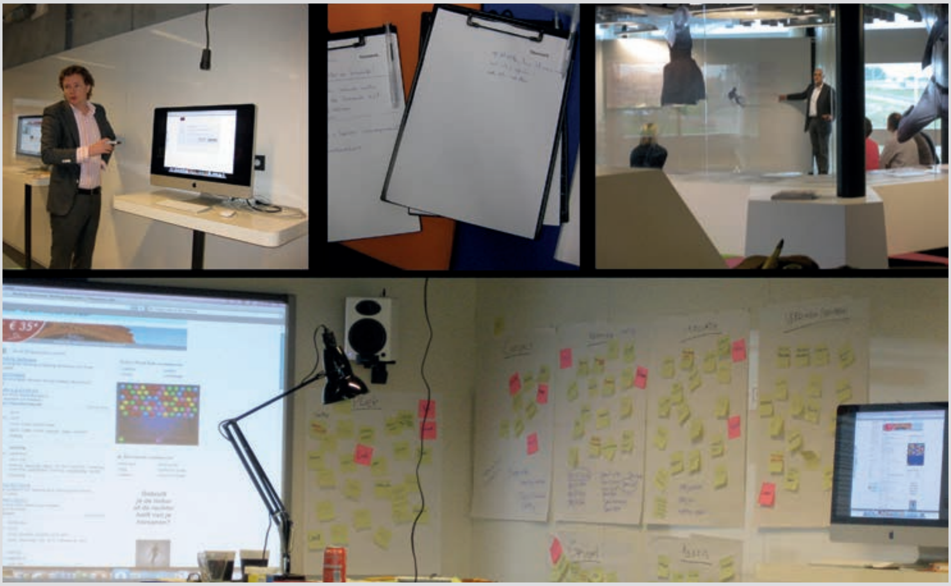


Figure 5.5 Top Left: Explaining and showing the routine of creating on the fly models on the whiteboard, while the computer is an obstruction. Top Middle: Note-pads used by participants in a session. Top Right: plenary discussion with one speaker standing and listeners sitting. Bottom: Pen and paper dominates the tools with which the results of a session are expressed in physical form. Interactive media are available but not often used (left: a 'smartboard', right, a desktop computer).

Given the set-up of the facility into separate, dedicated spaces, facilitators expressed the problem of how to 'get the results from one space to the next'. Related to this, in Figure 5.5 (Top Middle) we see examples of personal notes taken by individual participants, collected after the session. We see how notes were taken in the beginning of a session, while later on, presumably when the session 'started to fly', participants either forget or choose not to take notes: the bottom half of the note-pad is empty.

While part of the discussion was on how participants create annotations, all facilitators expressed the belief that ultimately the process is what really matters: whether people get socially aligned to one another, whether there is a good 'group spirit', whether everybody is involved and committee to the process. For example, one facilitator used the word 'back-benchers' to describe participants in plenary meetings that sit in the back and no longer actively participate. He worried: are these people still 'connected'? Facilitators expressed the need to have more insight into everything that is 'happening between people' in the subgroups, especially when the session involves many people. In this regard the spatial setting of the plenary meetings is of relevance. Here, usually one person presents 'the results' of previous sub-group activities, using the collected flip-charts and sticky-notes of those sub-group activities (Figure 5.5, Bottom) as a reference. (Figure 5.5, Top Right). Here we see a clear separation between the larger group of people passively sitting, listening, and just one or two people actively standing, adding to or reorganizing the collected materials. In fact, one facilitator described how handing out a felt-marker and inviting people to contribute to the whiteboard would get people involved: making a contribution to the physical record helps one to become more actively involved in the group discussion.

Figure 5.6. The 'serene' activity of photographing (left) and bundling (middle and right) all physical residuals of a session, after all participants have left the space.

After the session, when the participants themselves have already left, cleanup starts. Usually, the organizer and or the facilitator will first photograph and then physically collect all physical residuals. After the lively stir of a group of 30 people, this is in contrast a quiet, almost serene activity (Figure 5.6). One organizer expressed an ambiguity in what she was doing, stating she was collecting everything while at the same time predicting that she would 'probably never really use it again'.

4.3. The design of SNAP-THAT

One of the first ideas by the facilitators, based on their expressed need to have more insight into what people were actually talking about in subgroups, was a kind of dashboard on a tablet, on which relevant summaries would be projected of all 'topics discussed' and also an overview of the individual participants that apparently functioned as important 'social hubs', connecting to many other people within the group. Another early idea, building on the problem of how to transfer insights from one space to the next, was to have all text written on sticky-notes of each space end up on a continuous 'tickertape' running continuously through all spaces, presenting kind of general background context, so that all participants in all spaces can get a feel of what is happening in other spaces (Figure 5.7).

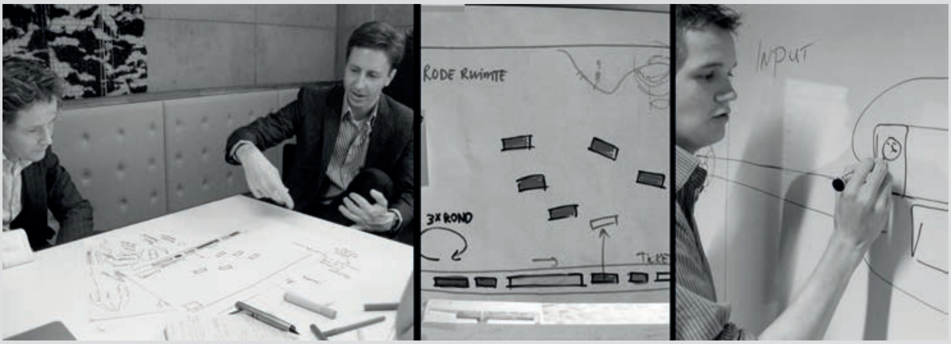


Figure 5.7. Co-designing with facilitators at the work-site: exploring the idea of a 'ticker-tape' of ideas running through all spaces.

Building further on such initial ideas and our growing understanding of current practice as described in the previous section, we created a basic scenario (Figure 5.8) and we focused design effort on the critical moment that a sub-group moves from an intimate sub-group activity, to a large plenary space.

Figure 5.8. The crucial moment in the scenario, as participants attempt to define the main conclusions of their activity, just before taking up their physical materials and moving on to join the plenary meeting in the next space. This picture was used to explain the scenario as introduction to the acting out activity (Original text in Dutch).

We speculated that individual people in sub-group activities create a personal attachment to particular sketches and sticky-notes, in particular, the ones that they have created themselves. This attachment is what generates meaning for these participants and what helps them aligning their personal perspective with the session as a whole. We then asked how we could make sure that such individual meanings, and hence, people's individual commitment, is not lost in a subsequent plenary meeting, when all sticky-notes are put on a large screen and individual participants are no longer actively working with the materials.

These questions lead to the final design proposal called SNAPTHAT (See figure 5.9 for initial explorations, and 5.11 further below for the final storyboard).

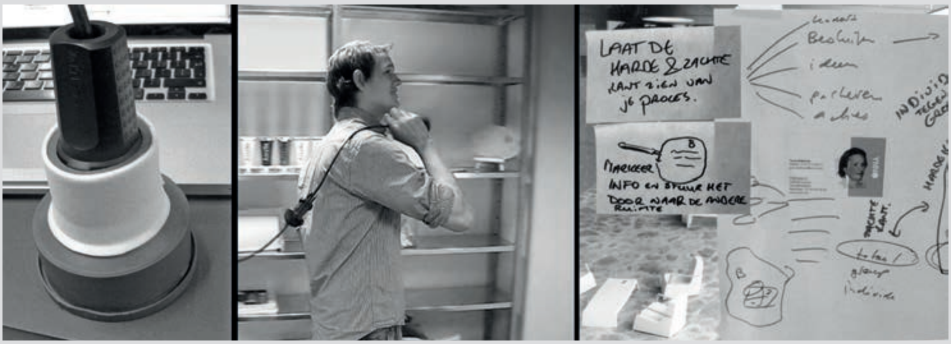


Figure 5.9. Exploring the idea of 'snapping' a trace, giving live comment on what the snapped image means to the user, and presenting these materials with people's pass-ports on an interactive screen.

The idea is as follows. As most of the spaces have interactive whiteboards we took these to be the main communication portals for transferring traces from one space to the next. To enable people to be recognized as active participants, traces are not recorded and presented 'automatically', as in the ticker-tape idea: participants themselves select the traces that will be transferred to the next space. At the end of a session, instead of just taking the physical flipchart to the next room, each participant grabs the 'snap-tool', which is located in each space, and creates snap-shots of one or two elements that are particularly meaningful to that person (e.g. an ad hoc model on the whiteboard, a relevant text on a sticky-note, an inspiring sketch). Upon snapping the image, the participant explains verbally to the group what s/he finds meaningful about it. The system stores a digital image of the trace along with a passport of the speaker, as well as the audio-recorded explanation. This collection of media is made available on the interactive screen of the next space (Figure 5.10, middle). By tapping the visual image, the recorded explanation is played over central speakers.

In effect the system connects the activity of personal involvement with the process, with the activity of transferring traces from one space to the next.

4.4. Acting out the prototype and finalizing the scenario

Figures 5.10 Left: Acting-out session with practitioners. Middle: Screen-shot of the interactive touch-screen, part of the mock-up, on which 'snapped' traces can be seen together with their personal passports. Right: initial storyboard sketches by the artist of the concept as acted out.

In a final acting-out with two facilitators, using a mock-up prototype (Figure 5.10) we collaboratively constructed a final interpretation of the concept, while the acting out was live sketched by an artist-designer. From this activity several conclusions and further questions emerged, such as:

1. The tool should enable people to combine images (and the associated passports) into clusters, by means of which the participants involved can express agreement: we are thinking the same thing.
2. What is the role of the facilitator? Perhaps he is no longer even present, and sits in a separate room, controlling the process from a distance?
3. Where does the process end? In what way is the final outcome of the session physically stored? Is the final result 'in the people', or 'on the whiteboard'?
4. What about feelings of shame and shyness: Will all people feel comfortable taking such a publicly visible role, with their personal ideas played over central speakers?

The final stage of making the concept concrete involved discussing the details of the storyboard with the artist. We mention just a few changes of the first sketches of the artist, as discussed for the final image.

5. In the first image, the user should be taking a picture of only one element, not of all created materials in the subgroup session. Focus is on one aspect of the materials that happens to be meaningful to that person.
6. The possibility of clustering is added, in the scenario, but only as the next step after people explain their own perspective to others.
7. The story ends with showing how the reconfiguration of items can also be 'snapped' with the tool, expressing the idea that developing shared insight essentially has no 'end-point' and can be reiterated, in theory, infinitely.

In figure 5.11 the final scenario of SNAP-THAT is visualized.

4.5. Reflections on In Company Lab 1

Our initial question was how to support the use of traces, in service of shared insight? We will now reflect on how our insights evolved over the first InCompany Week.

Initially, the YOUMEET study resembled the original focus of the NOOT study: rich insight is in danger of getting lost later on, since external representations do not capture such insight very well. The physical context of YOUMEET revealed this risk quite explicitly, as people continuously have to move from one space to the next.

The tablet 'dash-board' idea by the facilitators implicitly gives a view of the facilitator as a kind of central executive system, sitting behind the screens, being able to see and act on 'everything that happens' as it is detected, stored and neatly summarized into a handy overview by the computer systems. Such ideas, I suggest, align most closely with an information-processing perspective. At the same time facilitators also expressed that what they called the 'soft factors' are of equal importance, next to their need to record and store 'output'. This involves the question of whether people will become and stay connected to the process and as a group create a sense of shared commitment to its outcome. Connecting to principles of Socially Situated Practices, we therefore turned to investigating the way external scaffolds may work to support these 'soft factors'.

We saw a relation between the degree to which people are actively involved working with external materials, and the degree to which they feel personally committed to the process. Our design explorations contained two main aspects. The first aspect hinges on the 'physical' aspect of traces, and how re-presenting a trace which was created as a scaffold in one space, could help foster shared insight in another space as well. This relates to the early 'ticker-tape' idea. The other design direction focused on to the way in which traces function as personally meaningful objects that help to one connected and involved. This relates to the 'on the fly' created models in intimate sub-sessions, and the problem of the passive backbenchers in the plenary meetings. So, although we spoke a lot about how to prevent 'losing ideas' over the course of the session, in the end it really came down to the question of how to prevent 'losing the people' themselves.

In our final concept external 'traces' support the way people continuously and actively keep working with materials to align their respective views. This intermixing of social and physical interaction we will see again in the next lab, to which we turn now.

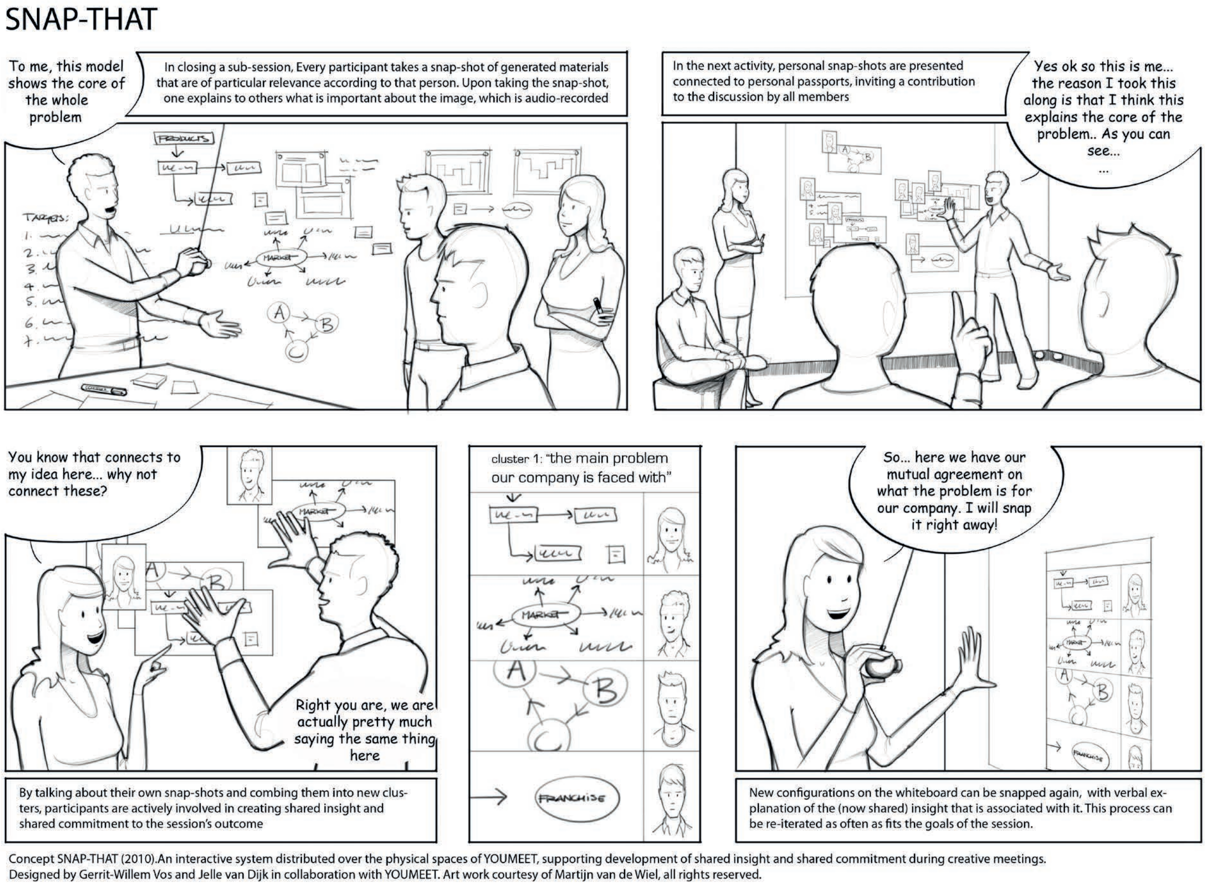


Figure 5.11. The final scenario of SNAP-THAT

5. Second In Company Lab. Van Berlo: A product design agency

5.1. Physical and organizational context

Van Berlo is one of the larger industrial product design companies in the Netherlands. We visited the bureau in Eindhoven, consisting of several floors of office space. On the main entrance floor, a number of meeting spaces are situated. These resemble quite conventional meeting spaces, each with a large meeting table, a magnetic wall, a whiteboard (smoked glass), and a projection screen for digital information and video.

Being involved in product designs for many external clients, the agency holds many patents and related 'company secrets', which makes it that the practice is not immediately 'open' in all its aspects for external visitors. There was an implicit boundary between the main floor, where the entrance and the canteen were situated, which was open to visitors, and the ground floor, which was were most designers were actually working on projects, with many of them working with digital visualization applications using drawing tablets and large desk-top screens. On the one hand, the organizational model seems to be flat, with no strong hierarchical structure. This is in line with the creative business: professionals have some freedom in using their creative minds and personal initiative to come up with the desired solutions for the challenges posed. On the other hand, the deadline pressure and external competition makes it so that there is goal-directed pressure from higher management to the work-floor, asking for new acquisitions and timely production of results. In our perception as visitors, practitioners in this setting need to continuously strike a balance between both these forces, for instance in deciding when and what to contribute in a creative session with clients, colleagues and superiors present.

5.2. Observed activities and participant experiences

5.2.1. Coordination of the conversation scaffolded by external representations and prototypes

Visual representations of design concepts or inspiration materials for the design are printed on paper and laid out on wall or table, or pinned to a large foam-board that could be saved for a next meeting or taken along the the individual designer's workspace. Participants in a meeting, for instance external clients, or colleagues, use sticky-notes or felt-markers to annotate directly on the paper prints. If possible, hi-fidelity prototypes are brought into the meeting as well.

As an example, I discuss observations of a design meeting between three engineers discussing a prototype of a water-filter (figure, 5.12). In what follows it is relevant to know is that the person in the dark-blue shirt, R, is new to the project, so the 'formal' structure of the conversation is that the other two participants, L, sitting with R at the table and project-managers P, standing at the whiteboard, present an 'update' of the project progress and current problems that need to be tackled. We see how external elements are used as scaffolds, e.g. one person explaining something to another person while pointing at a 3d model printed out on paper on the table. The initial structure suggests that R is the person that may bring in new solutions to existing problems, being new to the project. At the same time, R still needs to get a grip on the details of the project, while P and L have already become experts on the subject matter. Taken together, this leads to a subtle interplay of initiative between R and P. P, standing, explains the problem and the product in detail, by which he shows he has detailed knowledge of the project. R, on the other hand, tries to make himself relevant to the project by asking various further questions (using phrases like "Have you also thought about ..."). L, on the left, takes on the role of an intermediary, trying to connect and integrate the contributions of both R and P. This means L is shifting in attention between helping P in his explaining of the current status of the project thinking along new directions as initiated by the questions of R.

Figure 5.12. Using external scaffolds during a project meeting at Van Berlo. Details in text.

Critically, we see how the physical position of the people and the physical artifacts used influence how the conversation unfolds. For example, P regains control over the conversation by writing notes on the whiteboard (Figure 5.12, Top Left) and then photographing these notes from a distance (Figure 5.12, Top Right). While creating the notes, P loses contact with the conversation between R and L, which are moments when R takes control over the discussion by asking a question that is then answered by L (5.12, Top Left). In such cases, R repeatedly uses the picture on the table before him, as well as his personal notes located next to that picture, as an artifact to 'hold on to'. The effect of P taking a picture of his own notes is that R and L stop their conversation and attention is again drawn again to P's line of thought (5.12, Top Right). When P walks over to explain something in direct reference to a physical prototype of the water-filter, the situation changes (5.12, Bottom Left). P seems enthusiastic in talking about 'his' prototype, and at the same time R sees opportunity to ask several relevant questions to P directly. This helps both of them recognizing each others' status as important and relevant to the conversation. When attention shifts again to the picture on the table, P now sits *with* the group and all of them now use the picture as the shared point of reference (5.12, Bottom Right).

5.2.2. Using sketching to express yourself

At Van Berlo the activity of sketching as a means of expression in a meeting surfaces most prominently, as most practitioners are, by way of their profession, skilled artists. People we talked with used live sketching in support of what they try to express in a conversation, to each other, and also to us.

Figure 5.13. A designer talking while sketching.

Observing the activity of sketching (Figure 5.13) revealed much more clearly than that of writing a sticky-note, that the activity itself (i.e. creating the sketch) is as important for getting a grip (including ‘connecting’ as a person to the process), than is the content of the sketch as such. That is, as we already suggested in the YOUMEET study, it is valuable for participants to create *their own* physical expressions, and be actively involved with these external materials, rather than just passively looking at them.

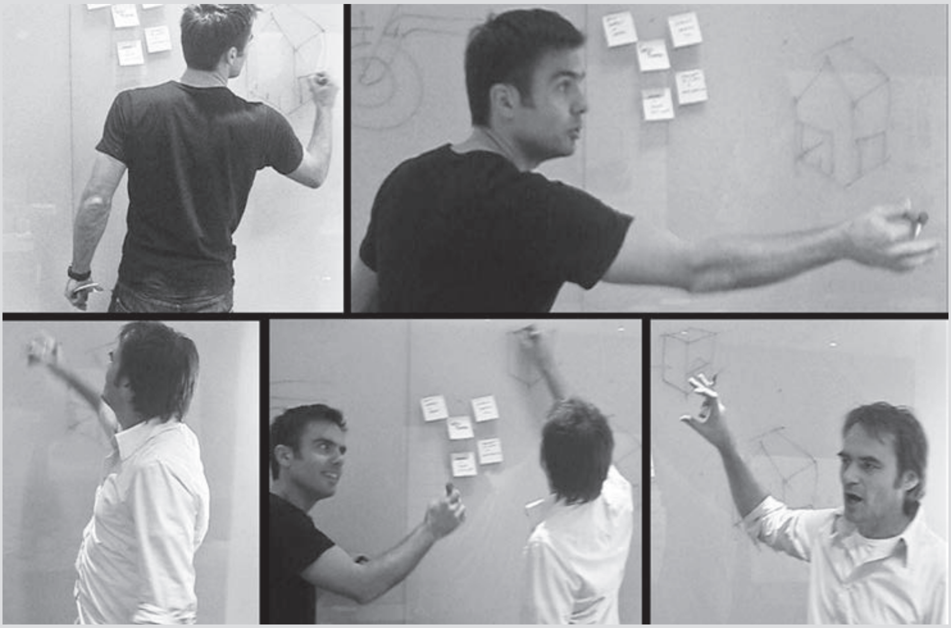


Figure 5.14: Sketching functioning in a social interaction. Details in text.

As an example, consider this episode from the kick-off workhop (figure 5.14). It figures N in a black shirt and S in a white shirt. The entire episode lasts for under one minute. First we see N who explains to us, as visiting researchers, how designers at Van Berlo will use the whiteboard in talking with a client. Later on we see how S pitches in to offer his own account of that same process. Superficially, they seem to be making the same point, helping each other in giving us an account of their practice. In what follows however, I will focus not on the content of what they say rather than how they create and use the sketch in order to communicate, and especially how they interact with each other in doing so.

At the start (Figure 5.14, Top Left), N is superficially talking to me, the camera-man. But we can see from N's body language that he is also nonverbally attentive to his colleague S, who is standing to the right, just outside the camera-frame. While explaining how he uses sketching, N 'acts out' how he would first make a sketch of his own, and how he would then present the felt-marker to his client, asking him to add something or other (Figure 5.14, Top Right). In doing so, N, on the fly, and with no verbal reference, nor informed consent - makes S instantly play the role of the client. N's body language in offering the pen suggests a little challenge to N: will you accept this role in my improvised play?

S responds to this 'challenge' in Figure 5.14, Bottom Left. I mention three aspects of it. First, note that S breaks into N's unfinished talk, starting his own account of the topic at hand, directed at me. Second, S does not accept the felt-marker offered by N, but uses *his own* felt-marker instead. Third, and perhaps most interesting, S steps *past* the existing sketch of N, and just to the top left of that sketch, creates *almost exactly the same sketch*, accidently covering up S's sketch from view behind his own body. Meanwhile, N continues his sentence, which means that for a moment both talk at the same time. During this short instant of confusion N displays the nonverbal expression as seen in Figure 5.14, Bottom-Center. What he says at that point is ".. and the client then says to me: N, you know I cannot draw as fine as you can, but I can still give it a try". S appears to ignore this continued offering of the pen and finishes his explanation while directly making eye-contact with N. He continues talking until after N has switched from talking to listening. (Figure 5.14, Bottom Right).

This episode hints at two phenomena. First it indicates that it is not the final visual form of a trace that helps people to connect in meaningful ways to the conversation, otherwise S could have just used N's sketch to tell his part of the story. Rather, it is the *activity* of creating the sketch, or more in general terms the activity of being involved with an external artifact, even if superficially it means duplicating information. Secondly, a personal expressive trace like for instance a sketch is not just objective information, it is also in a way a statement of personal identity. Creating an expression says in a way: here am I, and this expression is proof of the fact that I am contributing to this process. Creating and discussing sketches thereby becomes not only a matter of sharing information, but also a process by which people position themselves socially with respect to one another. That is: the role of the two sketches in the example above ties into a re-negotiation of the social relations between the two people involved, perhaps even involving a form of power-play, and not just to the content of what they are superficially talking about (see also chapter 7 of this thesis for a further theoretical grounding of this observation).

5.2.3. The fear of losing a participant along the way

The social aspect of a session was considered very much important by designers at Van Berlo, especially considering certain large-scale design meetings, with many people involved, including people high up in the organizations of the client companies involved (CEO's). In such important 'politically tense' meetings, with big commercial interests putting pressure on its outcome, it was expressed to be of critical importance to have a good sense of whether everybody present was still 'on board', and to make sure that the activities in such a session worked towards getting the designer's view and the client's perspective successfully aligned with each other. In the kick-of meeting a particular event was recounted in which a mismatch between designer's expectations and that of the participants representing the client party only surfaced much too late in the session. Apparently, even though the session had been well prepared, the designers somehow 'lost' the client already somewhere during the session, and later on it proved too late to easily 'repair' this lack of shared understanding between both parties.

5.3. Designing HOOK-ME-UP

Building on our insights so far, we designed a concept that made visible to all participants the way in which individual participants use particular external traces as a means to get connected to the group process and position themselves socially in reference to the other members of the meeting. The central idea was to have a way for participants to show to others, at any moment in the session, ‘where you are with your thoughts right now’. Expressive traces of people, such as sketches or sticky-notes, or models on a whiteboard, would be used as physical anchor-points that people could ‘hook themselves up to’. In other words, people would be able to take an external artifact and state: ‘this’ is where I am now, ‘here’ is where I currently stand’. Making such an explicit statement would also implicitly function as recognition of ones personal identity: ‘This is me: I am here, taking part in this process’. Taken together the system should help the group not to ‘lose’ individual participants somewhere along the way of moving towards the final group conclusion. The system could bring to light certain neglected, but important issues that the group as a whole had glossed over, but that an individual person was still ‘stuck with’ in some way.

The final concept, HOOK-ME-UP (See figure 5.15 for the first design explorations of this concept and Figure 5.17 for the final concept) is a tangible, personal avatar that could be positioned on a table or stuck onto a wall. The object relates to the physical disks that practitioners at Van Berlo sometimes use in sessions, with which people can ‘rate’ ideas (e.g. every participant gets five ‘disks’ that he can distribute over the ideas he likes most). The idea of our tangible device, instead, it that it is literally ‘hooked onto’ the artifact that signifies ones current position in ones evolving line of thought. This can be a sketch that is particularly meaningful, or a conclusion on a sticky-note, or a model, etc. The avatar shows the pass-port of its owner, so anybody can see at any moment ‘where’ everyone else is with their thoughts, and this already gives a first glance on the process is converging towards shared insight, or not. At various moments during the session, the facilitator asks everyone to reposition his avatar. Crucially, when people are invited to ‘take the next step’, and move their avatar from a favorite position to a new one (with the aim of moving towards one, shared, group conclusion), they are still able to ‘retain’ their old scaffold by taking a snap-shot of it. This snap-shot ends up in a cover-flow that the participant may flip through in an individual reflective moment. This enables the participant to look back to the history of his own evolving line of thought, and how he ended up with the current insight, that is, how one thing lead to another. This line of thought may then, if the need arises, be shared with others as well, on a visual screen, centrally placed in the space.

Figure 5.15. First expression of the final concept for Van Berlo (left) and a mock-up used in the acting out (right).

5.4. Acting out the prototype and finalizing the concept

During the acting out sessions, live sketched by the artist (Figure 5.16), a worry was expressed that this rather complex tool would perhaps disrupt the flow of a session. It was indicated that it would only work as long as the tool was kept simple and introduced explicitly as a game or method in the process, controlled by the facilitator. This is why we added an explicit facilitator role in the final scenario. Helping participants to ‘take the next step’ and making a physical reference for expressing ‘where you stand’ were appreciated in service of the group process. But a purely physical avatar (no technology inside) could already contain the core of that idea. In contrast, the possibility of individually making snap-shots representing your own thought process was appreciated as well, but mainly so as to help one to keep track of ones own thought process. Together, these two aspects were not clearly integrated in a coherent way, they seemed two separate ideas that needed further design iterations to transform it into a full-blown product concept.

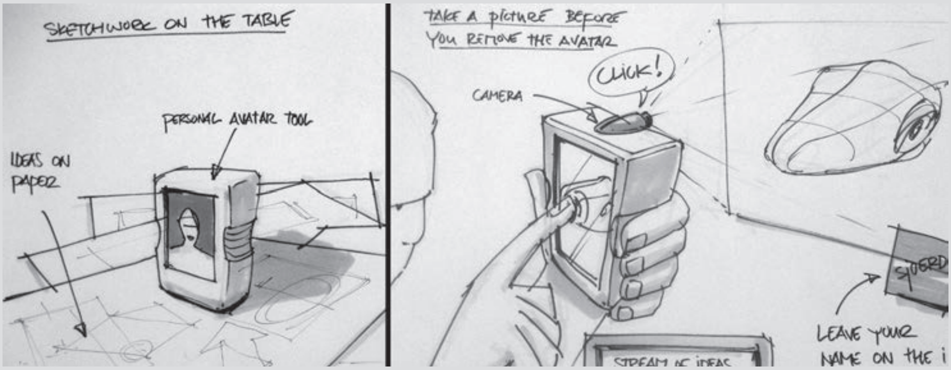


Figure 5.16. sketches live drawn by the artist during the acting out session of HOOK-ME-UP (Artist: Martijn van de Wiel).

In finalizing the scenario with the artist we changed the first proposal somewhat such that for instance in picture 2 of the storyboard, people are not standing in one group but are strongly dispersed throughout the space, to high-light that each person and his avatar may be ‘somewhere else’ with his thoughts, and that this is precisely what the system will show to the group. Instead, in the final picture we see that all people have their avatar placed on the same sketch, indicating mutual agreement has been reached. The statement of the facilitator, “We all agree...” is not so much a question that needs to be answered rather than a recognition of something that has already been accomplished through the process of gradually moving the ones avatars to one and the same external artifact.

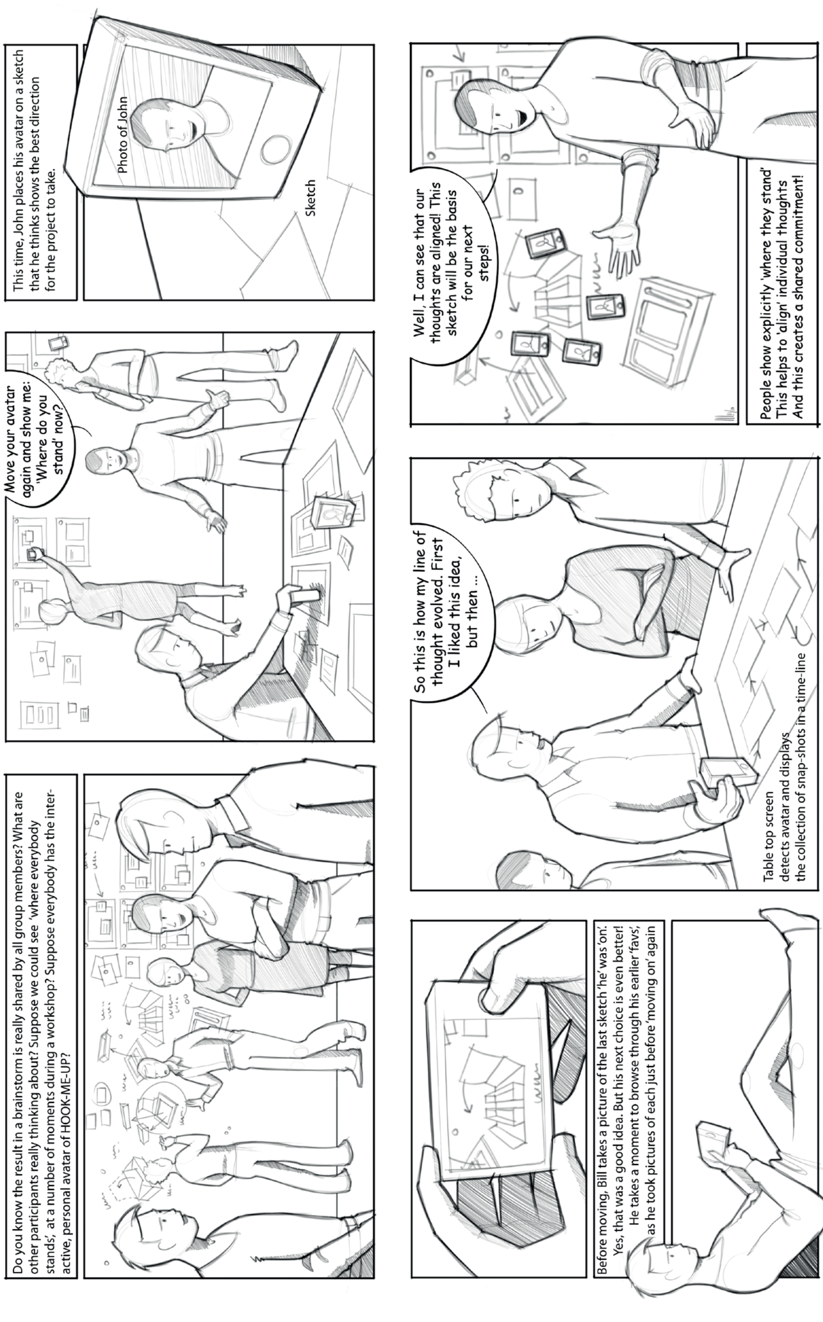


Figure 5.17. The final scenario for HOOK-ME-UP. Details in text.

5.5. Reflections on In CompanyLab 2

Again, the initial question was how to *support the use of traces, in service of shared insight?* I now reflect on how our own insights evolved over this second co-design week.

This co-design week provided one more step toward full recognition of the importance of social processes for insight generation, and how people may share the overall insight is determined first and foremost by the question of whether they are personally involved with the process or not. In contrast to YOUMEET, the *uniformity* and 'conventional' configuration of the meeting spaces directed our thoughts away from the properties of the physical meeting space, emphasizing instead the activities and interactions between the people in the space. The observations of actual meetings at the company suggested that the use of various external artifacts in the space in subtle ways coordinates social interactions and communication between conversational partners. And, just as we saw at YOUMEET, people use sketches and other external artifacts as communicative scaffolds in order to express their ideas and coordinate the conversation. We also saw that just as people can be said to 'stick' to their ideas, afraid of letting go, they can stick to 'their favorite sketches', for example the ones they created themselves. Actually we may speculate that this amounts to exactly the same thing: staying with a certain sketch, using it as a scaffolding reference point for explaining ones own thoughts and for understanding other people's contributions, means being stuck on one particular line of thought, with the danger of not being able to 'move on' to the next phase in the group's process towards a shared insight.

External traces play an important role in this relation between involvement and insight. We came to speak in terms of metaphorical question: 'where are you with your thoughts?' (a Dutch expression, asked especially if someone seems distracted and not attentive). Our concept of physical avatars made explicit 'where' people are with their thoughts, such that potential mismatches in insight would be revealed immediately. Moreover, the avatar's snap-shot facility and tabletop display may help people to make the move, by allowing them to take with them their personal scaffolds, and show their own 'line of thought' to others, such that taking each 'next step' would be smoothened, and respect would still be paid to their own, personal meaning making process. However, at the same time in the concept the personal process of recording the history of ones line of thought was not successfully integrated with the social process of reaching a mutual understanding between the participants. That is, the individual reflective process as described by Schön (1983) in which the creation and configuration of external artifacts may play an important scaffolding role, was not fully integrated yet with the socially situated negotiation of meaning as described in theories of situated practice (Suchman, 2007).

6. Third In Company Lab: LEF. The governmental Future Centre

6.1. Physical and organizational context

LEF (Figure 5.26) is a large in-house creative meeting facility of the Dutch Road and Waterworks Authority. It's goal is to facilitate "break-throughs" in highly complex projects involving multiple governmental departments and large engineering companies. In such projects there can be longstanding conflicts, bureaucratic rules and regulations that get in the way of progress, serious misunderstandings and differences in language and culture. Projects can be in need of a restart or kick-start in order to get them, to use the appropriate metaphor, 'on the road' again. The design of the space breathes a hi-tech vision. The facility contains seven large spaces, numerous projection screens and digitally controlled lighting conditions that can create various thematic 'atmospheres'. The vision of LEF focuses on influencing people's subconscious affective state, creating the right kind of mood given the particular problem of phase in the session process. The facility caters large sessions, involving up to 20-50 participants, often lasting one or two full days.

6.2. Observed activities and practitioners' experiences

The one thing that immediately drew our attention in LEF was the large space of surround projections, including floor projections, called the theater. This hi-tech media-space is used to create various atmospheres (Figure 5.18). However, the use of this system was not real-time interactive. That is: facilitators could chose from a number of 'presents' a certain theme of lighting, images and video projection, but the projected images did not react real-time to the activity in the space itself. We saw many possibilities for augmenting this space with real-time interactivity, and we thought about how the space could support not only a certain general atmosphere, but also working with the 'content' of the group process itself.

In contrast, what we observed was that the content of the group's process was itself not supported by interactive technology at all, and participants would support the actual conversation using conventional tools: sticky-notes, whiteboard and flip-charts. Facilitators at LEF emphasized the complexity and size of group sessions at LEF, often figuring more than 30 participants. One of the main goals for LEF was to align the various processes and different perspectives in each of the different government departments or sub-departments. Collaboration between these departments is crucial for successful projects but this is no easy task. This background context made it that the focus in our investigation was, as at Van Berlo, once more drawn towards the social dynamics between people in the space, rather than purely the question of how information is stored or made available in the space.

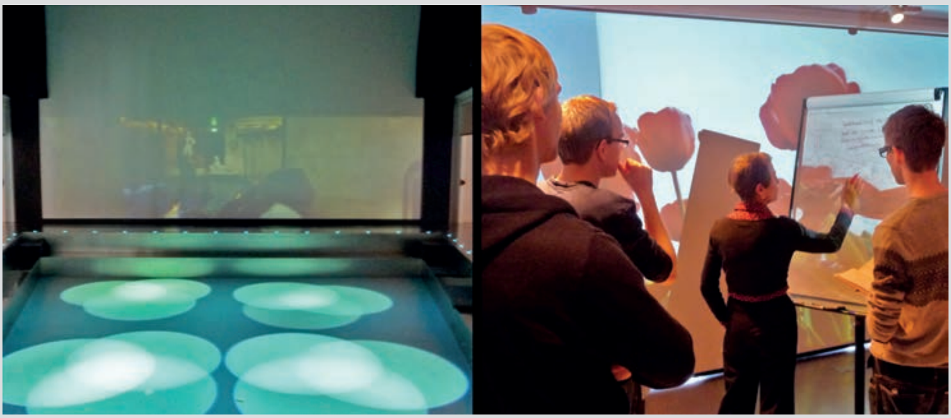


Figure 5.18, left: The Theatre. Right: a sub-group working within a particular 'atmosphere-setting'.

We observed a 30-participant, day-lasting session, which contained alternations of working in small subgroups and large plenary sessions, the latter situated in the theatre. As each of these sessions was situated in different physical spaces the situation was comparable to that of YOUMEET, again with the potential danger of losing important insights going from one space to the next. At YOUMEET we had already seen the problem that sticky-notes that would have personal meaning in a sub-group session but that this personal meaning would not always be retained once the physical materials were carried over to the plenary space and used by a facilitator to create an overall summary of the insights so far. At LEF we observed this phenomenon even more clearly. In the sub-sessions (Figure 5.19, left), we observed how individual people, for the first time since the plenary introduction session that had preceded it, would start to become actively involved with the event as such, contributing with ideas and personal experiences, creating sticky-notes, and discussing these on a one-to-one basis with other people. This was also the moment where participants would become acquainted with one another personally, and we frequently observed the exchange of business cards, as well as 'side-conversations' of people on topics other than the main session's theme. This 'intimate' activity was then followed by a plenary session in which participants would sit and listen to a talk by one of the organizers, or an invited speaker. In the session we observed the representational media used for this talk (a *powerpoint* presentation, Figure 5.19, right) had been prepared on beforehand, and so it seemed there was not real connection between what had happened earlier in the sub-sessions and the topic of this plenary session. In fact, movable carts with the sticky-notes from the sub-sessions could not be moved into the theatre as it was surrounded by stairs, and so these carts were basically left unused in the space next to the theatre (Figure 5.19, bottom)

Figure 5.19, left: an intimate sub-session, center: the plenary session, bottom: during the plenary session, the unused carts with people's sticky-notes from the sub-session stood to the side of the plenary space.

6.3. Designing Drag 'n Drop

Building on the insights developed during the co-design sessions, observations of the session and interviews with practitioners, we identified three directions to be integrated in the design. First, in explicit reference to the notion of traces, we saw in the large projections on the floor a possibility for literally having a gradually evolving 'trace' of people's activities. We aimed for people to actively create and further build upon their own 'traces' of the creative process. The assumption is that such active involvement will make people more committed to the final outcome of the workshop. If we look at the three In Company Labs, this was the context of practice that most readily afforded a connection to the theoretical idea of stigmergy, and our initial introduction along those lines already elicited various creative ideas by practitioners themselves on the first day. For example, one participant offered the vision of a virtual 'beach' projected on the floor in which one could inscribe ideas, that would then slowly fade away by the sea once in a while, upon which new ideas could be inscribed and so on. Secondly, we thought about supporting the actual, face-to-face contact between individual people, which we had seen was valuable in the sub-sessions, but was largely absent in the plenary meetings. We suggested that interactive technology might provide for a way to 'scale up' short moments of personal contact between people, in which two or three individuals would get to know each other and better understand one another's point-of-view, and connect such moments to the overall process of reaching a group level shared insight for the session at large: that is, to the desired 'break-through' that such sessions is aimed at. Finally, considering the physical space and the available technology, we figured that the space could support more than just output preprogrammed visuals and audio. If we could make the space interactive, the technological properties of the walls and floor could actually be connected to the practice of people making sense of the creative challenge, augmenting or transforming their conventional routines of creating sticky-notes and writing on flip-charts. We wanted to more fully use the scaffolding potential of the space.

The resulting concept for this week is Drag 'n Drop (see figure 5.21 for the final scenario). The concept contains two levels at which 'traces' are created. The first is that each person will create a personal trace of images of sticky-notes or other artifacts that proved interesting in sub-group activities for 'taking along' to the plenary integration activity. These individual traces all end up on the central floor of the theatre. Instead of a classical plenary meeting, people will be actively engaged, standing on the floor, clustering and selecting the materials on the floor. Groups of people on the central floor will negotiate which of the items should stay, by highlighting them with a physical object, and which items may in fact gradually fade away with each round of discussions. The result is a pattern of items that expresses the gradual process by which each of the individual people has aligned her own personal views and lines of thought with that of other people.

6.4. Acting out the prototype and finalizing the scenario

In Figure 5.20 we see an impression of LEF employees enacting the Drag ‘n Drop scenario, and the artists sketches drawn during that activity. Employees believed a more active form of ‘selection and clustering’ would work within their work practices. They already saw the gist of that process happening when people would stand around in front of a wall discussing sticky-notes. Reflecting on the resulting final trace would help facilitators in drawing conclusions that really had emerged in a bottom-up fashion from the activities of the participants themselves. Perhaps this final snap-shot could be projected on the wall as an end-result.

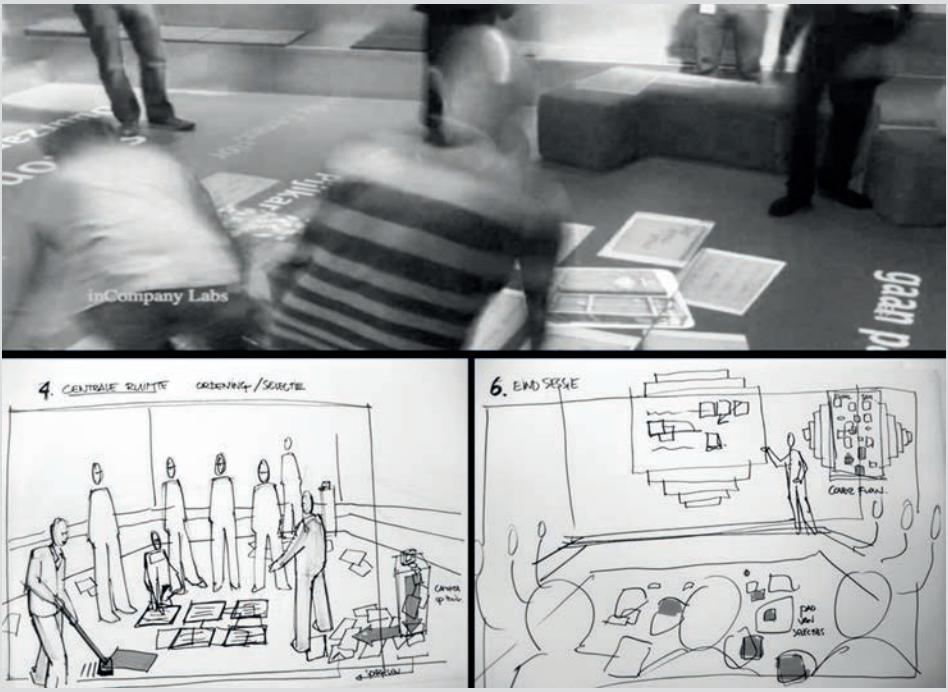


Figure 5.20. Acting out Drag ‘n Drop with LEF practitioners and live sketched images of that exercise.

We decided to start the scenario on the central floor, to preserve some sense of continuity: the facilitator would start by highlighting the key-topics of his own introduction, which would then provide the starting points for people to discuss on in sub-sessions. People might return to the central floor for several ‘rounds’, with sub-sessions in between, each time adding to the gradually emerging ‘global picture’ on the floor. In the final picture of the scenario, the situation most closely resembles the traditional situation, with one person summarizing the conclusion of the day, this time however inspired by a trace of images that has gradually emerged from embodied activities of all participants on the floor. In the background on the wall one sees a ‘cover-flow’ of intermediate stages that the floor has seen, together forming a history of how the final configuration of images has grown.

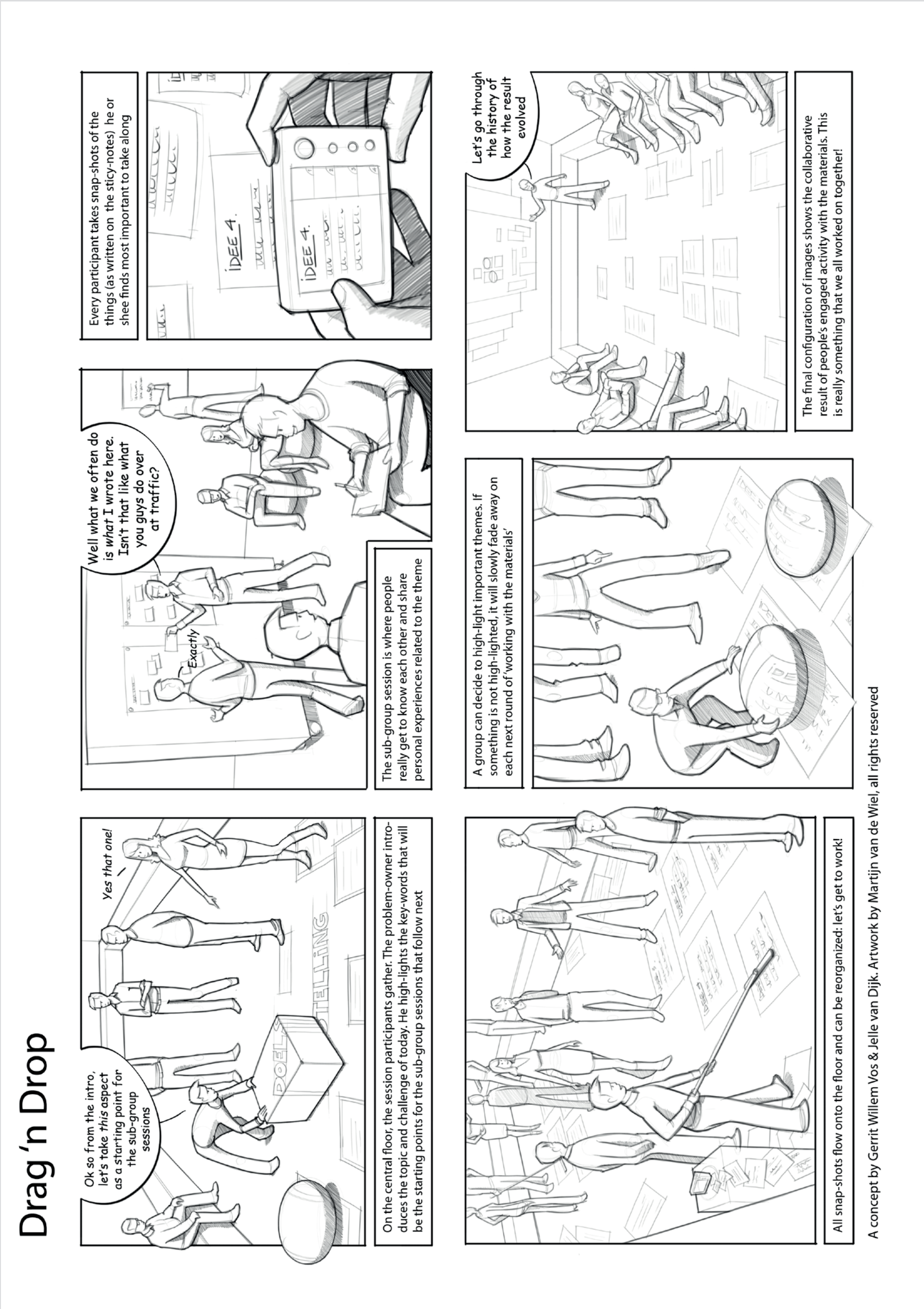


Figure 5.21. The final scenario of Drag 'n Drop.

6.5. Reflections on In Company Lab 3

I now reflect on how our own insights evolved in this third and final co-design week.

At LEF a number of themes resurfaced and connected that had already been opened up in the first two weeks. We had seen at YOUMEET how facilitators would 'clean up' the spaces by carefully taking all external traces, organizing, selecting and indexing them. At LEF we saw this same activity happening and figured that 'cleaning up' could be a sense-making activity in its own right, if only participants would themselves be involved in it. The idea of traces took its form at LEF on the floor, where the way people interact with each other and the traces each of them brings along to the floor has its gradual effect on the way the total display of traces is organized. Another theme that came back was the transition from smaller, intimate sub-sessions to the large plenary meeting. Much more strongly than at YOUMEET we observed at LEF how people would become 'backbenchers' that were in danger of no longer being committed to the process. This effect was highlighted in the observation that people's original sticky-notes were not used in the plenary summary meeting. We sought ways to allow people to bring the traces that they used for sense-making in earlier session to the plenary floor, and at the same time have them be actively involved with these traces. Most importantly, working with the traces on the floor continued the ways in which people would be interacting face to face with each other as a socially negotiated means to create a shared insight for the group as a whole. In a way, we transformed the large plenary meeting in just a continuation of the small-scale process that was taking place in the more intimate sub-sessions. In conclusion, we again took a step away from seeing materials that people produce as 'the output' (the insights, that would then be 'presented' and 'discussed' in a plenary meeting), and instead conceive of these materials as scaffolding 'things to think with', which is an active process involving immediate interactions between people, in this case situated on a large interactive floor surface.

7. Integration workshop with designers

A large workshop space at Eindhoven University that formed the setting for a one-day integration workshop (Figure 5.22). Next to the initial design team, nine design experts and (apart from myself) one theoretical expert on EC participated in the session. After an introduction of EC theory and the main design question, the three concepts were presented verbally and by means of rich visual materials created during the In Company Workshops, including many photos of the context of practice, design sketches and the final concept scenario's.

After getting familiar with the three ideas developed so far, three sub-groups were asked to think about ways to iterate on the existing concepts. After that, the group explored ways to integrate the three ideas into one coherent design proposal. From the first phase, a certain tension emerged between two lines of thought actually helped to force the emergence of the final design concept. On the one hand, ideas emerged that suggested artificial intelligence-like functionalities of the computer, such that it would aggregate large amounts of 'traces' by means of computational power into suitable formats and present the result to the user on a display. On the other side of the conceptual spectrum, ideas were developed which focused on transforming the way participants, in their ongoing activity in the space, could be supported in 'taking certain perspectives' and interactively sharing personal insights with one another in direct communication.

Figure 5.22. At the integration session. Starting the plenary discussion towards one integrated concept

Given these two lines of thought, the first crucial moment in the discussion that followed was an expressed critique, by one of the sub-groups, that the existing concepts in fact had little to do with people's actual bodily action. For instance, in the LEF proposal, the underlying vision seemed to be that the ultimate 'insight' generated was 'in' the configuration of the final traces left on the floor, not *in* the embodied interaction between participants and the floor. But the use of physical avatars in the Van Berlo concept caused equal resistance, as it could be seen as replacing actual bodies and their role in cognition to the use of a *representation* of that body – the physical avatar. These two criticisms caused the direction of thought to be centered once more fully on the 'body-centered' line of thinking.

In what followed, the idea of 'taking perspective' and sharing ideas in direct communication was continued, but this time posing the challenge of even more radically applying an embodied vision to the design. The next critical moment was when the physical avatar concept was evaluated very pragmatically against how this concept would work out in actual practice. The assumption in that concept was that at any one point in time a participant puts his avatar on *one* sketch or sticky-note that is most important to that person. Several designers objected to this assumption. Suppose a participant's evolving insight is sustained by many external traces in parallel? Does that mean one has to have just so many physical avatars present in the space? Would that be helpful for creating shared insight? Meanwhile, the workshop had moved from the plenary discussion of early sub-group activities into an acting-out activity in which all participants were involved. The latter part of the discussion was continued through acting out ideas and immediately reflecting on them, using improvised prototypes made with the available tinkering materials (Figure 5.23).

Figure 5.23. Final part of the integration session. Developing a line of thought by acting out improvised prototypes. Left: how can people communicate individual insights to others? Right: the first material expression of the final concept, in which projected digital images form a 'trace' of ones individual thought process, which then dynamically moves along with a participant's body as a person is in interaction with other people on an interactive floor.

From this activity the proposal emerged to turn the Van Berlo concept inside out, by replacing the idea of placing an avatar on an external scaffold, with the idea of placing snap-shots of the scaffolds as projections around the participant's own body. Various forms of projection and ways to interact with ones own 'trace of thought' were explored in acting out (Figure 5.23). This combined the Van Berlo concept with the spatial context of LEF, figuring a large interactive floor on which the images would be projected, moving along with the participant's movements. As traces would always automatically be everywhere that the participants themselves would be, there would be no need to transfer traces from one space to the other, which had been the issue at YOUMEET. In fact, the idea of 'traces' was somehow transformed from being a physical residual fixed in a particular space, to something that one always takes along wherever one goes, perhaps more like ones clothes (Figure 5.24).

Figure 5.24. Sketch made during the workshop of possible interactions based on the final idea.

7.1. Reflection on the integration workshop

One early line of thought we did not pursue in the final phase of the workshop was the one in which the computer would do heavy number crunching on large amounts of data collected a traces of people's activity and then present it back to the user as aggregated patterns extracted from those data. In fact, this line of thought resembles initial ideas at the YOUMEET lab in which facilitators asked for a dashboard with summary info of 'everything that was happening'. It highlights the strength of digital computation and the information-processing opportunities when large amounts data are available. It also focuses on how digital computing can generate information from the external traces, and it therefore puts the locus of the insight-generating process in the computational process itself, taking it away from people's own embodied involvement with these traces. This is why we abandoned this line of thought, even though it is a familiar and quite logical direction to take, considering the context of computational technology.

The critical question of 'where the body' is in the three ideas from the In Company Labs, put the focus back on how interactive technology can change our own 'embodied being' in the space. I conclude that the three In Company concepts were first steps into the general direction that EC suggests, but at the same time each of these proposals never went 'all the way'. As intended, these concepts were strongly influenced by the local circumstances and the way we had come to understand activities and potential problems at the site of practice. This meant we also let go for a while a strong connection to theoretical principles. In particular, the In Company Labs called our attention mostly to social interactions between people and the social structure of a creative session, and much less asked of us to connect to sensorimotor coupling and concrete bodily movement in general.

The integration session moved attention back to the body itself. Yet, in acting out the prototype, we discovered that traces directly connected to the body function to scaffold *social* interaction between people, which meant it retained the objective we had aimed for in all of the three In Company Proposals. Traces around my body – or 'as part of' my body, help me to express to others what I am thinking and it helps others to direct the conversation in order to help reach a mutual understanding. The final concept is therefore a more explicit step back to EC theory. It presents a vision in which insights are not somewhere 'out there', but always and only 'with me', as an integrated element of my ongoing embodied activity.

8. Designing and prototyping FLOOR-IT

In an additional acting out session and a prototyping phase, the result of the integration workshop was further detailed and implemented into a Wizard of Oz prototype. As we can see in the final scenario of the concept, called FLOOR-IT (Figure 5.26, see also: http://vimeo.com/22075247) there are two ways in which people can reach a shared insight: Individual images may be copied from one person to another during face-to-face interaction. This would be an instance where someone explains elements in his own trace and the other person gets so enthusiastic about that insight that she wants to take that image along in her own trace as well. The second way in which individual lines of thoughts can interact is by adding individual images to a new cluster fixed on the floor, with a physical place-holder as an anchor (comparable to the LEF concept). This is an activity where individual ideas are explicitly combined to form new group-level conclusions.

8.1. Evaluation of a FLOOR-IT prototype with stakeholders

We implemented the final concept in a partial Wizard of Oz prototype, using beamer projection, web-cams, marker-detection software and markers attached to head-caps for creating a live impression of the movement tracking. The goal was to communicate the intended user experience to the involved stakeholders and discuss in a collaborative session how the system would fit into/ influence existing practices.

8.1.1. Set-up of the evaluation

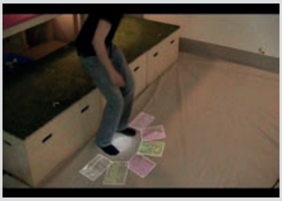
Twelve interested company stakeholders were invited to experience the prototype. The full-day meeting included a number of related activities, such as getting to know each other by exchanging personally meaningful pictures, and design assignments using FLOOR-IT as a general inspiration (Figure 5.25). Here we briefly discuss a number of themes that emerged from this workshop.

Figure 5.25, Left: stakeholders discussing the Wizard of Oz; Right: stakeholders who decided in a subgroup activity to enact a new variation on the design concept using physical sticky-notes as a mock-up

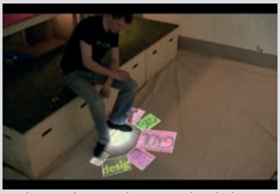
FLOOR-IT: a concept scenario
buiding shared insight through working with embodied traces in the creative meeting space

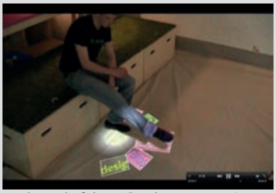
This system is used as part of a creative group meeting. The scenario starts at the moment participants have been working in a sub-session, generating ideas and insights. They then move on to a plenary meeting in a central space where individual insights need to be integrated into global session results.

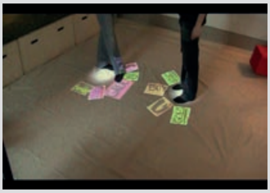

Participants take snap-shots of everything they want to 'take along' to the next phase

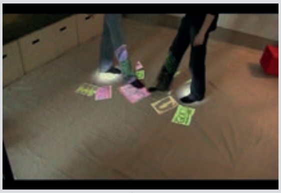

Upon entering the plenary floor, a 'trace' of ones images is projected around ones body


Using the foot one can enlarge images...


Relocate them in the trace, shrink them...


Or discard of them (by shoving away)


One may 'show' pictures to others


And copy a picture from ones own trace...


...to that of the other participant

Finally, using a physical placeholder, individual images from each person's traces may be added to a new configuration, a new trace that is, which represents the emergence of a group-level insight that integrates each of the invidual participant's point of view into a shared vision.

Figure 5.26. Final concept scenario for FLOOR-IT

8.1.2. Evaluation results

First of all, the tool is recognized as potentially enhancing personal commitment of participants in a session. The following quotes illustrate this:

> *"The question that often came back [in our own work-practice] is: "where do you stand right now". That question is now very much materialized [in this concept]".*
>
> *"Normally speaking I put it [my sticky-notes] on the wall and the facilitator will manipulate everything in such a way that I will never come to see my sticky again. Now it is attached to my body – 'this is the one': do I dare to let go of it? Or not? Do I trade for another one? Or not?"*
>
> *"The advantage of standing in the space [with a subgroup nex to cluster of traces] is that you feel your position [Lit: 'how you stand'] relative to other subgroups."*

Secondly, stakeholders acknowledged the idea that it is not the content of a sticky-note that really matters, rather than the fact that this artefact steers the conversation. This is exemplified in FLOOR-IT: the tool puts focus on the process between people:

> *"The idea that all input is important is not true at all. So [the real issue is] what do we need, and what this [the FLOOR-IT tool] offers is a way to influence the discussion."*
>
> *"A constraint in [conventional] thought is, that what is written on those sticky-notes is a kind of absolute given. [Instead] the process happens between the people, it is not really about the content."*
>
> *"I see a very beautiful instrument for more dialogue: one gives meaning to the way people are engaged with one another"*

Do we really need interactivity for this? One stakeholder commented:

> *"Yes this is also possible with sticky-notes. That may get some people active, but others will bail out. Using this tool, you have to stay actively involved."*

Another person offered:

> *"What you just did: instantly duplicating a sticky, that is of course not possible with real sticky's"*

One stakeholder offered that this tool could be integrated into a number of exercises or methods, that should however not be fixed on beforehand:

> *"These kinds of things go as they go: I can probably think of new work-forms every week"*

A number of questions or potential problems were also mentioned. For instance, does the tool really connect to the way insight is formed in groups?

> *"One problem is that a decision is not always made based on individually harvested ideas, instead one often get new ideas in the plenary discussion"*
>
> *"If everybody keeps starting to talk from his own perspective you haven't achieved anything yet"*

Another issue that came up was the added value of working 'on the floor' and whether some processes are better supported by projecting information on a wall. Someone worried:

> *"The size [of the projection] determines the space [for action] and that determines the number of people that can participate.*

Given that the system focuses on embodied action in direct contact with other people, some stakeholders felt the need to have the system create some sort of overview once in a while, viz. to be able to step back and look at 'the results':

> *"This system could create patterns and create rankings"*
>
> *"The participants do not 'see' the results while they are still working with the materials"*

This relates directly to the interaction design, because if one is 'in' the information, or rather, if the information is all around you, dynamically moving with you and with other people as they are moving, it is hard to see how to gain overview:

> *The landscape seems to become more important, but if you use this set-up, then you already lose an overview of that?*

8.2. Reflections on the FLOOR-IT prototype and the stakeholder evaluation

In our evaluations we saw confirmed the idea that ones physical position on the floor, amidst ones own 'traces', guides the ongoing conversation between people. Having your own 'ideas' with you creates a sense of urgency to get involved in the process, as well as respect for everyone's contribution to the group outcome. There are also a number of questions and problems emerging from the current concept.

If we look at the details of the way people naturally interact with the system, looking down to the floor may be incompatible with face-to-face contact. The question is whether alternating interaction with the floor and with each other will turn out to be a natural dynamic, or whether it works against fluid social interaction.

Another challenge in the current set-up could be that in smaller spaces, the space quickly becomes a clutter of overlapping images that are hard to deal with for users.

A more open question is whether the walls of the space could augment the interaction space and what are specific interactive qualities of wall and floor. Finally, the current set-up does not afford (in easy ways) the creation of new traces once on the floor, whereas this is what people would like to be able to do as part of the final phase of integration.

9. General discussion

The present study was an explicit attempt to build a system of 'traces'. The idea of traces that had emerged from the final reflections of NOOT (chapter 4) was that traces are external cognitive scaffolds that are both created and used by people 'in action', and these traces connect both to individual sensorimotor couplings and to socially situated practices. The present study further builds on the result of chapter 4, which was to go beyond a distributed representation and computation approach, where knowledge is assumed to be present in the environment (Norman, 2002; Hutchins, 1995), searching for ways to connect to sensorimotor and enactivist views, in which knowledge is an emergent property of embodied action itself (Merleau-Ponty, 1963; Dreyfus, 2002; Schön, 1983).

The design process started by designing the transfer of traces from one space to the next, linked to personal reflections; next it considered physical avatars representing 'where people are' in terms of their thought process; it then proposed evolving traces on an interactive floor that everybody could actively 'work with' and it finally ended up most closely to the body itself. In the final concept, a person carries around with him, as projected around the body, a trace of his own evolving line of thought, consisting of the external artifacts that are most meaningful to that person. The differences between the various contexts of practice steered our design activities in particular directions. For instance, in the Van Berlo lab the politically sensitive relations and the absence of an explicitly designed 'creative room' lead us to recognize the importance of social interactions between people, regardless of the particular physical context. In contrast, in the LEF lab the physical space strongly dominated the situation and this helped us to find opportunity based on ideas of *stigmergy* and bodily movement – though this time with the focus on social relations as well. I now discuss a number of further implications based on the design study so far.

9.1. Where 'is' the insight?

RQ 1. How to design interactive systems in support of embodied cognition?

RQ 1.2. How does embodied cognition inform designing for the way in which the interactive system at large connects to people's real-world, embodied and situated practices?

Designing FLOOR-IT proved to be a continuous struggle between a perspective in which the shared insight, as the outcome of a sense-making activity, is somehow 'stored' in traces of people's activities (Norman, 2002), versus a view in which these traces work as active components in the *activity* of sense-making itself (Kaptelinin & Nardi, 2006), which relates both to sensorimotor coupling as well as to 'in situ' social interactions.

Each In Company Lab outcome can be seen a step into the latter direction, but in each case we did not go 'all the way'. In part, 'going all the way' may have been hampered by the fact that existing practices are currently organized and understood by practitioners themselves on the basis of 'information processing' metaphors, which bias thinking about technology as storage media. The 'dashboard' idea envisioned at YOUMEET is one example of this, as is the habit of photographing all the 'results', even though participants knew they were never going to use these 'traces' later on.

The final concept is the strongest move so far towards a radical embodied view in which insight is always somehow 'with me, in my interactions': insight is an emergent property of my ongoing embodied activity. Seen from that point of view, a trace of images attached to ones body creates *new ways of acting and perceiving* (Merleau-Ponty, 1963, Dreyfus, 2002). That is, traces afford new kinds of sense-making *activities,* or yet in other words, a new way of interacting with the larger environment. This larger environment, in turn, is first and foremost the *social context of other people* (Goodwin, 2000; Suchman, 2007; De Jaegher & DiPaolo, 2007).

9.2. The 'discrete' character of taking pictures

RQ 1.1. How does embodied cognition inform designing the relation between the digital process and physical form of the interactive system?

In FLOOR-IT, digital process mainly supports generating dynamic, visual patterns that, to the user, are aspects of the actual space. Bodily traces are designed first and for all to function as scaffolds (Mascolo, 2005) for direct communication between people: they help me to express to others what I am thinking and invite me to ask of others what they are thinking, both of which scaffold the creation of shared insight. As the conversation continues, organizing traces into clusters as the result of person-to-person talk gradually creates an overall configuration that further scaffolds the ongoing conversations at the group level, in line with principles of stigmergy (Theraulaz & Bonabeau, 1999).

However, the process of first instantly creating snap-shots, and then later on perceiving these snap-shots as ready-made objects, also retains a discrete character that readily invites a more representational interpretation in which digital processes store and make available information-objects. What seems to be missing still, in terms of a more 'enactive' approach, is that on the level of individual engagement with the images the digital-to-physical mappings of the system do not yet afford a more *continuous* form of creating, refining, reworking, annotating ones' traces. Consider, by way of contrast, a designer sketching a drawing, while at the same time talking to another person. This practice we have frequently seen during the Van Berlo lab (see figure 5.19). In this case, the *activity* of transforming the trace goes hand in hand with the evolving insight. Instead of sketching what one is thinking, one thinks *through* sketching (Schön, 1983; Van der Lugt, 2005). The way the trace evolves and how that evolving trace in turn influences further sketching-cum-thinking activities *is,* I offer, what the sketch 'means' in terms of EC.

The question is how to connect digital interactivity to this kind of practice in a meaningful way. One reason that we used the digital snap-shot action and the instant display of the snap-shot on the floor is that we tried to connect closely to *existing practice* as observed generally in the co-design labs. Apart from the sketching designers at Van Berlo, who were trained artists, existing practices in general mostly involved having a conversation while using more traditional 'external representations' like a text on a sticky-notes, a photo on a card, or a diagram on a whiteboard. Focus is less on the skill of the *trace-creating activity*, like sketching, or constructing prototypes. Starting from a practice in which the interaction is mostly conversational in speech-based face-to-face communication, FLOOR-IT is what we ended up with. It proved hard to 'go all the way' to something like sensorimotor enactment

(Varela et al, 1991) in the manner of a skilled, continuous crafting of materials (Dreyfus, 2002)[13].

9.3. The social and the body

RQ 2. How does (the practical attempt at) designing interactive systems for shared insight in creative meetings inform the theory of embodied cognition?

RQ 2.2. What is the relation between the social situatedness and the physical embodiment of cognition (sensing and acting in the physical environment)?

9.3.1. The role of the body

The various design proposals in this chapter all to some extent build on the idea that we need bodily activity in order to create sensorimotor couplings to the world, and that these sensorimotor couplings are part of the system that underlies cognition. In order to support such couplings with our interactive 'traces', we assumed that 'where the action is' (Dourish, 2001) is exactly where a trace should be created (as it is also the case in nature) and where the action is later on, should be where that trace is made available as a scaffold (the flexibility of which would be the added value of interactive technology). In the final design, this place 'where the action is' simply became: wherever your body is. In fact, this idea of large floor projections and gross bodily movement (walking around) at least helped us in focusing more on the body and its possibilities for creating meaning in action. But this should not be read as stating that embodied interaction is simply about physically moving your body parts. The early idea of 'Thought Juggler' (Figure 5.6) was envisioned to be a physically demanding game. Something of this was retained in the LEF proposal, where ideas fade away if they are not used. But in the end this says something about ones engagement with the world, about the kinds of things one is attentive to, which is something that cannot be measured in calories. Enactment (Varela et al, 1991) is all about the emergent coupling that sensorimotor activity can sustain, even if this means just a subtle series of eye-saccades.

9.3.2. The role of social interaction

Of particular interest turned out to be the way traces connect social interactions with individual sensorimotor couplings. The social context turned out to be omnipresent in the In Company Labs and could not be ignored in design. This 'social' factor actually goes beyond the common-sense intuition that 'two people know more than one'. The social influence we observed and which formed part of the way people collaboratively make sense of things in creative meetings relates more fundamentally to how people *actively relate themselves socially to one another*, and how *that relation* is part of the way insight in the group is created and sustained.

This theme was opened up with all practitioners expressing the worry, in some form or another, that participants in a creative session would not be truly committed to the session's outcome, and that in creative sessions, part of what makes the insight 'valuable' is whether or not everybody feels connected to the process and to each other over the course of generating the insight. If people 'drop out' along the way, the final insight can be a fine statement on the whiteboard, but in actuality has little meaning for these people, and so the question can be asked whether it means 'anything' at all (whether 'shared insight' in that case has been formed).

We saw a cause for this problem in the way expressive artifacts such as sticky-notes are used. In current practice these artifacts are often disconnected from their makers when going from one session to the next. If they are used, they are often taken at face value, as 'factual' information. The personal connection, however, is lost.

Instead we came to think of the group process as supported by the way one is able to use ones own most meaningful traces as a scaffold in connecting to other people, not unlike, perhaps, the way children learn to pay attention and respect to each other through such class-room exercises as 'show and tell'.

9.4. 'External representations' as traces: from the body to the other

RQ 2.1. What is the role is of 'external representations' in the embodied cognitive process?

In the introduction it was offered that traces of activity' are not necessarily the same as 'external representations': e.g. a graph of people's walking patterns is very different from the pattern of actual footprints in the sand.

Our design activity took the existing practice of using sticky-notes and creating on-the-fly sketches as a starting point. We called these 'traces', and made them interactive using technology. The way we designed the interaction tried to make these traces more (radically) 'embodied', and less 'representational': more 'like' biological, stigmergic traces, that is. Projecting images on the floor, moving along with ones body, creates a very different experience than when these same pictures would be seen fixed on a wall display. In the next chapter (chapter 6) we investigate the dynamics of this process in more detail.

If we look at FLOOR-IT, we may offer that the group's gradual process of organizing and selecting traces on the floor coincides with the way the group's shared insight is formed.

The current proposal might conceptually be positioned as between the on the one hand, the Sensorimotor Coupling and Enaction view, that would see the visual traces as *part of the body*, through which each participant relates himself to the world (like when using a conventional tool that becomes a bodily extension); and on the other hand, the Socially Situated Practice view, which sees publicly visible artifacts (representational or otherwise) as mediating in social interaction between people. In that 'middle' position, FLOOR-IT offers a way of gradually transforming individual interactions with the environment 'through' creating and using a personal trace, towards a coupling of the team as a whole to the complete floor.

9.5. What does this design study tell us about creative meeting practices?

I now briefly turn to the practice itself. We have seen creative practices through the eyes of designers, trying to build an interactive system, based on the theory of embodied cognition. What image did that peculiar 'frame' provide us on the practice itself? Can we give some feedback to the practice, some insights that can be valuable for practitioners, apart from the design proposals themselves?

There is one topic that has struck me in each of the co-design sessions, which closely relates to the main themes developed in this thesis. As I experienced creative practices, the implicit assumption, for participants as well as facilitators, seems to be that ideas and insights are *objects* that are 'thought up' by individual people. These ideas can then be stored in a suitable external format, such as a sticky-note, and these external containers can then be used to share, combine, select, expand, discard, and so on. Taken together, the set of external representations of all ideas and insights produced is seen to be the 'result' of the session: it shows what came out of it. In that light it is not at all surprising that many information processing tools designed to support collaborative work are based on this very idea, with the information system taking over the storage function of analogue media such as paper or whiteboard. Reasoning along that line, the design goal then becomes to try and facilitate the process of reliable storage and easy retrieval of these 'results' as best as possible.

Hence, we have seen facilitators express the need to 'store all results' and then 'make them available very quickly and easily' after a session. People will say "I've got the results", holding a pile of flip-charts under their arm. Participants photograph all materials (Figure 5.27), 'so as not to forget what the results were'. However, the word 'result' is truly an ambiguous term. Participants and facilitators were perfectly aware of this ambiguity, saying things like: 'I'm taking these home, but you know of course, nobody is going to look at these flip-charts afterwards. They will end up in a drawer somewhere'.

Figure 5.27: Photographing 'the results'.

Based on the insights so far, this is only to be expected. Physical materials do not in and of themselves 'store' the actual insight generated in a session, but function mostly as cognitive scaffolds facilitating 'insight generating activities'. Taking an empty sheet and a pencil may at times be much more motivating action to start an insight generating activity than is the laborious rehashing of stuff created as part of a process that is already done and over with.

The power of the sticky-note, in a creative session, lies in sense-making *activity* it supports. For all we know, perhaps the best insight comes when the facilitator is cleaning up, organizing and piling up all the materials, letting her mind wander over the days' events, trying to recollect who said what and when, meanwhile separating the stuff to keep from the stuff to trash. Cleaning up is an activity that can bring a lot of insight. But this process is almost never shared by the participants, as it is assumed already that the 'content' is in the materials, and the participants can safely go home to find the report in their mailbox.

If one generates materials on the basis of some insight-generating activity, it might be worthwhile to already think about how it can be a rewarding, and useful experience (perhaps even fun?) to *do something* with these materials later on, because whatever the 'content' one tries to put in an artifact while creating it, the true value of such material lies in the extent to which it helps to generate *further* activities – not just whether it contains a correct and complete description of the current insight[14].

What facilitators *also* say is that the 'real' result is ultimately in the *personal transformation* of the people involved. The best session, from that perspective, is the one in which the participants leave the room as a committed team, ready to take action, aware of each other, with no need to store anything in a report, since they already themselves 'embody' the outcome. So instead of trying to put the results in an external artifact, it may therefore be more rewarding to try and put the results 'in the people' themselves. The main goal should not be not so much to try and transform *the whiteboard*, as it should be to try and transform *the people using the whiteboard.* And instead of designing interactive systems that help us to better (easier, faster, etc) 'store' and retrieve the results of a session, we may therefore instead try and create interactive systems enhance the quality of the activity of being in the session itself. NOOT and FLOOR-IT are two such proposals.

9.6. Next steps

In the next chapter we report on a user study, for which we designed and built a follow-up prototype, FLOOR-IT II, consisting of a version called FLOOR and a control version WALL that could be compared in a controlled observational setting. This new prototype has movement tracking of personal sets of images for multiple people on a floor that spans a projected surface of six large beamers, as well as a technology enhanced Wizard of Oz of the individual manipulation of images on the floor that provides the experience of a fully working real-time operating prototype. The results of that study will be our final step in trying to integrate sensorimotor, enactive principles, with the theory of socially situated practices. It also forms the closing chapter to the design cases grounding this thesis (chapters 4, 5 and 6).

1 *Ik sta dus ik ben, zonder standpunt, ben je nergens.*

2 *The relation between Schön's theory and theories of Sensorimotor Coupling, introduced in chapter 2, is made explicit in (Clancey, 1997), see also chapter 7 which discusses Clancey's view in some detail.*

3 *As we saw in the previous chapter, sticky-notes and sketches are also traces, playing their part in embodied cognition, but they are unable to retain their embodied meaning for extended periods of time. In any case, they do not specifically support the sharing of individual reflections on the ongoing process with the group. Precisely when the group is in flow and a participant has a fleeting hunch that 'something important is going on' she would not use sticky-notes to hold on to such a hunch. People will make personal notes (which could be 'personal sticky-notes'), but these are generally not shared with the group. In effect, using conventional tools such fleeting moments are easily lost as potential drivers for the insight generating process on the group level.*

4 *Think, for example, of the way that an ant leaves scent-markers that other ants use to navigate. All local interactions between ants sustain, at group-level, a feedback system which creates reliable traffic between nest and food-source.*

5 *Clark would perhaps call the trail in the forest a representation nonetheless, although an Action Oriented Represention: information for what to do, rather than information on 'what is the case'. This allows him to stay within a computational framework and still talk about 'know-how' in Ryle's sense (affordances/ information-for-use, in Norman's sense). I think my study does not necessarily prove that this is the wrong way to frame it. What it does show is that this computational reframing of for instance a trail in a forest would, in the context of design for interactive systems, cause confusing or a certain bias on part of the designer towards designing the system such that people 'get the information they need in order to be able to think' – which is different from creating a system that directly creates/supports certain 'visuo-motor' couplings to emerge between what people perceive and what they do. And that means that, before you know it, the real challenge of designing for 'embodied cognition' is not really addressed by such designs.*

6 *E.g. Kleinsman (2008) speaks of 'shared mental models'. The notion of mental model is typically used within a Cognitivistic perspective. (As does (Norman, 2002)).*

7 *Unless otherwise specified, 'we' and 'the design team' refers in this chapter to Industrial Design masters student Gerrit Willem Vos, for whom this was his graduation project, myself, and in the Van Berlo and LEF study also Industrial Design masters student Sippe Duisters, who joined us as part of context of a research project. Many thanks to Gerrit-Willem and Sippe for their valuable contributions. The concepts are collaboratively designed by Gerrit Willem and myself, with Gerrit Willem taking the lead in the interaction design and building the prototype, and myself focusing on grounding design choices conceptually in EC theory. The final interpretations of 'what the concept is', as they are expressed in this thesis (including the texts used in the storyboard scenario's), are mine.*

8 *In the NOOT study we also involved external companies as stakeholders, but in a less structured way and with less intensity than in the present study. Moreover, in the present study focus is on the involvement of company employees in their role as potential end-users, which should be distinguished from the fact that, in the case of Van Berlo design company, the end-users are themselves also (industrial product) designers. While in the NOOT study Van Berlo actually took on the task of designing the physical form of the NOOT prototype in iteration 3, in the present project, the design expertise and ideas offered by Van Berlo employees were relevant only inasmuch as it added to bringing the end-user perspective into the co-design process. Of course in practice, these two 'roles' cannot be completely separated when considering a concrete contribution of a person in some co-design activity.*

9 *There may be confusion about the fact that 'the practice' involved here in some way resembles our own activities, which contained a number of creative meetings as part of our design process. When I speak of 'the co-design sessions', I refer to our approach, and the sessions we organized in order to involve potential end-users of our interactive system. These are part of the method by which we wanted to get a grip on 'the user practice', which is what these end-users were involved with in their daily work. That user practice, however, also contained facilitation or organization of 'creative meetings', and to confuse matters, these are also sometimes co-design sessions, co-creation workshops or stakeholder meetings, as this is a recent commercial trend in these businesses. Yet even though there were these correspondences, our approach, grounded in academic industrial design, was also in a way very different from the what we saw happening at the sites-of-practice. Sessions at YOUMEET and LEF, for instance, are best positioned in the tradition of change-management and organizational theory, instead of design. This put focus more on talk and using writing, and less on sketching, creating, building, crafting, if only because this was generally not the skill of the participants in such sessions. At Van Berlo of course the design culture was omnipresent, but here we didn't really see co-design methods applied, let alone with a research component, rather than colleagues amongst themselves in a regular design meetings, or designer-client meetings (discussing the design brief or evaluating the outcome). Hence, although all of these practices in someway show overlap with each other as well as with our own, in practice it proved relatively easy to separate information coming from our own process, from insights drawn from either one of the user-practices involved.*

10 *www.livescribe.com*

11 *I chose to separate these topics for reasons of readability. As explained in the section 'Approach' there was no strict separation between analyzing the practice and designing the concept, e.g. the kick-off session on the first day was co-design session that already involved both gaining insight into the practice as well as collaboratively generating ideas for design.*

12 *Prof. W.F.G Haselager, principal investigator at the Donders Institute for Brain, Cognition and Behaviour, Radboud University Nijmegen, Netherlands.*

13 *In a future vision concept based on FLOOR-IT, designed by Industrial Design student Sijme Geurts, projection is combined with projection on the surrounding walls. Here, the ability to continuously adapt further work on each*

individual trace is added, using a pen control that at the same time can be extended to become a stick which replaces the foot-based interaction with images of FLOOR-IT. See figure 5.28. and http://www.sijme.com for a video concept scenario.

14 *This thesis is certainly not an example of this advice, especially concerning its size.*

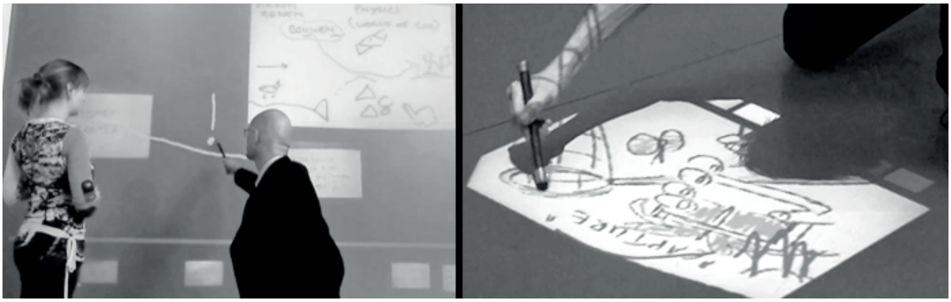


Figure 5.28. A future concept in which EC aspects of WALL and FLOOR are combined

6.

“There you are!” Expressive traces supporting social positioning

“If movements and sense-making are foundationally linked... and people’s movements can be interindividually coordinated ... we have a way of conceiving of a sense-making that is truly intersubjective.”

(De Jaegher, 2009, p. 539)

1. Introduction

This chapter presents a qualitative study comparing the use of a prototype of FLOOR-IT (see chapter 5) with a control prototype, in order to gain insight into the role of FLOOR-IT in the way people create shared insight in interaction with both the social- and physical environment.

1.1. Expressive artifacts & FLOOR-IT

In the previous chapters, we saw how sticky-notes, sketches, quick diagrams on the whiteboard, and so on may scaffold the formation of shared insight in creative meetings. We may now add tot this list the ‘tangible moments’ of NOOT (chapter 4) and the bodily ‘traces’ of FLOOR-IT (chapter 5). Both these interactive system concepts are designed explicitly to emphasize the role of artifacts, created and used by participants, as supporting embodied cognition. These systems at the same time de-emphasize a representational role of artifacts as external containers of ‘content’. In chapter 5, recasting expressive such artifacts as ‘traces’, helped us as designers to focus on this more dynamic, embodied role. We asked the question of *how to support the way people create and use traces in support of shared insight* (chapter 5). As explained in the introduction of that chapter, the term ‘shared insight’ here refers to a stable coupling that arises within a *shared activity.*

At the end of chapter 5, FLOOR-IT was proposed as an answer to this question. FLOOR-IT creates a trace of digital snap-shots of personally meaningful expressive artifacts like sketches, physically located around the body and moving along with it. FLOOR-IT helps to find ones own position in the sensemaking process relative to what the team as a whole is trying to achieve. On the basis of the final co-design evaluation it was concluded that people’s physical position on the floor, amidst ‘their own traces’, of their earlier sensemaking activities, guides further conversation between people. As such, the system helps individual people to fuse their individual insight in a natural way into the group process. The co-design evaluation further showed that having your own 'ideas' with you while talking with others, creates a sense of urgency to get involved in the process, as well as eliciting attention to, and respect for, everyone's invididual perspectives. Especially when individual ideas and insights of earlier exercises have to be integrated into group outcomes, FLOOR-IT respects each person's unique contributions and allows for a gradual integration of these contributions into the group outcome, such that every individual stays 'connected'. Taken together, interacting with each other in the FLOOR-IT context helps participants to shape and sustain a shared insight in the group as a whole.

1.2. Embodied Cognition as Socio-Sensorimotor coupling

At the end of chapter 4 I speculated that traces relate both to *social interactions* between people (Suchman, 2007; Dourish, 2001), as well as to *sensorimotor couplings* of individual people (Dreyfus, 2002; Beer, 2008; Schön, 1983). The findings of chapter 5 further strenghtened the idea that *scaffolding traces* relate both to social interactions and sensorimotor couplings, thereby supporting the creation of shared insight.

On the basis of the findings so far, I therefore propose to describe EC essentially as a form of 'socio-sensorimotor coupling' that is formed in ongoing action, with scaffolding traces playing a crucial, binding role (Goodwin, 2003; 2000; DeJaegher & DiPaolo, 2007). Interactive systems designed on the basis of this perspective can serve to support people in creating and using (new kinds of) such traces, enabling various kinds of embodied sense-making. FLOOR-IT is one concrete proposal for such a system.

1.2.1. Empirical testing

In the present chapter I report on an empirical study, using FLOOR-IT as a physical hypothesis (Overbeeke, 2006; Koskinen, 2011) of EC as socio-sensorimotor coupling through interaction with traces. One goal is to find empirical confirmation of, as well as further insight, into the idea of these 'socio-sensorimotor couplings' through traces. Another goal was to get clear on the specific contribution of the interactive systems in relation to these traces.

For practical reasons, we could not build the entire FLOOR-IT concept of chapter 5 as a fully functional prototype. Optimizing our options for creating a useful set-up in light of technical constraints, we decided to create two partial systems, called FLOOR and WALL, which could be compared empirically in the context of a creative meeting activity. FLOOR is the physically embodied proposal of EC as socio-sensorimotor coupling. WALL is designed as the null-hypothesis or 'base-line' condition against which to assess the effect of FLOOR.

Both systems create interactive visual projections of digital images. Both can be used in a subsequent 'integration phase', in which earlier ideas are to be combined into one coherent group-level outcome (i.e. a group conclusion, a list decisions, a design concept, etc). The 'content', in the classical, information-processing sense, is the same for both systems: a set of digital photographs created by the participants. Both systems allow for the same basic manipulation of this content: creating it (by taking snap-shots), re-ordering it on the display, and enlarging individual items. However, all ‘crucial ingredients’ of FLOOR-IT, as the embodiment of EC theory, lack in WALL. In FLOOR-IT, series of images are clustered *as traces,* moving *along with a person’s body* on the floor; and can be controlled *by ones feet*; in WALL, images are *grid-wise* projected on a *wall, not connected* to individual people’s bodies, and controlled by a *conventional mouse*. Further below we define exactly all differences between WALL and FLOOR.

1.2.2. Predictions

The predictions, then, are the following:

1. *Differences between FLOOR and WALL are expected in the way people collaboratively work towards shared insight, measured by analysis of verbal- and nonverbal behavior during a creative meeting activity.*
2. *FLOOR supports social interaction, and helps team members to be attentive to one another’s personal perspective and contribution more so than WALL. That is, if the goal is to connect to each other ‘as people’, WALL is expected to be less useful as a tool than is FLOOR*
3. *FLOOR and WALL differ in terms of the way the traces become part of both sensorimotor interactions and social interaction. We expect that in FLOOR sensorimotor coupling and social interaction go hand in hand, mutually strengthening each other via FLOOR. In WALL we may expect dissociations between sensorimotor couplings, the use of WALL, and social interaction.*

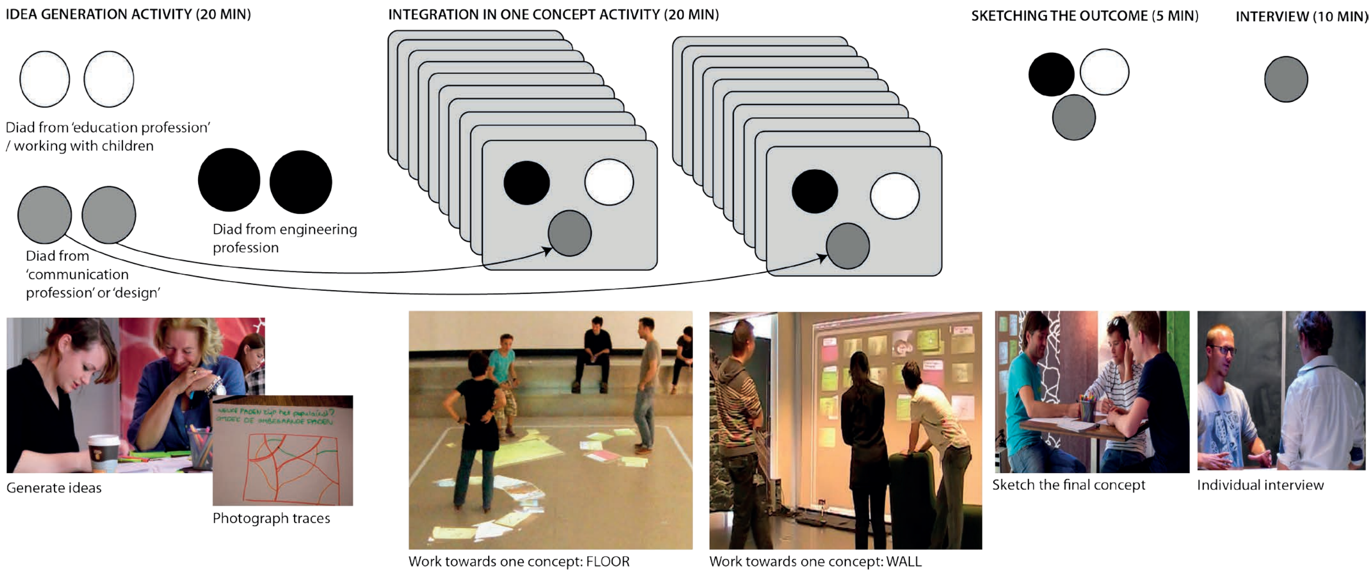
2. Method

2.1. Study design

The study design is visualized in figure 6.1. The study, comparing groups of participants interacting with two different prototypes, was situated in Future Centre LEF, Netherlands (see chapter 5). The task for the participants was to design a concept for a multi-touch game for children. Participants first created ideas and took snap-shots of the traces they found meaningful. In a second phase they were asked to create one integrated concept together with two other participants they had not met before. This triad consisted of participants from different professional backgrounds that each related to a different ‘framing’ of the creative challenge. In this second phase, triads collaborated towards a shared concept for the game, using either FLOOR or WALL as a supportive technology. We analyzed data from twenty such 20-minute ‘integration sessions’. Further details of study design, task, physical context and data acquisition are given in figure 6.1.

2.2. Procedure

1. *Practice interactions. After a short introduction, participants would be introduced to the prototype (as the triad they would later be working in) and they would later be working with and practice with all its basic interactions.*
2. *Generating ideas Following the practice, the actual experiment would begin. First, in a separate space, participants would work for 20 minutes at generating ideas, this time in diads consisting of people of the same professional background, with a version of the assignment tailored to the corresponding design frame. For example: two students of engineering background would together generate ideas and their instruction, other things being equal, would contain special focus on the multi-touch table (including a picture of the touch-table).*
3. *Creating personal traces by taking snap-shots. At the end of the idea generation phase each participant would photograph the ideas he or she found worthwhile taking to the next activity.*
4. *Integration phase (the experimental manipulation) Participants would engage in a 20 minute integration phase in triads, with one person from each frame-group in each of the two new teams. That is, one person of each diad entered FLOOR and the other person entered WALL. The instruction was to work together to create one coherent design proposal. Participants received a short reminder of the interface. They were then asked to discuss with each other what had come up in the idea generation activity and to then create one integrated concept. It was not possible in this phase to create new sketches or take further snap-shots.*
5. *Sketching the concept After this 20-minute conversation ended, the group was given a table and asked to sketch the final proposal on paper.*
6. *Post-interview Each participant was individually asked to reflect on process and outcome[1].*



Participants

60 participants were selected in three groups of 20. Group one: people with a professional background in child-education, or related (e.g., a mother of three), and no technical background. Group two: professionals or students of business communication or marketing, or related. Group three: Students of media-technology & engineering. Conditions were controlled for age and sex.

The creative task

The creative task for the participants was to come up with a concept for an interactive game for children on a touch-table in a Nature Park. The task contained at least three different frames (Schön, 1983): what possibilities does touch-table provide (the technological frame), what would children like (the user frame) and how can the Nature Park communicate to its customers by means of the game (the marketing frame). See the appendix for the exact texts of the assignments

Context

The study was undertaken at the government Future Centre LEF of the Ministry of Traffic & Waterworks (see also chapter 5). The FLOOR condition was situated in the Theatre. Due to the floor projection light was more dimmed and the ceiling considerable higher in the FLOOR condition than in the WALL condition. The WALL condition was situated right next to the theatre in one of the regular square-formed creative spaces of LEF.

Data-set

The main data set consists of video & audio of the twenty 20-min integration sessions. Video and audio acquired using high-definition cameras and microphones in front and back for CONTROL and from one side in FLOOR. All materials created by participants were photographed. An individual post-interview asked to reflect on both the process and outcome.

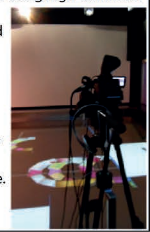


Figure 6.1. Experimental design comparing the FLOOR prototype with its control WALL.

2.3. Prototypes (experimental manipulation)

In table 6.1 the differences between FLOOR and WALL are defined.

FLOOR uses projection on the floor with a system of six projectors, creating a large canvas. Movement tracking was fully operational using the Microsoft Kinect. FLOOR implements the projection of images as a trace around ones body on the floor, following bodily movement. We introduced a small lag such that the trace would start to move only with sufficient moment, avoiding continuous gitter. Images can be scaled, re-ordered, presented to other participants, and the entire trace can be repositioned (circle-wise around the body), using various gestures by foot.

Foot-based interaction was implemented as a Wizard of Oz set-up where three assistents used Wii-motes to control the images in realtime in accordance with each participant's foot actions. Critically, participants were unaware of the Wiz-of-Oz set-up and were quite surprised when the 'secret was revealed' after the session[2].

WALL consists of a wall-sized projection of a random grid of the selected images by the participants (see table 6.1.,top right). Like in FLOOR, images could be scaled and re-ordered, this time using a conventional mouse controller placed on a small column to the right of the wall projection (figure 6.1).

Figure 6.2. The 'opening' action, which enlarges and rotates a picture such as to 'present' it to another participant.

The crucial differences between WALL and FLOOR are listed in table 6.1:

FLOOR	***WALL***
FLOOR prototype with assistents controlling the Wii-mote wizard (see figure 6.1)	*WALL prototype, images controlled by mouse (see figure 6.1)*
A prototype operationalization of relevant aspects of the Floor-it concept, where generated sticky-notes and sketches are projected as an individual trace around ones physical body	*Control version, lacking the crucial aspects that FLOOR has. The overall set-up losely resembles a digital version' of a conventional display of items on a wall*
Images projected on the floor	*Images projected on a large wall display*
Images are organized in personal sets connected to one person's body	*All images lumped together regardless of origin and randomly projected on wall*
Images are projected in a circle around ones body	*Images are projected in a 6x6 square grid on one wall, roughly from knee-height to one arms length just above the head*
Images move along with the body movements of person	*Images do not react to body movement*
Individual images are controlled using foot gestures (tap, swipe, drag)	*Individual images are controlled by conventional mouse*
Individual images can be 'opened' to others which would enlarge and rotate the picture to face the other participants (see figure 6.2)	
Each person could only interact with his/her own trace; all participants could interact in parallel	*Any person could interact with the entire set of images; only one person a time could control images by mouse*

Table 6.1. Differences between WALL and FLOOR prototypes

Figure 6.3. Extracting critical sequences (Top Left), Creating overview (Top Right), Interpretation by sketching and annotating (Bottom left and right).

2.4. Data analysis

Initially the idea was to combine both a quantitative- and qualitative analysis. The quantitative analysis involved scoring different types of 'moments of interaction' between people and the prototype and looking for differences between the two conditions. However, during the analysis it became clear that a straightforward interpretation of the quantitative data would be problematic, for reasons that surfaced during the scoring process. Appendix D discusses what the quantitative analysis entailed and the descriptive results of it, and why these proved to be problematic for straightforward interpretation, while at the same time opening up a relevant qualitative difference between the conditions as well. The results section below therefore concentrates on a qualitative analysis of the data, focused at careful and detailed descriptions of critical moments of interaction between participants and the system.

2.4.1. Qualitative analysis

The qualitative analysis proceeded in four subsequent stages (see also Figure 6.3):

7. ***Exploring the materials.*** *Going through all materials in detail, marking out and annotating each 'interaction', as explained above. Annotations were made of general patterns in how the session evolved and critical moments or salient phenomena that stood out.*
8. ***Extracting critical short sequences*** *of interaction (conversation) in the form of photo-sequences of snap-shots from the video. Writing out speech episodes.*
9. ***Creating an overview****, start clustering and naming.*
10. ***Determining the main insights****. Final interpretation was done through sketching the critical interaction moments based on video-stills and annotate them visually.*

3. Results

In this section I will describe the qualitative patterns that emerged from the analysis of the video materials. Based on a number of critical moments identified in the analysis I will describe how the group of three participants negotiated shared insight in the context of the creative task. I will specifically focus on the differential effect of the two prototypes. Although there were many commonalities between the two conditions, there were also some noticeable differences that can be attributed to the way the interaction with the system influenced the interactions between people. These differences are the main focus of the present analysis.

3.1. A general description of the conversational pattern

3.1.1. The evolution of the integrated proposal

On a broad level of description, the two conditions showed a similar pattern in the way the conversation unfolded. In both conditions, the conversation roughly followed the pattern going from 'starting up', to a phase of explaining and asking questions, which resulted in a first attempt at creating an integrated concept, after which certain problems would often arise, which were then solved by proposing a new, final idea or a satisfactory revision of the earlier proposal.

The evolution of the conversation thus showed the following sequence:

1. Starting up. Some groups would first check on each other as to what assignment they had been given in the previous phase, and what the goal would be of the current phase, or check on the others how to proceed ("So we have to come up with one concept, right?").
2. Explain and ask. Then participants would engage in a process of explaining to each other ideas and insights generated in the idea-generation phase ("Well we had this idea of a treasure hunt…").
3. First attempt. After that someone would make a first attempt at formulating an opportunity for integration ("I like this idea of a treasure hunt, maybe we could …"). Sometimes this would immediately lead to a final solution.
4. Sub-problems. Often possible problems, further thoughts or disagreements would emerge ("But it really had to be something with multitouch, right? I do not see the touch-table in this idea") . These problems would be discussed.
5. The final idea. The first formulation of the final idea would function as the resolution of the problems experienced earlier ("Maybe something like …","Yes, and then combine that with …"). The cycle of detecting a sub-problem and solving it could repeat, until the final solution would be proposed

3.1.2. Creative outcome

In response to the task of designing a multi-touch game for children to promote visiting a Nature Park, the ideas generated in both conditions are very comparable. The typical outcome involved a proposal for a fun and engaging educational game enabling children to learn about animals or plants that can be found in the Nature Park, to be played on a multi-touch table. In both conditions, discussion mostly centered on where the table should be placed (how many tables there should be), and how to combine a multitouch table with outdoor activities (a treasure hunt, spotting real animals, etc) in the park itself. In some groups, there was quick agreement. In other groups, there was more discussion. Post-interviews showed that some triads were more in agreement over the final solution than other triads. There was no clear difference between conditions on this aspect.

3.1.3. Conversational pattern

If we look at the flow of the conversation from moment to moment, in both conditions each participant contributes to the conversation by recounting experiences, expressing opinion, asking questions, casting doubts, identifying problems, suggesting solutions, offering ideas, and so on, in a pattern marked by *turn taking (Schegloff, 1991).*

Phase 2 (Explain and ask) involved a more formal taking of turns, where each person would be given the chance to explain to the others ideas generated in the first assignment. Going towards the first attempts at integrating individual ideas into one proposal, the basic pattern of conversation would be one in which two people would be responding to one another directly, while the third person would temporarily in the role of an observant listener. At some point, the third person would take her turn to speak, and the roles would shift accordingly, with one of the earlier speakers now taking the observant role.

3.1.4. Physical positioning

In FLOOR people would automatically position themselves in a circle-like fashion, and the conversation would be played out in the middle. In contrast, in WALL attention would be immediately drawn towards the wall, with people standing next to each other, facing and 'talking to' the wall. In general WALL induced various asymmetries, such as:

- One person would take lead of the mouse controller. A second person would then take the lead in initiating a line of thought, in reference to the images, while a third person would be more of a passive listener standing more to the back of the space (for examples see below).
- In WALL the triad would *either* be working with the images in which case they would mostly look at the wall land not at each other, *or* there would be a more 'reflective' kind of conversation, which meant they would face each other and this automatically also meant they would no longer use references to the images. Such sequences would alternate, or the group would stay focused on the wall throughout the session

3.2. Contrasting the two prototypes: general differences

I now turn to a more detailed comparison of the way the two prototypes had impact on the conversation.

3.2.1. Explaining individual images versus 'ones point of view'

Concerning the first part of the session, a qualitative difference that stood out was that in FLOOR, participants would not be focused on the images as such, but rather used the images as illustrations in one overall story in which they recounted the previous exercise. Along with that story, people would then tap on relevant images, presenting them to the others, in visual support of, and going along with, the overall story. In doing so, they most participants would only explicitly address a sub-set of all the images in their trace, highlighting only those images that fit the storyline.

In WALL, instead, the focus of the group activity was explicitly on the individual images. Participants would explicitly explain what each of the images meant to the others, one by one. In one session, participants did so by following the (randomly placed) order of images in the grid, discussing each picture in turn, going from top-left to bottom-right, instead of ordering the conversation person by person (as did all other groups in both conditions).

3.2.2. Cluster-talk

In both conditions teams at some point expressed the wish to cluster items in groups. This was however not part of the assignment and had not been implemented in the current prototypes. In WALL, however, it turned out people could still 'cluster' items by assigning a 'column' of images to a category, or assign the 'right side' of the wall to one cluster and 'the left side' to another. In fact, in WALL, when the first step towards the final idea has been proposed and agreed on, the activity would at some point readily evolve into a focused activity of re-organizing the images on the wall (clustering) into a desired configuration. This configuration activity in a way replaced the conversation, and creating the right cluster on the wall would come to represent the remaining negotiations concerning the concept[3]. For instance, it would be decided to put all images representing 'the final idea' to the left, and the other images to the right[4]. This means that, from that point on, the images were used not only to create a shared insight, but also to 'represent' it (in the sense of forming a temporary physical artifact that would be referred to in talk as 'the final concept'). It is in this stage that 'cluster-talk' showed up, a strongly 'deictic' form of speech that hardly contains any content word, as can be seen in the example in Excerpt 6.1. (The actual episode goes on much longer in this same fashion)

Participant A	*Participant B*
"ik denk dat dit… [lopen en wijzen]	*[verplaatst beeld]*
"I think that this … [walks and points	*[moves the image]*
"als je nou.."	*"dan moet die dus…"*
"What if you"	*"Then this one must…"*
"die moet ook " [wijzen]"	*[klikt met muis]*
"That one should also [point]"	*[clicks with mouse]*
"die eigenlijk ook [wijzen]"	*[klikt met muis]*
"that one also, really [points]"	*[clicks with mouse]*
	[many, seemingly random clicks]
"die ja!" [lopen wijzen zeggen]	*"deze?" [klik]*
"that one, yes" [walks points says]	*"this one?" [clicks]*

Excerpt 6.1, Session 12, Wall, part from a larger episode from 6.57 – 9:24

Clustering items was practically impossible in the FLOOR condition, as images would immediately move once people would move. Here instead people would negotiate the final idea using direct verbal and nonverbal interactions with no concrete placeholder representing it. Sometimes one enlarged image of one of the participants would function as a central 'meeting point' for discussing the final idea. In FLOOR, people would also make deictic references in speech, such as "I like that one", but the role that these references would have in the conversation would be very much unlike the deictic references that were part of the clustering activity in WALL.

3.3. Further analysis of differences: How to 'hook on'

One situation observed throughought the conversation in each of the sessions is when a person attempts to join in on the conversation held by the two other participants. I call this 'hooking on' to ongoing talk. By hooking-on, the individual participant can relate his own ideas and insights to the overall line of thought that is developed in the conversation. Hooking-on is different in FLOOR than in WALL:

3.3.1. Hooking-on to the conversation in FLOOR

Consider first a typical situation in FLOOR. In figure 6.4, top left, we see two women in a conversation. They refer to images in each others personal traces. There is also a continuous switching from looking at the images on the floor and directly facing each other and making eye-contact. Together this behavior shapes the coupling in conversation between these women. The man standing in the back-left is a passive by-stander.

The visual display of images in FLOOR makes it that the man is likely to be visible already in the peripheral visual field when two participants talk about an image. This makes 'hooking-on' relatively easy once the man takes a turn to speak at a natural moment of silence. He first makes verbal reference to, and points to the image that the women were themselves referencing (figure 6.4, top right). He then proceeds, once eye-contact has been established, to 'concatenate' a reference to one of his own images to the current shared attention. He 'presents his image' to the women and explains what it illustrates in relation to the conversation (Figure 6.4, bottom left). In this way the man 'graciously' carries visual attention from somewhere between the women, towards his own ideas, with his own picture as a final point of reference in this sequence.[5] This move is reaffirmed by the woman in the front who says "Yes, that one!" in a positive intonation, upon which the woman on the right makes a further move with her body opening up more fully to the man and his trace (Figure 6.4., bottom right).

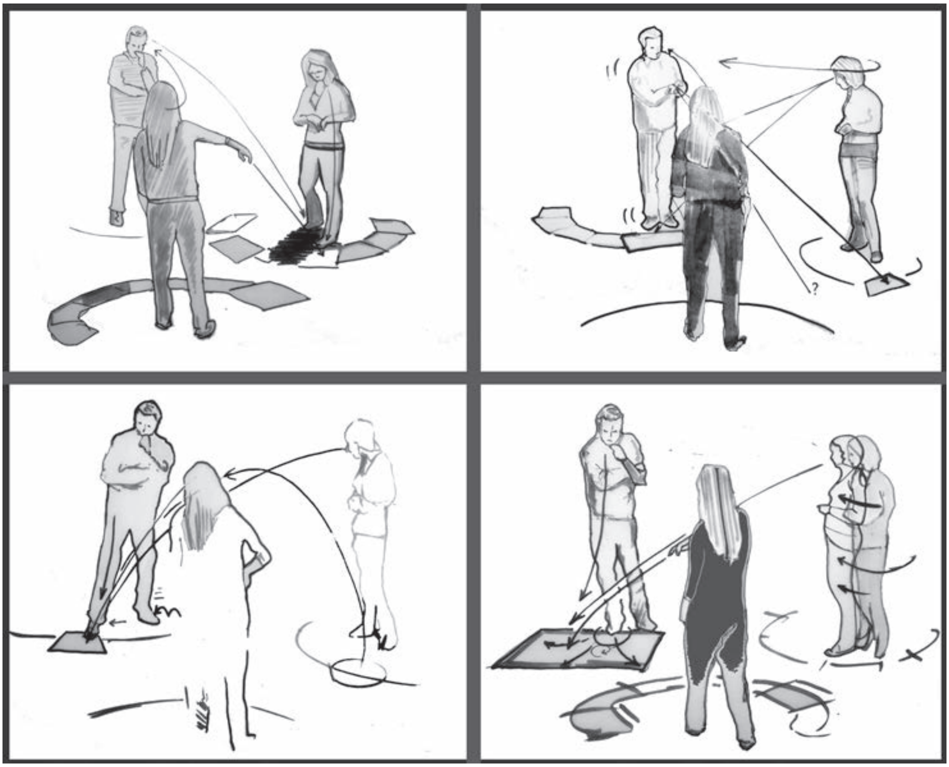


Figure 6.4: hooking on to an ongoing conversation using FLOOR: top left: two women are in conversation. Top right, intervention by the man, while referring to the images that the women were using in their talk. Bottom left, graciously moving over to his own picture, carrying with him attention by the women. Acknowledgement by the women: "Yes that one" (Woman in centre) while pointing, and opening up body position (Woman on the right).

3.3.2. Being outside, attempts at getting in

Now consider a comparable situation that was typical in WALL (Figure 6.5). Here, two men and one woman are facing the WALL. After the introduction by the researcher, one man takes the lead in explaining his ideas (Figure 6.5. top left, center position, called M), while the other man walks over to the mouse (long hair, standing on the right, R). As the two men move towards the wall and start interacting with the images (Figure 6.5, top left), the woman is still in her original position, standing in the back, taking now the role of an outside observer. M expresses his personal line of thought, speaking towards the wall, with the images as a reference (Figure 6.5, top left). R is connects to M, not by speech, but by moving images in reaction to what M says. For a while, this situation does not change. At some point we see the woman gradually moving over to the left of the man, taking position close to the wall display (Figure 6.5, top right). She positions her body in visual periphery of the other participants. At that same moment however the man in the middle turns to the right, facing R while explaining something (Figure 6.5, top right). The woman now decides to actively break into the conversation (Figure 6.5. bottom, left). She starts to speak and manages to draw attention from M, who turns to face her. He can now no longer see R, whom he was in conversation with. He switches his gaze back and forth a number of times between the two and the wall in the center.

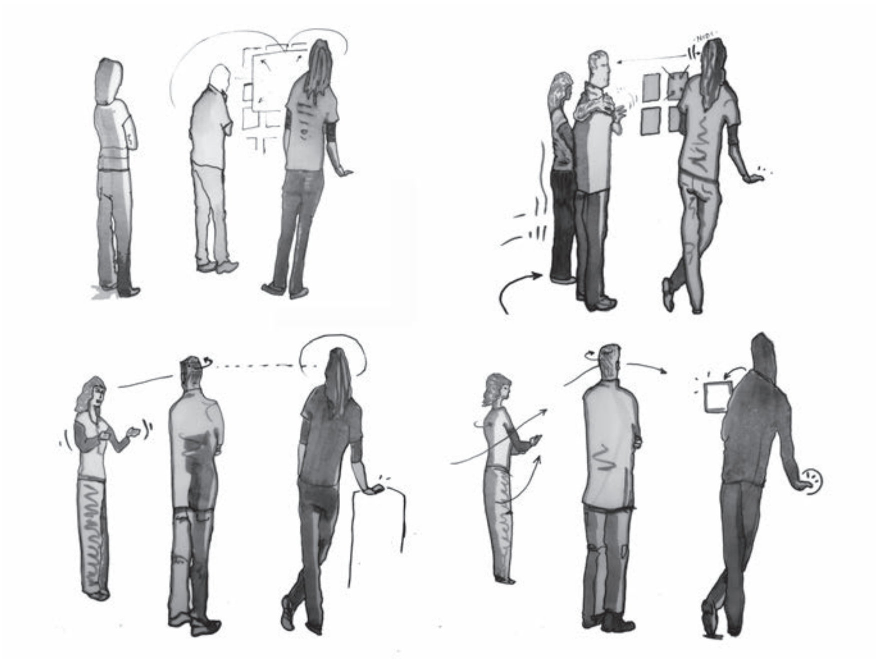


Figure 6.5. (Failed) attempt at 'hooking-on' to the conversation in WALL, details in text.

The woman starts to speak louder, actively seeks eye-contact of M, and her gestures become more pronounced. In Figure 6.5, bottom, right, we see how the woman makes a gesture, underscoring her verbal statement. This gesture happens to be a wave-like movement accidently directed towards the wall (it is not intentionally directed at any of the images). R, meanwhile, has been shuffling around images using the mouse, perhaps in random fashion, or perhaps in service of his developing a private line of thought. The result is that the woman actually 'carries' the attention of M from herself back to the wall, where M now finds himself looking at what R is doing with the images (Figure 6.5, bottom, right). After this, M moves physically closer to the wall, inspecting the image the boy has just put in front of him, and starts talking again about his own ideas, continuing his earlier line of thought, disconnected from the woman's contribution. The disconnection is affirmed nonverbally by the woman, who now turns to face the wall, folds her gesturing arm on her body, rests her hand on her mouth, and utters 'or something like that....', in a hesitant intonation, effectively giving up her attempt to 'hook on'.

3.3.3. Forcing oneself 'in'

In WALL, hooking-on to the conversation sometimes is accomplished by means of an assertive form of 'breaking-in' that we do not see in FLOOR. It is accompanied by a physical movement towards the WALL, thereby drawing attention and overruling the conversation that was taking place. For example in figure 6.6 we see how the man in the middle at some point cuts right across the conversational space. By taking the middle position in front he succeeds in gaining attention:

Figure 6.6. Actively 'forcing' oneself in by taking the centre position

In this session, the role of passive by-stander actually switches a number of times between the woman on the left (who was talking in Figure 6.6., left) and the man in the middle (who takes over in figure 6.6., right). Both change position and take over the centre stage a number of times, basically following the same strategy[6]

3.3.4. Invitations to join in and returning the favor

In figure 6.7 we see a situation observed multiple times in FLOOR but never in WALL. The woman on the left has been talking to the man in front and they both have developed a possible idea for the final concept. She now makes eye-contact with the girl in the middle. The girl has made no contribution to the conversation yet (she seems a bit shy). The woman on the left invites her to add to the conversation by asking if there is in her set perhaps a picture that might connect to the ideas as developed so far. That is, her images are not simply 'taken' and discussed as images: talk about the images is used as an invitation to the owner to contribute to the conversation. The girl 'returns the favor' by referencing back to one of the images of the woman on the left as part of her contribution to the conversation. This does not mean that people were less friendly or social in WALL. Most sessions went on quite constructive and open, in both conditions. But I have seen no instances in WALL where referencing images is used to invite the person to contribute to the conversation. Instead, referencing a picture in WALL was always directed at the content of the picture itself: it would be a matter of 'should this picture be part of the concept' and not 'do you have anything to add to the concept?'.

Figure 6.7. Actively inviting contribution and returning the favor

3.3.5. Invitation to overcome impasse

A similar kind of invitation is also used to overcome an impasse, as can be seen in figure 6.8. Here, the boy on the right was the last of three to give an overview of his results from the idea-generation phase. The girls however remark that none of his ideas relate to the Nature Park, which was part of the assignment.

Boy: "Well, yes… ehm… to do something with the Park. <He swipes back his enlarged image, (Figure 6.8., left, (1))> .. you know we have this assignment at school… and so I am already … I have all these other ideas in my head …"

At this point, there is an immiment impasse, as the girls realize that none of the ideas of the boy suffice, while they also feel that they should involve the boy's ideas in some way, which shows as follows (Figure 6.8, left):

Front girl: Yeah well, can you say what you would like to definitely have in the idea, I mean if we have to combine our three ideas, what should go into it?
Boy: Well…
Girl back: Yeah well and what is that one over there then? <Girl points at one of the boy's images that he has not spoken about (Figure 6.8., left, (2))>
Boy: O that was just a little idea…
Back Girl: …Because I see an animal there <grins>

The boy now starts to see an opportunity arising. He takes effort in getting the other picture in front and presents it to the girls. In explaining the idea he mimicks with his hands how an animal would come out of the grass at the Savanna (Figure 6.8, right, (3)). This movement is mimicked by both of the girls while they positively affirm the idea (figure 6.8, right, (4)):

Back Girl "That is something I really like .. "<looks at the other girl for confirmation>
Front Girl "Yes that you find on the table that it really becomes a way of … <etc>

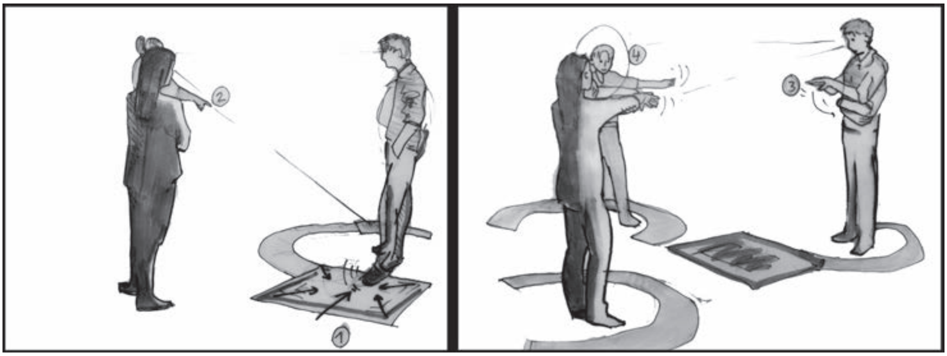


Figure 6.8: An impasse is resolved by asking about another person's trace as invitation (details in text).

3.3.6. Individual lines of thought: WALL and FLOOR

In FLOOR the transition between a moment of individual reflection and rejoining the conversation is made explicit. Looking at, or interacting with, ones own images, in a brief moment of reflection, does not disturb the process, and after this moment one can rejoin the conversation in a smooth way (See figure 6.9, left). In WALL, central attention is continuously drawn towards one, shared display. The positive aspect of this may be that people are forced to deal with one another at all times, which may enforce integration of ideas. However, there were moments in which each participant actually is momentarily 'in his own space of thoughts', as can be seen in figure 6.9, right. I suggest these are important moments for individual participants, for example as one sometimes needs to take a couple of seconds to briefly review ones own ideas and insights and check whether these still match up with the overall direction the conversation is taking. These moments are not well supported by the WALL, and often there is not enough time or space to take that moment and finish the reflection (this relates to issues discussed in chapter 4, on NOOT).

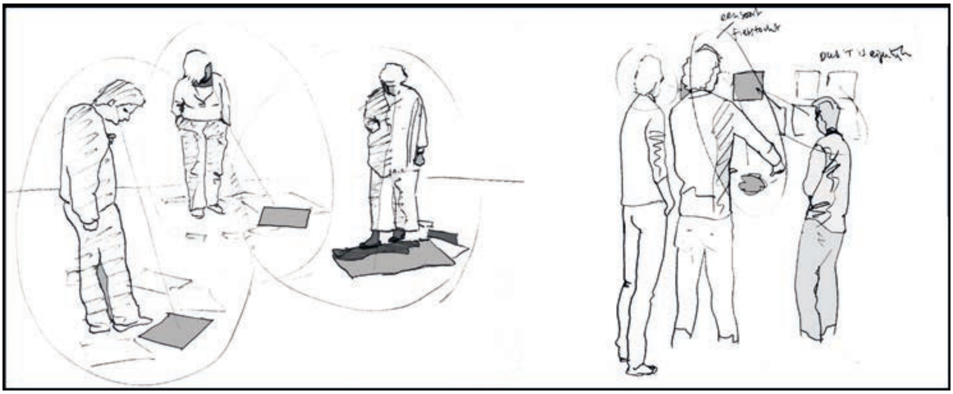


Figure 6.9, left: each person couples visually to his own trace in a moment of individual reflection, before returning to the conversation. Right: while the conversation goes on, each person has a brief moment of individual reflection. The person left is looking at the wall, not speaking. The person right is looking at the wall as well, verbalizing his own line of thought. The person in the middle also verbalizes a personal line of thought, while coupling visually to his own gestures, disconnected from the other two men and the wall.

4. Discussion of results

For this study the following predictions were formulated:

1. Differences between FLOOR and WALL are expected in the way people collaboratively work towards shared insight.
2. FLOOR supports social interaction, and helps team members to be attentive to one another's personal perspective and contribution more so than WALL.
3. FLOOR and WALL differ in terms of the way the traces become part of both sensorimotor interactions and social interaction

The results show qualitative evidence that confirm these predictions although I was unable to confirm them with quantitive measures (see appendix D).

4.3.1. What FLOOR does

In FLOOR people would start by giving a general expose of their line of thought so far. The traces functioned as a set of illustrations of partial ideas upon which a story was built. I suggest this helps people in understanding each other's overall viewpoint or perspective. In all, the patterns of interaction described in the previous section suggest that indeed FLOOR supports social interaction, and helps team members to be attentive to one another's personal perspective and contribution more so than WALL, which was the second prediction. Crucially, FLOOR works such that traces, situated in the centre between people, and connected to their owners, are used by participants in service of what I call social, interpersonal positioning. Interacting with traces, in interaction with others, signifies: this is where I stand and I acknowledge where you stand. From that basis, one can start connecting to each other from each person's respective, and mutually respected, position.

Sensorimotor couplings form a crucial part of this social positioning. Crucially, it takes place both in WALL and in FLOOR, but works out differently with respect to the role of the prototype in it. For example, the embodied process by which one 'carries' visual attention, through gestures and body positioning, from one external object to the next (as in figure 6.4) happens both in FLOOR as well as in the WALL. However, in FLOOR this helps to create a fluid coupling between people, functional to the conversation. In WALL, this coupling seems to require more effort (figure 6.5). In terms of social positioning, the wall induces a kind of asymmetry in the space of embodied action, forming a source of distraction, such that people have difficulty in connecting to each other, or find themselves outside of the process altogether. People in WALL have to make more effort to 'get themselves into' the conversation.

4.3.2. Expressive traces

In chapter 5 I reformulated the term 'external representation' to 'traces'. Presently, I propose to call these artifacts 'expressive traces', emphasizing the function as just described, where artifacts are created and used by people to 'express themselves' in relation to others.

4.3.3. What WALL does

In contrast, WALL induces its own type of dynamic. In most sessions in WALL, each picture would be discussed one by one as a separate idea. After that, it was the logical next step to try and combine these ideas in some kind of configuration, to select the best ones, and so on. Something of that happened also in FLOOR, but when individual images were referenced and discussed it would always be in relation to the fact that this was someones idea, and we could see such social effects as an invitation to join the conversation, or returning the favor with a compliment, with the images as a carrier.

In WALL context, people's attention is drawn towards the pictures, and much less to each other. The wall induces a more object-oriented, and less people-oriented mode of communication. This can be seen by the phenomenon of 'cluster-talk', where the conversation between people at some point is completely taken over by the joint activity of organizing the pictures in a certain configuration, and all conversation between people is in service of the task of clustering the items. In this way, a cluster that everybody agrees on comes to represent 'the shared insight'.

4.1. Problematic aspects of FLOOR and some insights resulting from it

In the discussion so far I have concentrated on what FLOOR facilitates and WALL doesn't. This should not be read in any way as saying that FLOOR is the better product proposal than WALL. In fact, both are incomplete as 'products'. WALL was set-up to function as the null-hypothesis in comparison to FLOOR, the two systems were not meant to be two complete concepts in competition. Varying the form of the interaction between FLOOR and WALL helped to tap into the way expressive traces function within social- and sensorimotor dynamics in the creative session. Both these systems have useful aspects that could be integrated in a final, actual design concept. And both are just parts of what would be a complete system, with many features currently still lacking, such as the ability to create new 'traces' by combining images into clusters.

Moreover, in the sessions themselves many kinds of things happened that we have no space to discuss here. This analysis should therefore not be seen as a comprehensive overview of everything that happened, rather than an analysis in service of answering the specific questions asked concerning social interaction and sensorimotor coupling, where the focus is somewhat biased to the functional properties that FLOOR either has or lacks.

Having said this, we should therefore presently discuss note a number of problems with the FLOOR prototype. For one thing, participants had more trouble with getting control over basic interaction with the digital images than in the WALL condition, and they overtly reported this. Part of this had to do with the timelag induced by the Wizard set-up.

4.1.1. Looking down versus looking up

Two participants reported it to be distracting to have to look downwards at the floor, saying that "If I look at the images I cannot see people's faces: I want to look at their faces". This made us think that the physical position of the pictures could be optimized; perhaps pictures should be projected behind people, or on their bodies, or 'everywhere', instead of purely on the floor. However, note that in WALL, people would also be practically unable to look at each others faces when they were standing next to each other facing the wall, which is what they during most of the talk. But here, nobody complained. This may actually suggest that in FLOOR people at least become aware of each other, which induces the natural need to make eyecontact, whereas in WALL, attention is focused on the pictures and people 'forget' each other.

4.1.2. Creating new traces

Teams in both conditions expressed the wish to cluster ideas, or to create new images, i.e. to make a shared expressive trace relating to what they were presently discussing. In FLOOR it was practically impossible even to make a new, shared configuration of existing images. This caused open frustration ("we cannot make a group, that is stupid"). In WALL there was less frustration because the grid structure allowed for a rudimentary form of clustering, which people readily started to do in almost all WALL sessions. In the original FLOOR-IT concept there is of course the possibility to create new clusters, that stay attached to the floor (see chapter 5), and so the frustration of this lacking functionality provides support for having such a function. Especially concerning the 'final result', one may want to look at it as a team from some distance, reflecting on what has been achieved. This may perhaps best be displayed as a configuration of items on a wall. One of the main insights of this study however is revealed precisely by *not having this conventional 'work-space of items' at eye-level, continuously drawing central attention of all participants (like in WALL): in FLOOR a different kind of conversation emerges in which people are more directed towards one another as people, and the images on the floor function more as figurative elements in the way people express themselves to others. FLOOR provides at least a first step towards answering the question of how an interactive system of expressive traces could support that kind of conversation as well.*

4.1.3. Trapped in your own idea

A problematic aspect of FLOOR that I think goes against the spirit of sensorimotor coupling is that the circle of images around a person's body actually inhibited people to walk and move: the circle often became a barrier, in which they would be confined. One reason for this is that people did not seem to want to step (in a forward movement) onto their own images. Unfortunately, when stepping backwards, images would also move along backwards, and so what happened in several cases was that a person would move ever more backwards, finally being 'trapped' in a corner by ones own trace (see figure 6.10). This is actually a nice example of a sensorimotor coupling – but unfortunately the result is inhibiting rather than enabling the conversation.

Actually, gross movement of people on floor turned out to be irrelevant to what is happening in FLOOR, which in itself is not in contradiction to sensorimotor theory. Having a conversation may involve subtle nonverbal activity, such as seeking eye-contact, positioning the body relative to that of others, connecting by pointing, gesturing, and so on (Goodwin, 2000), and this is what we saw happening. What is however missing in FLOOR is the idea of 'working actively together on something', in the literal sense of building or constructing something. For instance, in chapter 5 the idea had emerged that 'cleaning up' all the materials together would provide for a new round of reflection and creating shared insight, in the act of deciding what to keep, what to discard, and why. In a way this is what may underly the 'clustering' activity in WALL. But in the present form of FLOOR, this constructive, generative aspect of 'embodied sensemaking' is not supported with FLOOR. In FLOOR people interact physically with external materials and each other in service of sustaining the immediate social relation, as part of the ongoing conversation (Goodwin, 2000).

Figure 6.10. After having gradually been 'trapped' in a corner by his own circle, the man 'breaks' with the evolved, but undesired, coupling, by deliberately 'crossing' his own circle and walking back to a more suitable position in the space (including explicit commenting on it to the other participants while doing so).

5. General discussion

In this section I relate the current findings to my main research questions.
I first address the second question:

RQ 2. How does (the practical attempt at) designing interactive systems supporting shared insight in creative meetings, inform the theory of embodied cognition?

RQ 2.1. What is the role is of 'external representations' in the embodied cognitive process?

RQ 2.2. What is the relation between the social situatedness and the physical embodiment of cognition (sensorimotor coupling)?

I will discuss this question in an integrated fashion. The notion of external representations is now further refined by introducing the term 'expressive traces' (see 4.1.2 above). The assumption was that these traces play a binding role in connecting sensorimotor coupling to socially situated forms of sensemaking.

5.1. WALL as the 'conventional' way of dealing with expressive traces

Purely from a usability perpective FLOOR is a tool one has to learn how to use, and most users experienced some effort in trying to control the images, commenting that it was 'strange' or 'not easy' to use the system. WALL instead quite naturally connects to what people are used to when having a group meeting in a professional context: there is a canvas with information on it, and one simply starts to talk about, and organize, what is on that canvas.

5.2. Different roles for expressive traces when comparing WALL and FLOOR

From the theoretical perspective we however see an interesting phenomenon: WALL gives the images a different role in the sensemaking process than does FLOOR. FLOOR connects expressive traces both to social interaction and to sensorimotor couplings. This relates to theories on sensorimotor enactment. For example, De Jaegher states:

"Analyses of interactions and conversations show that people interindividually coordinate their movements. The coordination found in this domain is variable both in kind and in strength: among other things, people mirror each others' movements, anticipate them, temporally synchronise or desynchronise and so on."

(De Jaegher, 2009, p. 539. See also Goodwin, 2000)

WALL instead, to some extent, separates these aspects: the body's actual movements are considered irrelevant with respect to the 'cognitive' task of reconfiguring the images, and the engagements with the images on a wall to one side of the space stand in the way of making the necessary social connections, with the most salient effect that one out of a group of three easily becomes disconnected from the main process. WALL might best be seen as a 'visual display' of items of information that can be re-organized and referenced: a 'screen', that is, very much like any conventional GUI display. This is also why people found it a quite natural artifact to deal with, as we are very much used to such interfaces.

If we conceive of both WALL and FLOOR as such visual displays, enabling the presentation and manipulation of a set of 'external representations' of ideas and insights generated earlier, then FLOOR and WALL would by and large offer the same representational content. However such a vision would ignore people's continued attempts at social positioning: at making themselves known and acknowledged within the social situation of other people. And this is what distinguishes FLOOR from WALL.

5.3. What does it mean to make sense through social interaction?

Distributed cognition acknowledges the importance of social context. However, while Hutchins (1995) sees social interactions mainly as a cognitive resource for problem solving, the current analysis would claim that social interaction has its own crucial role to play. We may even propose the opposite idea: To put it bluntly: I do not engage in social relations in order to be able to use other people as a knowledge base for solving my problems; instead, the shared activity of together creating a solution to a problem is just a behavioral form, like any social ritual or game, by which we create and social relations. But even if we wouldn't go that far, we can at least conclude that social and sensorimotor processes impose their own, particular dynamic on the way people collaboratively construct a shared insight or idea, and this dynamic is not explicitly recognized if we see interaction between people purely as distributed strategy for problem solving.

To give two examples: walking towards a picture to point at a picture and thereby crossing the line of sight in WALL (figure 6.6), is not primarily a 'deictic reference', helping to express an idea more clearly, or with less cognitive effort. The observations discussed above show instead that such an action is actually a way of taking control of the (social) situation, and making sure that ones contribution gets acknowledged by the others, and will be of influence to what happens next. Similarly, pointing at another person's trace on FLOOR and asking what it means (figure 6.8), is not necessarily the process by which a person uses an external representation to communicate an insight from one person to the other. As the example in section 3.3.5 shows it is in the first place a way to connect oneself to the other, and to invite this other person to join in on the conversation, that is, to become part of the group process. These kinds of effects are more readily explained by theories of socially situated, embodied processes (Clancey, 1997; Goodwin, 2000; Robertson, 1997; deJaegher & DiPaolo; 2007) than by notions of external representation or computation. In the words of Clancey, 1997:

"The understanding I am constructing and affirming [by creating an external representation based on my embodied experience] is my conception of my self: who I am and what is happening to me ... as a social actor ...constrained by social norms and right now playing an interactive role."

(Clancey, 1997)

The phenomena observed in the present thus hint at something beyond simply 'collaboratively reaching an understanding' that stands apart from who we are as people: they suggest that the understanding is formed on the basis of the social relation that is formed between people: if you and I socially position ourselves in relation to each other, this means we are in the process of 'participatory sensemaking'.

(DeJaegher, 2009)

5.4. Consequences for design

I now discuss the first, design-oriented research question:

RQ 1. How may we design interactive systems in support of embodied cognition?

RQ 1.1. How does embodied cognition inform designing the relation between the digital process and physical form of the interactive system?

RQ 1.2. How does embodied cognition inform designing for the way in which the interactive system at large connects to people's real-world, embodied and situated practices?

The question for design is what the interactive system should support in relation to the ideas put forward in the previous section. In WALL, the 'shared cognitive task' folds back on the 2d space of the WALL itself: What 'is happening' is happening 'on the wall': 'where the action is', to use Dourish's words, is on the wall, where the images are moving. This would all be fine if the content of the images would contain all that is relevant to the task at hand, and if reorganizing these images would fully represent 'the shared insight' as it is created in the interaction between people. But as we have seen, this is not the complete story.

For one thing, what is not in the images is the question of who made them, and what that says about the personal 'sensemaking' connection that this individual has to the process as a whole. Social coordination in the space also takes place in WALL, but it is not supported by the interactive system. For instance, people would actually stop interacting with the wall and have a separate talk standing in a circle. In the FLOOR the process was never centered on the images, and if a picture was in the group's attention, it was always 'someone's' picture being considered. "The action", in FLOOR, is always right within the ongoing verbal and nonverbal interactions between the people. Images play a crucial role in these interactions. They become part of the socio-sensorimotor couplings formed between people, for instance in 'carrying' visual attention from one person's trace to the other, thereby seamlessly connecting between two personal perspectives. The graceful carrying of visual attention, in figure 6.4., reminds one of what Tim Ingold has called 'wayfaring' (Ingold, 2005), to be contrasted from the discrete 'transport', from one state to the next.

A wayfarer establishes his path in a rich process, where he relates to the environment and other humans: ... the actors are actively part of the process or "alongly integrated".

(Ingold 2005)

In the present context, expressive traces reconfigure the path of the wayfarer (i.e. the participant): they help create sensorimotor couplings with other participants that would be more difficult to sustain without external support. Ideas like wayfaring have actually inspired new kinds of skillful, embodied design techniques (Buur et al, 2004; Jensen Buur & Djajadiningrat, 2005).

5.4.1. The relation between the digital process and the physical space

Cognition, on this latter view, is an achievement brought about by people in interaction with each other and external artefacts in embodied space. This is not the world of digital objects projected on a surface: it is the actual space in which one finds ones own body. In response to RQ 1.1., then, we can say that in FLOOR, expressive artifacts, even if implemented as digital projections, are part of the embodied space, and take part in the embodied interactions in that space, and they are not represention of it, living in a separate, digital space.

All of this does not say that distributed cognitive strategies as described in Hutchins (1995) do not occur, or are unimportant: we have seen many instances of that kind of interaction in the data as well. The fact that people started to use the WALL for the purpose of clustering, thereby creating a temporary placeholder of the final result that people could refer to (even though we had designed WALL so as to make this difficult to do) is a case in point. It shows that 'epistemic actions' (see introduction) are important and used in all kinds of settings, even if the design of the system works against it.

5.4.2. The role of the system in the embodied, situated practice

However, if we consider the overall process by which a creative team makes sense of the task and settles on a shared outcome, the physical manipulation of external traces is not meant purely to store memories, nor to offload computation: interaction with traces actually enables one to socially position oneself to others, and create a suitable social coordination between people. This socio-sensorimotor aspect of expressive traces is largely ignored, and may even be obstructed in a set-up like WALL. But it forms the very foundation on which FLOOR, as an instance of EC design, is created. At the same time, specific problematic interactive properties of FLOOR, such as the 'boundary' created by ones own traces, highlight the way in which such a system can impact the socio-sensorimotor process in which the user is involved, and asks for further research in how to design the system to support rather than inhibit the process at least in this particular case. In answer to RQ 2.2., I therefore conclude that a system that offers ways for people to use expressive traces, in order to to socially position themselves through sensorimotor couplings, firmly integrates such a system as part of people's embodied, situated practice.

1 *Participants were asked both about the process (how well did you manage to integrate ideas with one another? Are you comfortable with the end-result?) and their framing of the outcome (can you tell me in your own words what the final idea is?), first without and then with the sketch as a reference.*

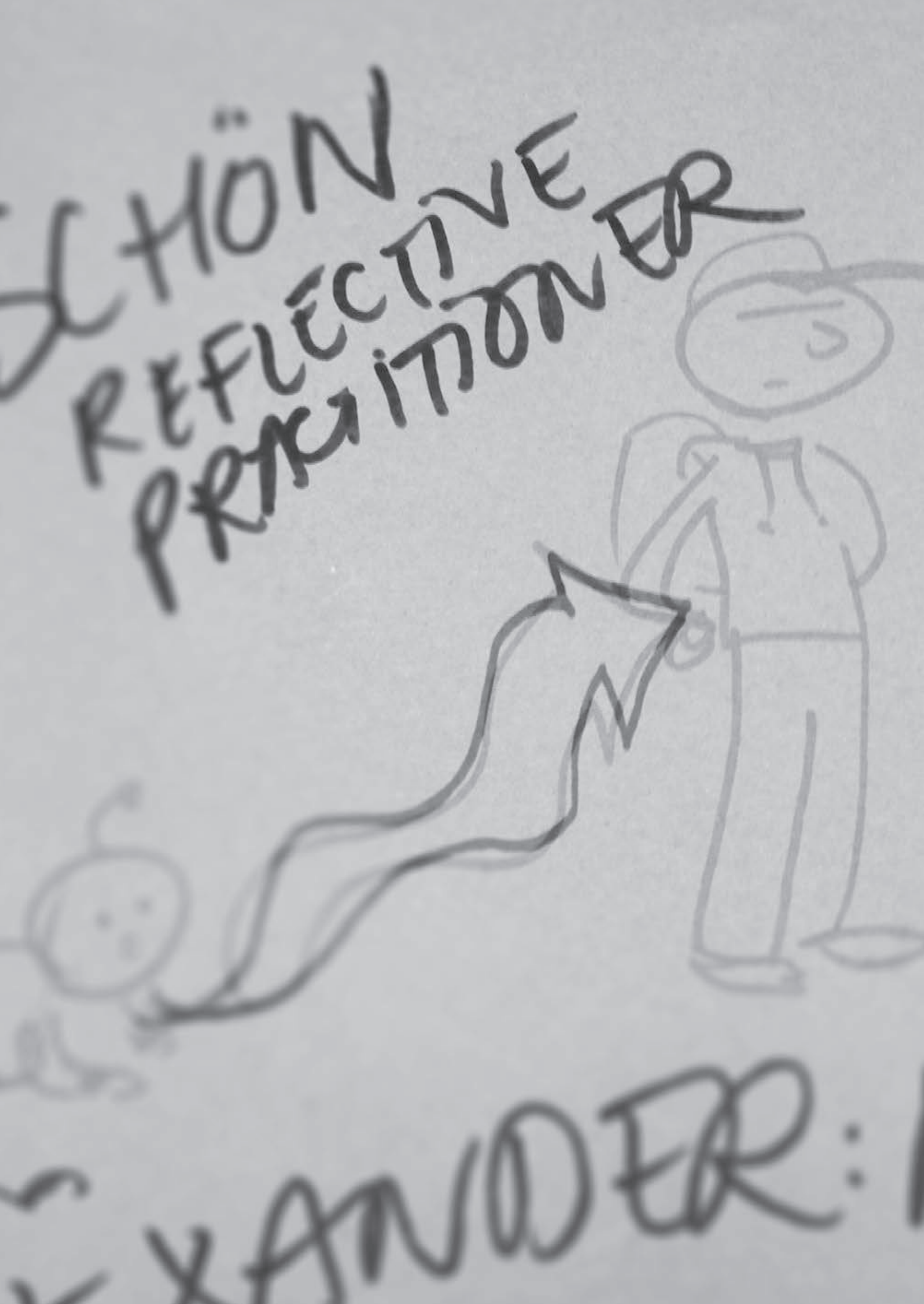
2 *We discarded two trial sessions and the first experimental session, as in these sessions there were still people noticing the Wizard set-up. From session four onwards the assistant controllers were so skilled in their task that their role was no longer noticed by participants. People did sometimes experience the system to be 'less responsive' or less 'sensitive' than desired, having to redo certain actions before their action would finally be 'detected' by the system. More on this in the discussion.*

3 *At the same time, however, in WALL triads would also be seen to at some point step away from the WALL and the clustering task they had assigned themselves to do, and discuss some further issues concerning the concept, standing in a circle, while making no reference to the WALL at all.*

4 *In fact we had tried in the design to avoid the possibility of clustering, as this was also not possible in the present implementation of FLOOR. For instance, in the grid there could be no 'white space', between items. But the teams nevertheless managed to find a way to cluster, by designating columns to different categories of items.*

5 *This episode of social interaction ends with the woman in front reconnecting to the woman on the right with verbal expression, accompanied by a small hand gesture and head move, which ends in direct eye-contact, thereby 'closing' the circle that binds the three participants together. This last connection is however not shared with the man, who is again engaged in a private manner with his own image, and has lost nonverbal contact with the women. But this does not mean he is completely out of the process. Although, relative to the two girls, this man is and remains the most passive participant in the session, he is not neglected nor refused to enter the conversation, and at various moments he enters and leaves the conversation in a fluid way, similar as described.*

6 *This 'power struggle' is supported by the fact that a quite explicit disagreement is played out later on in the session, with a strong discussion that is not fully resolved and continues during sketching the concept, where we see that actually two sketches are made, with the the two men creating and referring to the one and the woman creating and referring in talk to the other sketch.*


CHÖN
REFLECTIVE
PRACTITIONER
XANDER:

Intermezzo: Sketching insights

Sketching insights

I once participated in a day-lasting creative workshop, involving a large group of designers and creative professionals with various backgrounds. In a plenary morning session, my role was to visually sketch important themes, insights and ideas on the wall, in parallel to the actual conversation that was taking place in that same space. Later on, I photographed all of the visual elements and tried to create a storyboard showing the 'order of appearance', but it proved very difficult to trace back the temporal order of my own sketching. One may of course ask whether it important to do that: whether any structure in the *process of creating* a representational artifact tells you anything relevant about its content. I had been sketching 'what people were saying', and so that information should be *in* the sketch, not?

Figure I.1. Talking about my sketches with a session participant.

However, based on the insights resulting from this thesis, I suggest we reject this idea. The evolution of the sketch does contain information that the sketch as such does not, and vice versa. More specifically, the way one engages with the sketch is what brings you the insight that you will then later attribute, in the way you speak about the sketch to others, to the sketch itself. This engagement is a dynamical process by definition, involving interactive couplings to the world, evolving and dissolving over time.

Back to the session. When I discussed the gap in my memory with a participant, she said: "I do remember some of the order of these sketches because I am associating them with what I can remember from how the conversation in the group evolved and who spoke first and who spoke next." This was exactly the experience that I missed! It implies that the participant's engagement of being 'inside' the actual conversation, including interactions with other people, enabled here to remember things that I could not, as I had been primarily engaged with creating the sketch. Even though we had been in the same room at the same time, I mostly remembered what I was thinking when I heard people speaking, and this primarily involved deciding what to draw in a number of scenes, but there wasn't much need for me to attach meaning to the order of their creation because i*n terms of the sketch* they were purely a sequence of unrelated 'snapshots'.

Now in many other situations, either in creative meetings, or in everyday life, these two kinds of engagement are not so neatly separated. For example, in most creative sessions, people seamlessly switch between either being involved in the continuous flow of the conversation, or being involved in the 'offline' process of creating on-the-fly descriptions of particular elements that somehow stand out from that continuous experiential flow. Along with that seamless switching, there grows an external collection of 'expressive traces', shaped, transformed, and used as a scaffolding structure for developing shared insight in the group as a whole. In the NOOT study, we explored ways to intervene into precisely this switching process, and support the type of conversation I was having with that participant, enabling the sharing of individual reflection in order to create shared insight.

Let us return to the anecdote once more. As I was sketching, I never really wondered what we would actually do with these sketches later on. I simply assumed it was useful to have a 'record' of what we had been discussing. As it turned out, 'we', as a group, didn't do all that much with 'my' record. This may have to do with the fact that most other people in the session didn't relate personally to the sketches, if only because they hadn't been actively involved in creating them: these sketches were 'mine', not 'theirs'. And this may have to do with the fact that I was physically positioned at quite a distance at the wall, away from the large circle of people sitting in chairs, discussing themes while directly facing each other. And so it was me who carried 'my sketches' to the afternoon meeting in the central hall, who attached them to the wall again, and it was me who at times referred to these drawings in the afternoon discussions.

In contrast, in that same afternoon, participants were also asked to divide up in groups and create a lo-fi prototype to further explore the session challenge. This time, a sense of personal ownership did emerge: the mock-ups were not just expressions of 'ideas', but at the same time functioned to position the perspective *of that particular subgroup* in relation to the other groups and the group as a whole. The mock-ups signified both how that group had come to understand the challenge and the particular way in which these people had become personally engaged with the challenge. It said something about the people just as much as it expressed their insight into the challenge, or rather, it signified the relation between those aspects.

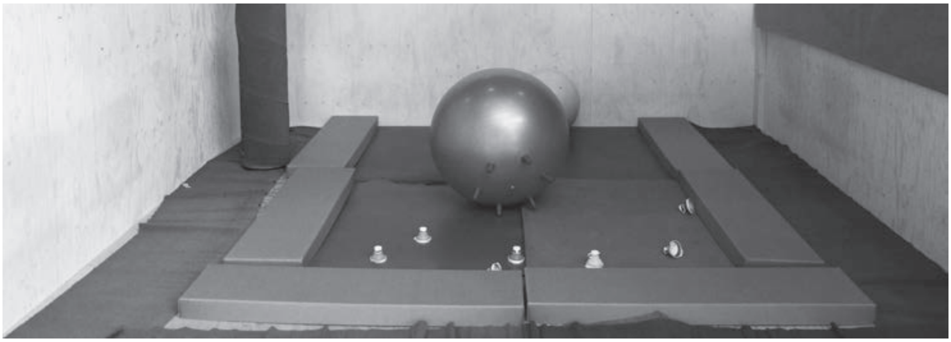


Figure I.2. One of the collaboratively created mock-ups from the afternoon session.

This meant, for one thing, that we couldn't simply select the 'best' idea and discard the others, since this would neglect the people behind that prototype and their involvement with the session. All of these prototypes were part of the web of social relations that had been emerging, and this web was a crucial part of the shared insight of the group as a whole. This interpersonal process, where people use expressive traces to get connected to the evolving insight in the group as a whole, was the central theme to study called TRACES, which focused on enabling people to gradually move from involvement with their own, individual scaffolds to shared commitment to group-level insight.

Towards conclusions

As one can see, in this anecdote, practically all of the main topics and insights of this thesis pass the scene. The events just described took place in actuality, as I recounted them here. The interpretations, however, are of course my 'revisionist' framings afterwards, based on the insights developed over the course of this investigation. I offer this 'sketch' of the main insights as a concrete example, a 'cognitive scaffold', if you wish, on our way to the discussion and conclusions drawn in the final chapters.


Cafetaria
CHAO
Marieke
HOGESCHOOL

7.

Theoretical reflections:
Making sense of design

' T ain't what you do, it's the way that you do it.

Sy Oliver & Trummy Young

In this chapter I reflect on the two design cases at large and on the insights that emerged from the series of design iterations, including the various user studies. I reflect on how our practical attempts at designing interactive systems shaped my understanding of embodied cognition. I subsequently weave together some common threads and relate the findings back to the theory that was put forward in chapter 2.

The aim for this chapter is to give answer to the main theoretical question:

RQ. 2. How does (the practical attempt at) designing interactive systems for shared insight in creative meetings inform the theory of embodied cognition?

2.1. What is the role is of 'external representations' in the embodied cognitive process?

2.2. What is the relation between socially situated practices and sensorimotor coupling?

In the final chapter, following after this one, I take up to the design-oriented question: how to design for embodied cognition.

1. Relation to chapter 2

As explained in chapter 2, the three variations of EC and the way I relate them to design in that chapter did not precede the practical design work, but evolved in parallel to it. The reflections and discussion presented below can therefore be seen as a final discussion of theory that completes the discussion started in chapter 2. Chapter 2 presents the theory as framed 'in advance', before the actual design cases, and refines the main research and design questions. The present chapter instead 'looks back', discussing many of the same themes, this time explicitly referring to concrete design experiences and study outcomes[1], and drawing general conclusions. I will also give a brief *extension* of the literature base reviewed in chapter 2, discussing in the current chapter in some detail the work of Bill Clancey, whom I think gets very near describing the core of the final insights that emerged from the design cases. Clancey is one of the few to discuss the *relation* between socially situated practices, sensorimotor couplings and representational artifacts. He draws from *transactional* theories, which puts a person's ways of personal expression by means of interacting with the world at the center stage. This perspective has some resemblances to the phenomenological orientation (Clancey, 1997). The reason to discuss his work here, and not earlier, is that I only came to see its specific relevance in rereading it in my final reflections[2].

2. Reflecting on the design cases

Looking back, I guess have been continuously trying to 'deconstruct' interactive systems design, by showing in various ways how the majority of interactive systems today are still designed and (assumed to be) used, on the basis of implicit, lingering Cognitivist intuitions. In response, my 'constructive' aim was to try and see what interactive systems would start to look like when we would reject such intuitions, adopting instead as alternative grounds principles of Embodied Cognition.

This goal seemed quite problematic right from the outset. Interactive systems, after all, are computers. And computers are technological artifacts that evolved in close alliance with the development of the disembodied theory of cognition called Cognitivism (Miller, 2003; Hayles, 1999; Wiener, 1948). Computers represent, compute, abstract, modularize, rationalize, plan ahead, they treat input as separate from output: basically computers are just about everything that EC claims human cognition is not (Van Dijk, 2009). How could I ever transform these Cartesian beasts into tools for embodied cognition, operating in actual contexts of practice?

2.1. Using the environment for cognition

In the first explorations of NOOT (chapter 4, iteration 1) my focus was strongly on enabling people to use the physical environment for cognitive processes, i.e., using objects and structure in the creative meeting space as a 'cognitive scaffold' (Clark, 1997). This approach relates to Norman's idea of 'knowledge in the world' (Norman, 2002) and Kirsh's epistemic actions (Kirsh & Maglio, 1994) reducing cognitive load (Kirsh, 2010).

2.1.1. Two Notes from Design

Two events during the first iterations of NOOT were particularly insightful in revisiting this interpretation. The first was very early on in the project, when design students were prototyping an interactive tangible that could transform writings on paper to digital projections on the wall. One day, the students came to me and said: "Listen, you want us to digitalize written stuff on paper. But we don't see the point in that. And, what we really want to work with is audio." (Two of the students were personally interested in audio-technology). A purely personal interest in audio did not convince me to change course just like that. Yet they got me moving with another argument. They showed videotapes of several creative sessions from the brainstorm company we were working with and said: "Look, participants talk a lot about the ideas they come up with, but they hardly write down anything. They may write down just one word on a sticky-note, and then explain in quite a few more words what they mean to say with what they have just written. So we want to record audio and stick *that* to the tangible object instead"[3]. This step formed the basis for the audio-recording function of NOOT.

Later on, while prototyping NOOT, we had a long discussion on *how long* the sample should be. The students were implicitly thinking along the lines of a distributed form of memory: Assuming the audio should contain 'the idea' as it was uttered by a participant in a brainstorm, they wanted to make sure that all the relevant speech was captured by the sample. I saw all kinds of problems in making this work, because it would ask of the technology to be 'intelligent', i.e. to 'know' certain things on the basis of which to decide when to start recording and when to stop. Instead, I offered that the samples can all be of a fixed length and do not need to be *precise* or complete in what they capture at all: NOOT provides external triggers that the group can use to revive a discussion held earlier; and it would already be enriching if some of the detail and atmosphere of the original conversation could be re-experienced (Van Dijk et al, 2008).

2.1.2. The bias towards the 'external memory' view, and moving beyond it

Both these moments in the design process reflect a pattern in which the system seemed to move towards becoming a kind of information storage device, with as its main function the recording, storing and presenting *outcomes* of a creative conversation. In both examples this direction then lead to a problem (Why digitalize physical sticky-notes? What for? How can we know that the relevant talk is captured in the audio-sample? How long should the sample be?). And the solution in each case was a move *away* from the storage-metaphor, towards more forms of environmental scaffolding. I abandoned a straightforward application of 'knowledge in the world' (Norman, 2002).

2.2. Nudging sensorimotor dynamics

One reason to abandon the distributed storage idea was that part of the theory I was trying to apply focused less on representation and much more on behavioral dynamics. These sensorimotor theories, based on work in robotics (Clark, 1997; Brooks, 1991) dynamical systems theory (Thelen & Smith, 1994; Kelso, 1995) and ecological psychology (Gibson, 1979) kept nudging me to thinking about tangible objects and the physical space as creating affordances for action, and enabling the formation of sensorimotor couplings (Clark, 1997). In these theories, perception is for action, and taking action in turn shapes ones perception (Gibson, 1979). It suggested that what is important about the 'external loop' through the environment is not whether helps a person to represent (store, retrieve) something, or to compute something: what is important first and foremost is that it helps to create a stability in a person's behavioral routines. Merleau-Ponty refers to this ongoing interaction as moving towards 'maximum grip' (Merleau-Ponty, 1962). Sensorimotor principles were slowly growing into the concept of NOOT, but we couldn't quite get our heads around it. For instance, we spend a lot of time thinking about the physical form of the NOOT-clip, but over the iterations this issue became actually less important and the focus turned more to the whole network of clips as spatially organized in the creative space. Meanwhile, other aspects took the foreground, in particular, the situated human *practice* in which NOOT should function.

2.3. Situating the system in a practice

A third line of thought that was present at start but only came into view strongly later on in the NOOT project. It was revived by my rereading of Lucy Suchman's Plans and Situated Actions, in its new, revised edition (Suchman, 2007). I realized that I had never quite understood the significance of the fact that Suchman comes from anthropology, and uses methods and theory from the social sciences, which are a world apart from cognitive science and cognitive psychology (Agre, 1997). I realized the *situated* aspect of cognition means not so much that the system is distributed in the environment, but rather that the system is *situated* in the environment: it is but one *element* in human *practice*. Drawing on (Klemmer et al, 2006) we explicitly discussed in the team how we could add, or augment, the existing practice, rather than *replace* it by first creating a digital version it and then attach a tangible user interface to that digital version. For example, NOOT was designed to be a handy physical placeholder for sticky-notes and sketches, which were the prime artifacts used in the practice as we had observed it. Activating a NOOT, in our first interpretations of it, should be totally unobtrusive: it was envisioned to be a by-effect of clipping the paper to the placeholder. And where the clip would be placed, and how it would be used, would be determined by the ways people normally position and use sticky-notes (chapter 4, iteration 1).

2.3.1. Appropriation of the system and transformation of the practice

But when we observed and interviewed facilitator F and his session participants (chapter 4, iteration 2), I realized that we had made a mistake in trying to design an unobtrusive system that would seamlessly match existing practices. NOOT was anything but seamlessly integrated. I realized it makes little sense to try and create an unobtrusive 'add-on' system and 'stick it onto' and existing practice. Practices don't work that way. NOOT clips were not used as an extension of sticky-notes. NOOT was not enhancing the memory function of sticky-notes: NOOT turned out to have its own potential, apart from sticky-notes, creating a completely new kind of scaffold (chapter 4, iteration 2). Finding out what this function was demanded a process of appropriation for the user, and it also meant several problems needed to be resolved by us designers. But in any case it we found out that marking a moment with NOOT was an intentional, expressive act that meant something to the person acting, not an implicit by-effect of something else.

2.3.2. Sensorimotor couplings as situated in the practice

Sensorimotor couplings came back in view when I recognized how the routine of taking a clip, making the mark and position it in space helps a person to 'fix' a fleeting moment in experience that may otherwise have gone unnoticed, and it effectively changes a persons' way of perceiving the situation, turning her, if only for a moment, into a reflective listener (Schön; 1983).

However, just playing audio fragments at random over central speakers did not make sense to participants. Speech is part of a social interaction and operated according to rules of turn taking (Schegloff, 1991). This made me realize once more the audio-fragments were not in and of themselves meaningful: they are representational artifacts that *people use* to *communicate with others*. So if someone would say "Hey everybody, I think *this* may be something" (and play a NOOT clip), it would be the social context of that person giving that introduction that would frame the way people would understand what was subsequently played over the speakers. This was the moment at which the *social* aspect of a situated practice became really important.

2.4. The social turn

Meanwhile, the first phase of the TRACES project had started, with first the co-design weeks and later the development of the FLOOR-IT concept. The co-design sessions confirmed the importance of social interaction (chapter 5). At the same time a discrepancy could be observed: On the one hand, people would *talk about* representational artifacts (sticky-notes) as if these *were* 'the ideas and insights', and they collected and saved them, either transporting them between sub-sessions, or taking them home at the end of the day. On the other hand, these sticky-notes were not at all sufficient for retaining insights and moreover, people were aware of this fact. External representations were useful mostly *within* a session, as deictic references that people would point to in service of communication and personal reflection in the moment itself. We turned our attention once more to how these physical artifacts function in ongoing session activity, and not to their ability to store and transmit content. At that same time, a function of NOOT we saw emerging in its final iteration depended on the fact that the action of taking a clip is publicly *visible* to others and *addressable*, especially since the physical clip will be a publicly available object in the space (Heath & Luff, 1991; Suchman, 2007; Dourish, 2001). Through its public availability, NOOT could potentially link individual moments of reflection to group-level development of shared insight. In the co-design weeks, similar ideas were emerging as well (e.g. the Van Berlo concept that makes explicit 'where everybody is with their thoughts').

2.5. Back to the body

The opportunity we had found for interactive systems was to enable people to create and use external 'traces' of their sense-making activities that could subsequently be used as scaffolds in social coordination towards shared insight at the group level. This related most strongly to theories of social practices. Grounding embodied cognition firmly in social interaction was not our starting intuition, and it also not something all theories of EC would readily accept. Yet our experiences in designing and observing the use of our prototypes and mock-ups made it so that we simply could not ignore the social factor: people were always primarily making sense in interaction with each other, much more so than 'with' the physical environment.

Given this social foundation, 'getting the body back in' was not straightforward. Theoretically, I was interested in connecting my recent 'social turn' to sensorimotor theory. In terms of design, we needed some constraints that could inform decisions at the concrete level of physical interaction between the user and the interactive system. For example, we needed to decide whether and why to use sound or light, real-time responses or slowly evolving rhythms, touch, haptics, gestures, a 2x2 meter projection surface or a 20x20 meter one; that is, we needed to design concretely the form of the physical objects and the form of the interactive behavior that the system should have. Social practice theories themselves do not really constrain design decisions at this level of concreteness, as they primarily describe phenomena at the level of cultural, linguistic and social meaning (Geertz, 1973; for an exception see Goodwin, 2000). And we did not want to design forms on the basis of metaphorical mappings based on a distributed representation and computation, as in the classical tangible user interfaces (Ishii & Ullmer, 1997; Dourish, 2001). In fact, the theoretical question and the design question were really just asking the same thing, and we could use the design solution to answer the research question: how to integrate social interaction with sensorimotor interaction.

In the designers' integration workshop, following the InCompanyLabs (chapter 5) we managed to reconnect bodily action to two forms of social scaffolding that had been developed earlier in the co-design concepts. We connected sensorimotor activity to 1) a growing physical trace consisting of images on a large floor, which were created and organized as part of ongoing social interactions (an idea taken from the LEF concept) and 2) a personal trace consisting of snap-shots taken by that one person of sticky-notes and sketches (or anything else) that was considered important to that person for making sense for herself of the group activity (taken from the Van Berlo concept).

In this workshop we learned not *represent* the body in making these connections (as the avatar in the Van Berlo concept in fact does, chapter 5) but to let the body 'represent itself'. In a normal session, people also create 'traces' (a sticky-note is a trace), but how and where these traces will subsequently be used depends on all kinds of circumstances. In FLOOR-IT traces become directly connected to a persons' body, which means the trace is always everywhere that person is, and can automatically be taken up as a scaffold in any social interaction with that person. In other words, the connection between sensorimotor coupling and social scaffolding is made at the physical body itself, right where 'the action is' (Dourish, 2001). Only then, *on the basis* of that connection, will people gradually start to build a shared space of traces that endure on the floor with the aim of grounding the final configuration of items firmly in the personal commitment and engagements of each of the participants.

2.6. Sociosensorimotor couplings, expressive traces, and personal identity

In the user study, where we compared FLOOR and WALL (chapter 6) we saw in actual practice the subtle relations between sensorimotor coupling and social interaction, the way they were scaffolded by traces. Traces play an important role in sustaining what I call 'socio-sensorimotor couplings' in the reflections of chapter 6, for lack of a better term. The images projected on the wall, and those on the floor, functioned as objects that people use to make a *personal expression* that was visible to others, for example by showing a picture to another person and telling something along with it, but also by asking a question of a picture, criticizing it, or suggesting to combine it with another picture, and so on. Each of these acts of self-expression is a way of taking up a *social position* in relation to the other participants, repositioning oneself, or confirming ones position and strengthening it, and this social positioning formed a crucial element in the way the group as a whole came to an understanding of the design challenge they were faced with. The differences between FLOOR and WALL provided confirmation of the idea that this process was really tied into the sensorimotor level of interactions with the system, and that sensorimotor couplings could therefore not be seen as operating separately from socially situated cognitive processes.

When I analyzed the role that traces played in this process, I decided to call them 'expressive traces'. This is because *expressive traces* not only relate to the idea or insight, but also to the person that has the insight, and her relation to the other participants. To give just one example, this means one cannot carelessly propose to discard a sticky-note just because it seems a bad idea: as this artifact is associated *with someone*, this means one is dealing with that person as well, and in social dealings proposing to discard something that somebody else found worthwhile is a risky affair.

In summary, action geared towards creating shared insight, is always at the same time directed towards creating and sustaining social relations, wherein people position themselves relative to others. This means getting a grip on the design challenge, is very much the same process as 'getting a grip on each other'.

3. Consequences for embodied cognition theory

3.1. De/re-constructing chapter 2

In chapter 2, I presented EC in three variations. Even though similar variations have been proposed (e.g Anderson, 2003), it was only on the basis of my concrete experiences during the two design cases that I could define these particular variations of EC. The categorization I settled on is not trivial: for instance, I have split up the more general idea of 'situatedness' (Hutchins, 1995; Clancey, 1997; Suchman, 2007) into on the one hand the ethnographically inspired theories of socially situated practices (Suchman, 2007) and on the other hand the more cognitive science oriented work on distributed cognition (Hutchins, 1995; Kirsh, 2010) which I called distributed representation and computation (DRC). I also neglected certain work (see chapter 2 for details). I chose to ignore the fact that various roboticists, which I discussed under the heading of Sensorimotor Coupling and Enactment, themselves explain their work in terms of how the robot 'uses' his interactions with the environment to *compute a solution to a problem*. This latter interpretation effectively sees these robots as instances of DRC (Brooks, 1991[4]). Instead, I have discussed another aspect of these robots: their ability to create on the fly, dynamical couplings to the environment, which makes them an instance of the sensorimotor view, focusing on self-organizing patterns of interactive behavior. Furthermore, not all theorists on sensorimotor coupling adhere to a phenomenological, or even enactive perspective (Beer, 2008), while others do so explicitly (e.g Dreyfus, 2002; Noe, 2004).

My reshuffling and relabeling of existing theories was the result of the practical pursuit of trying to build interactive systems in support of embodied cognition, and experiencing in the design process being pulled into a number of distinct conceptual directions, as recounted in the reflections above. So, with chapter 2 now in place, and the design reflections in hand, we can presently discuss its final consequences for the theory of Embodied Cognition.

3.2. Beyond distributed representation and computation

The NOOT study resulted in distinguishing between a DRC and more radical embodied proposals. In trying to 'go beyond' DRC, the question of course becomes all the more pressing what the role is of 'external, representational artifacts' if it is not just simply to represent or compute things (Q. 2.2.) Furthermore, the more open question stated in chapter 1 concerning the relation between the role of 'bodily interaction' and 'the social situatedness' of cognition (Q. 2.1.) can now be reformulated by asking how, in going beyond DRC, we may find a way to integrate principles social situated practices and sensorimotor, enactive coupling; the two more radical proposals.

3.2.1. EC and design: What lies beyond DRC

If we fail to distinguish between a distributed account and more radical alternatives, it may seem that 'embodied interaction' is just a form of distributed representation. Applied to design, this gives the impression that what we need to create is suitable physical representations of digital contents, such that we may interact with digital content in 'embodied ways'. Paul Dourish seems to promote this interpretation in "Where the action is" (Dourish, 2001). I am highly sympathetic to this seminal work on embodiment and phenomenology in the field of HCI and interactive systems design. However, Dourish curiously maps the works of Merleau-Ponty and Gibson straightforwardly onto Ishii's tangible media. In my view he thereby fails to see that Ishii creates distributed representation and computation (DRC), and that DRC is a class of theory a world apart from Merleau-Ponty (1962) as well as from Gibson (1979, see the discussion in chapter 2). This essentially leaves open space for applying Merleau-Ponty and Gibson's work to design.

I have proposed, in chapter 2, that Stienstra's speed-skate and Bruns' interactive pen (Stienstra et al, 2012) are two candidates for filling that gap, since they show how the meaning of the digital signals that the interactive systems produce is not predefined, but instead emerges from the very way that these signals are generated from- and come to be taken up as meaningful elements in the ongoing sensorimotor loop.

Dourish (2001), Suchman (2007) and Heath & Luff's famous ethnography of flight-strips used by flight operators, all describe the ways physical artifacts function in mediating in socially situated practices. If we consider again Dourish's analysis (2001), we see that he discusses social theories on embodiment (the work of Suchman and Alfred Schutz) completely apart from the 'sensorimotor' work (the work of Merleau-Ponty and of Gibson). This allows him to apply social theory to his vision of 'social computing' which is not constrained further by sensorimotor principles. For instance, as applications of his social computing, Dourish discusses several examples of GUI-based collaborative tools (Dourish, 2001; pp. 95, 182-283), making no reference to sensorimotor effects. In his theoretical analysis Dourish states that both the social- and the sensorimotor aspect are part of the same overall idea of embodiment, but it is not clear how they relate in the designed system.

I have instead mentioned the Reactable as a physical-digital system in which both sensorimotor couplings and social interaction take place as part of one and the same musical skill (chapter 2). This example aligns with the fact that my own design projects became increasingly aimed at trying to answer the question of how social practices and sensorimotor couplings can be *integrated* in one system, i.e. how they can be part of one and the same embodied activity.

3.2.2. There is no separation between socially situated practices and sensorimotor coupling

As a preliminary answer to Research Question 2.2., I offer that my design reflections show no separation between social interaction and sensorimotor coupling: they are themselves coupled in they way they connect to the interactive system.

Phenomenology, e.g. that of Merleau-Ponty, has always treated the social- and the physical- as forming an integrated aspect of the embodied manner through which people relate to the world (Merleau-Ponty, 1962). Social ethnographers like Goodwin have likewise started investigating the two as a unity, asking for an extension of the original focus on natural speech to include the full richness of embodied interaction:

"Clearly all of the phenomena noted — the visible body, participation, gesture, the details of talk and language use, visual structure in the surround, images, maps and other representational practices, the public organization of visual practice within the worklife of a profession, etc. — are relevant. The question arises as to whether it is possible to analyze such disparate phenomena within a coherent analytic framework."

(Goodwin, 2000b, p. 164)

Similar calls have been put forward in (embodied) cognitive science as well. For instance, De Jaegher & Di Paolo explicitly connect social interaction to sensorimotor coupling [5]:

"As an activity, sense-making is intentional and expressive; it is essentially embodied in action. ... regulation of social coupling takes place through coordination of movements [which] are the tools of sense-making. [Therefore] social agents can coordinate their sensemaking in social encounters."

(De Jaegher & Di Paolo, 2007, p. 497)

And philosophers like Erik Rietveld et al (forthcoming), in discussing the notion of affordance, likewise suggest to combine both social and 'physical' interaction with the environment, in one 'affordance field' we readily respond to:

"Are we just responsive to the socially relevant, expressive behavior of others...? Our work on skillful unreflective action suggests that it is the whole field of relevant affordances (social and other) that we are responsive to. ... [S]tarting from bodily or skilled intentionality, our perspective avoids an artificial separation between social cognition and non-social engagements with the environment."

(Rietveld et al, forthcoming, p.3)

In order to understand more fully what this means, however, we turn now to answering Research Question 2.1, the role of expressive traces.

3.3. What is the role of expressive traces?

Once we have decided that social interaction and sensorimotor coupling are part of the same basic 'socio-sensorimotor' coupling to the world, the question is what may be the role of 'expressive traces' in this respect. (RQ 2.1).

In DRC, expressive traces created in creative sessions, interactive or otherwise, are first and foremost seen as 'external representations', or as scaffolds for performing computations 'in the environment' (as in the activity of 'clustering' items, chapter 6). In theories of Socially Situated Practices, the artifacts people produce are also called external representations, but what is emphasized in these analyses is not so much that they represent or help to solve problems, but primarily that they are important public vehicles by which people show to each other what they are doing and thinking, such that people's activities may become socially coordinated in action (Suchman, 2007).

In reference to theories of stigmergy (Theraulaz & Bonabeau, 1999) I decided to call the artifacts people produce in creative sessions 'traces'. This helped me to focus on the sensorimotor aspect, instead of their more commonly understood 'representational' or 'social' function. If something of a representational character would emerge, this would always already be an inherent aspect of the embodied interactions of people in the physical space, just like the trail in the forest is first the result of action, and only later comes to guide it (ibid). In other words, traces are concrete physical residuals of human activity. Once left as endurable elements in space, they are the kinds of things one may stumble upon, the things that may draw visual attention, that suddenly come into view (as when you turn around and spot them) - they may be 'too far away to see', inviting you move in order to get closer, they may be passed around, or their form may be too cumbersome to keep moving about (large flip-charts), and so on. They are things that can be hidden from others (personal notes), shown to others (photographs), get collected, organized, shoved away, or get in the way, like any other physical object. All of this immediately influences the sensorimotor couplings in which these artifacts figure, just like the ant-trail has impact on coupling of any particular ant to its environment.

However, in the final stage of the design project I renamed them 'expressive traces', because, contrary to ant-trails, foot-prints, or clutter, they are not *just* traces. Making a mark with NOOT, photographing a sketch or presenting ones images to others are all *intentional expressions*, acts involving objects through which a person expresses herself as a person in a social world. This is not a new insight, but I needed to find my way back to that insight *starting* from the physical aspect of traces 'as traces', and their role in sensorimotor couplings. The idea emerging from the design studies is that through creating and subsequently using expressive traces, people put themselves into a relation to others, in a series of expressive acts. Yet what is literally 'expressed', in the trace, i.e. the text that is written or the picture that is sketched, does not in and of itself fully *represent* that what the person is expressing by performing the act of expression: the meaning of that expression can only be found in the act itself (Goodwin, 2000), and the artifact is a scaffolding element in performing the act (de Jaegher & Di Paolo, 2007).

3.3.1. External representation versus expressions of embodied experience

We are now in the position to discuss more precisely the role of these expressive traces. In his book 'situated cognition' (Clancey, 1997) Bill Clancey analyzes the use of what he calls *descriptive artifacts* in pretty much the way I have come to see what 'expressive traces' are, and what role they play in embodied cognition, and so I will draw on his work in this section. This final discussion of theory can be seen as the closing part to chapter 2, but I present it here because it relates most clearly to the results of the design studies, not to their starting questions.

What Clancey (1997) tries to make us realize is that there is a tendency in cognitive science, and perhaps in science and philosophy at large, to mistake the world that is created by a system of representational artifacts, the ‘descriptive world’, with the real world itself, which is the world of embodied engagements of people, where these descriptive artifacts are themselves created and then take on an active scaffolding. In other words: we have a bias into mistaking the map for the territory: we are easily lead to believe that how we describe something to be, *is* that same something. This is already a lesson to take away for any designer of systems that involve digital representations, for it is exactly this bias that makes one believe that the digital objects and processes *are* the world in which the user acts (Agre, 1997).

But there is more we tend to overlook, according to Clancey. If we describe, for instance, on a sticky-note, something we have come to understand within a group conversation, we tend to ignore the fact that this description is not just descriptive of some object in the external world – even if we talk about it that way - instead each act of expression is principally describing *an experience, i.e. in this case, having the feeling that one has understood something*. This means the artifact we produce and put in the world relates both to the world *as well as to ourselves*. If I write: “Images are expressive traces” on a sticky-note, then the sticky-note, and the role it takes in what follows next, does not refer purely to ‘images’, or ‘traces’ or ‘expression’, it refers to “the experience I had of realizing that images are expressive traces”.

3.3.2. Clancey’s view on representational artifacts versus DRC

In order to frame Clancey’s discussion of how this works in practice, let me contrast it with a distributed representation interpretation, as explained by Hollan et al (2000).

“One key focus of ....distributed cognition is the nature of representations and the ways that people use representations to do work. People may develop [strategies to] exploit the physical properties of the representing tokens themselves. .... People often shift back and forth between attending to the properties of the representation and the properties of the thing represented.”

(Hollan et al, 2000, p. 185)

We see here that distributed cognition draws attention to the distinction between the physical object that is the representation, and the thing represented by it, i.e. its ‘content’. They then proceed to show how people *switch* between attending to either the physical or the semantic aspect, and use both as resources for cognition. When a person choses not to respond to the content of a representation but purely to its physical form, Hollan et al (2000) call this an instance of ‘stepping out’. This is what we saw happening in the WALL condition (chapter 6), where at some point people would just be organizing the pictures in a visual format, and no longer discuss their contents in a detailed manner. Framing it this way, the more basic ‘mode’, or ‘true’ mode of interacting with descriptive artifacts would be to attend to their semantic content, while ‘stepping out’ and dealing with them as physical objects in space is seen as an epistemic work-around, a handy trick that may reduce cognitive load (Kirsh, 2010).

Clancey turns this distributed interpretation up its head. In his theory, the *normal* way of making sense of the world is embodied interaction with the world, that is, the creation of sensorimotor couplings, situated in a social context. In Clancey's vision, people also at times 'step out' of their more natural mode of interaction, but this means the reverse of 'stepping out' in Hollan et al's sense: it means stepping out of ones ongoing sensorimotor couplings, and engage in an act of *reflection* on ones activity, by *describing* it.

Clancey calls the physical artifacts that get produced through such 'offline activity': *descriptive artifacts*:

"Describing the world and behavior is a way to step outside of [the mechanism] that coordinates activity more directly. [It involves] descriptive arrangements, such as drawings, notated music, a phone message, directional signs. As far as we know, descriptive arrangements are created only by people."

(Clancey, 1997, p. 221)

Here we already see that the 'traces' created in descriptive acts are more than just traces: they are descriptions.

3.3.3. Descriptive artifacts and sensorimotor couplings

However, the activity is strongly tied into embodied sensorimotor couplings that they temporarily 'step out of' and return to again. In this, Clancey draws on Schön's ideas on reflection in- and on action (Schön, 1983). Crucially the creation and expressive use of a descriptive artifact – or what I would call an expressive trace - 'is itself an activity, constrained by time, space, *conceptions of one's role* and the values of the community, and so on' (Clancey, 1997, p. 219).

In sum, one is first involved in the activity and then temporary stepping out to make a descriptive reflection. This descriptive reflection in turn comes to constrain further embodied activity in its role as an external scaffold. As Suchman already showed, descriptive artifacts, that Suchman calls 'plans', do not themselves prescribe rather than that they 'reorient' us, transforming how we perceive and act in interaction with the world (Suchman, 2007). As Clancey notes: "Perceptual details are given meaning by describing what is happening. [Describing] 'holds active' disparate experiences originally associated by only a superficial [sensorimotor coupling], allowing a more abstract conceptualization to be constructed (Clancey, 1997, p. 219.). This actually comes quite close to the idea of NOOT clips 'holding active', or re-activating past moments experiences of individual insight in order to be able to integrate these within the ongoing conversation.

And once descriptive artifacts start to influence our way of perceiving the world "both the perception of the phenomenon and the previous description of the phenomenon [are] transformed" (Schön, 1983, quoted in Clancey, 1997). This is what Clancey calls the 'dialectic' relation between describing and perceiving: how we see the world influences how we describe it, and we have been describing it influences how we see it. (ibid)

3.3.4. Descriptive artifacts in the social context

Clancey then proceeds to discuss how this process of creating descriptions of ones' embodied experience can only be understood within a social context, and in reference to ones personal identity:

"The understanding I am constructing and affirming [by creating descriptive artifacts]... is my conception of my self: who I am and what is happening to me. That is, for a human being, the primary notion of context or situation is with respect to the person as a social actor, as being someone who is right now constrained by social norms and right now playing an interactive role in some persona (even when alone). (Clancey, 1997, p. 220)"

As a result, descriptive arrangements created as part of that situation are "constructed as being representations or being contributions within a social milieu. Without social feedback - without the pragmatic orientation of a participant, [interaction with the artifact] is not a social-transactional event, putting stuff out into the lived-in world for others to see."

3.3.5. Descriptive artifacts and the self

Anderson (2003) senses a particular kind of subjectivity in Clancey's theory, and quotes him as follows:

"This subjectivity is ... a form of feedback between how the world is perceived and how the person conceives his or her identity. Conceptualizing situations, problems, and alternate actions inherently involves an aspect of self-reference. ... That is, a person's understanding of 'What is happening?' is really 'What is happening to me now?' "

(Clancey, 1997, p. 27)

This self-referential, enactive aspect corresponds to the final insights revealed in studying FLOOR-IT (chapter 6) where we saw how people position themselves socially in relation to others in interaction with expressive traces. FLOOR can be distinguished from WALL exactly on the basis of the fact that the FLOOR, more directly so than WALL, supports the subjective aspect of creating, in Clancey's terms, 'descriptive arrangements' ('who am I and what is happening to me?), and putting these arrangements 'in the lived-in world for others to see'. That is: *Me showing you this picture here,* communicates not just an idea I had earlier, but also who I am and where I stand in relation to you and to the session as a whole (chapter 6).

From a phenomenological perspective, ongoing embodied activity of a person brings forth a world that is inherently meaningful as it is 'enacted' through our own embodied engagement (Varela et al, 1991; Merleau-Ponty 1962). Clancey's views above are quite in line with a general phenomenological perspective. It matches Clancey's 'transactional' theory in stating that bringing forth a meaning world, at the same time creates and sustains ones self-identity. It relates to the idea of the skilled craftsman (Sennett, 2008; Ingold, 2006) who, in the act of crafting, not only produces the work as a physical object, but at the same time, through applying his skills in an expressive manner, develops and confirms his own identity as a craftsman. I suggest that something of this 'self-expression' is part of everyone's activity in dealing with the world (Dreyfus, 2002), even if we consider the micro-level of everyday social interaction in a team meeting, where ones identity gets expressed by something as mundane as writing a sticky-note and putting it up on the wall for others to see. However insignificant this act may appear to be in relation to, say, a famous architect drawing sketches for the New York World Trade Centre, in both cases it expresses not only: here is an idea, but at the same time also: here am I, this is me.

4. Conclusion

People find themselves engaged in ongoing embodied activities, situated in a social practice. As we have seen, both the sensorimotor- and the social aspect of this engagement are strongly tied in to one each other: we cannot treat them as separate processes if we try to understand embodied cognition. Human beings, in contrast to other animals moreover create what I have called expressive traces. These traces are descriptive of ones own experience of creating insight-in-action, but we must not mistake the description for that what we aimed to describe when we produced it: descriptive artifacts themselves function as scaffolds *within* embodied interactions, and moreover, what they signify as part of their scaffolding role pertains both to the world as well as to the personal identity of the person that is creating and using these traces in her social relations to others. The temporary stable couplings that emerge within the dynamics of this socio-sensorimotor network, shaped by expressive traces, is embodied cognition.

How to connect interactive technology in a sensible way to embodied cognition as just described is not a straightforward task. To name just two challenges: one is easily lead back into either purely focusing on the social aspect, where physical properties of the artifact do not seem to matter so much, or into representational-computational thinking, where objects are primarily containers with knowledge inside. In the design projects I have tried to find more radically embodied function for interactive systems. This involved integrating sensorimotor coupling and social situatedness and connecting the system to it by offering new ways creating and using expressive traces.

Both the traditional gap between 'digital representation' and 'action in the real world', as well as the gap between 'bodily interaction with physical objects' on the one hand and 'social interaction between people' on the other, were not at all easy to overcome, especially not in practice, in designing the concrete form and behavior of an interactive system. In the design proposals of NOOT and FLOOR-IT, I believe I was only partially successful in bridging these gaps, even though the attempts at it have resulted in a better understanding of what asking this design question actually means. In the next, and final chapter, I will present a number of possible pitfalls and opportunities for an embodied cognition design and discuss why it is such a complex challenge to design for EC, as well as provide some pointers into the direction of how it might be done.

1 Perhaps the visual format most consistent with the process would have been to merge chapter 2 with this one and present it as continuous side-bar on each page, in parallel to the contents of chapters 4, 5 and 6. For practical reasons I have chosen for this alternative organization.

2 ...even though I had read it cover to cover and it had been sitting on my shelf for 17 years.

3 Taken from personal notes 5/5/2010.

4 In this regard Brooks' maxim to 'let the world be its own best model' (Brooks, 1991) is ambiguous, as it can both mean that the robot does use a representational model, but that this model is physically realized by the structure in the world itself, or, alternatively, that we can principally do away with the explanatory construct of 'model' altogether in order to explain intelligent robot navigation. Roboticist Beer (2008) also uses the term 'computation' to describe what his robots do, but his computational models are of highly dynamical, nonlinear systems with emergent coupling effects, which is a very different use of computational language as compared to e.g. the distributed computation that Kirsh sees happening when he describes how people manipulate physical objects in order to solve an abstract problem.

5 Interestingly, De Jaeger & Di Paolo (2007) offer as example phenomena of the relation between the social and the sensorimotor, amongst others: "collaborating in a joint research project" and "reaching an agreement after group negotiation". They then proceed to say "But these examples are hard to unpack". I hope to have shown that a RTD approach can actually help to unpack such phenomena, with the evolving prototype as a guiding artifact that supports the researcher's emerging insight. Using RTD, we can get a grip on the phenomenon in its totality, complementary to the modularized approach that underlies the psychological experiment (see also chapter 3).

8.

Embodied Cognition Design

"[W]e now enter an era that shows respect for a person as a whole (with a mind, heart and body) and exploits all his skills. Moreover, technology influences our culture and people's everyday lives, and embodiment can help to shape people's engagement with reality."

(Hummels, Overbeeke & Klooster, 2007, p. 679)

*"My mind is divided in online and offline. When I am offline, I don't think so much.
I only start thinking when I get online. I live online."*

(Dutch teenager)

In this final chapter I discuss 'implications for design', being aware of Dourish' critique of that term (Dourish, 2006). Following Dourish, the aim is to reveal 'ways of thinking' that may 'shape research [and design] strategy', rather than presenting 'constraints or opportunities faced in a particular design exercise' (ibid).

This chapter forms my final answer to Research Question 1:

RQ 1. How may we design interactive systems in support of embodied cognition?

RQ 1.1. How does embodied cognition inform designing the relation between the digital process and physical form of the interactive system?

RQ 1.2. How does embodied cognition inform designing for the way in which the interactive system at large connects to people's real-world, embodied and situated practices?

I answer the main- and sub-questions together in an integrated way. In what follows, I list seven pitfalls for those that intend to move beyond more conventional interpretations of interactive systems, towards an Embodied Cognition Design. I then discuss what an Embodied Cognition Design may look like, based on the lessons learned in the design cases, presenting several design opportunities. I end with prospects for the future, asking how Embodied Cognition Research-through-Design may add to the overall project of societal transformation (Hummels, 2012).

1. Beyond Descartes?

One conclusion of this research project is that a lingering Cartesianism is hard to get rid of in practice (Koskinen et al, 2011). In any concrete design project, cognitivist intuitions fuel implicit design assumptions that hinder a more radical form of design for embodiment. These intuitions see a design challenge first and foremost in terms of systems of representation and processes of computation. This influences not only ones conception of the function that an interactive system may take, but also the way we conceive of the human activity that needs to be supported. In fact, precisely because representations and computations have this descriptive, abstract character, defining a situation in terms of it means that in many cases one can equate the ‘model’ of the human practice with the ‘model’ of the system to be defined: the definition of the system is the human activity that needs to be supported (Agre, 1997)[1]. As a result, the objects and processes that define the digital system map directly onto the objects and processes that are assumed to drive the human practice. As Clancey (1997) argues (see chapter 7), this is a category-error, mistaking the map for the territory. In the worst case, it means that the digital system prescribes how the user should act, effectively overruling the embodied practice (Redström, 2008; Suchman, 2007; Schuler & Namioka, 1993).

1.1. Implicit intuitions revealed

If we want to get ahead with exploring ways to create Embodied Cognition Design we must first become conscious of these implicit cognitivist intuitions that will turn up in any particular project. I have summarized a list in table 8.1 that we must critically assess in order to be able to go beyond it. These well-known functions stem historically from classical computer systems such as the early mainframes and the first generations of desktop PC’s (Dourish, 2001)[2]:

'Cognitivist' functions in interactive systems	*Classic interface form*
Create data (i.e. quantifying 'what happens in the world' by registering change at a sensor and storing the result in a variable value)	*Autonomous sensors that transform events into data; pattern recognition software; databases that count, index and store them for later use*
Store and retrieve items in memory	*Possibility to 'input' data, Possibility for providing parameters that define a search for stored data, and present the result of the search action*
Reduce large amounts of 'data' to summary descriptions (categorize, name)	*Display data visually as text, graphs, models and/or images on a screen. E.g. present data recorded from a sensor in a graph on a screen.*
Perform computation (rational, deductive reasoning on the basis of known facts in a database that models the world) reliably and fast	*A communication channel allowing for asking questions/ posing a well-defined problem as well as presenting back the answer/ solution.*
Sending messages from one person to another	*Like the previous, but here the system functions as an intermediary between two people, instead of between one person and the internal, digital model.*

Table 8.1. Cognitivist functions in interactive systems and their associated interface forms

However, even when we consider todays' latest concepts for tangible interaction, ubiquitous computing, augmented reality, multi-touch surfaces, hand-helds or even wearables, we can still spot these same concepts of information processing concepts and interface forms in it, if we look beyond superficial appearances.

One response to this could be: how can it be otherwise? These systems are, after all, computers. And computers are by definition computational-representational systems, creating data from sensor readings and presenting outcomes of computation back to the world. There is simply no other way.

Or is there? The challenge, as I see it, is not to mistake the technology, i.e. what happens inside the box, for the way a technology may take on a function in relation to human practices, i.e., what the technology *does* (Winograd & Flores. 1986). Even though internal to the system a computer is essentially processing digital representations by means of computations, this does not mean that the meaning of what the system does for the user, 'on the outside', that is, should necessarily be described or understood in these same terms. In fact, in contrast to mechanical tools, digital technology provides an enormous freedom in deciding how internal processes map on to, and serve to support, human activity 'on the outside' (Djajadiningrat et al, 2004, Frens, 2006). We can envision systems, based on digital technology, taking on functional roles in human practices that are very much unlike 'computation': for example by supporting continuous interaction rather than discrete message passing, enabling situated activity rather than data storage, dealing with the concrete rather than the abstract, and so on. When designing for EC, this is what we need to do.

1.2. ‘What computers can’t do’

From an EC perspective, the functions and interface forms in table 8.1 fail to address, in the design concept itself, how it is that a user gives meaning, or makes sense, of the world. If the tool is to ‘summarize’ data, then what determines what is to count as ‘data’, and more importantly, how to summarize it in a meaningful way? If the system is to compute a solution to a problem (i.e. ‘solve’ it), then where do the required problem representations and computational procedures for solving them come from? If a tool sends messages from one person to another: how does it help these people to find meaning in the messages as such? In most of todays’ interactive systems, all necessary meanings needed for being able to use the technology ‘in a meaningful way’ are presupposed: they are attributed to the system by the user, who implicitly follows the definitions provided by the designer.

The ultimate grounding of the way the tool helps a person to understand or grasp whatever it is that she is trying to understand or grasp lies somewhere outside of interacting with the system as such. For instance, my understanding of a message in a pop-up box on a screen on a computer is grounded not in the design of the system, and not even in the interaction between me and the pop-up box: it lies in the way human beings have developed the capacity for communicating in natural language, how we have learned to understand the world on the basis of prolonged experience, what we have incorporated into our habits by means of formal education, and what emerges as ritual and routine from being active participants in a culture. In embodied cognition the physical objects we encounter from birth and learn to deal with, from the sand in the sandbox to sophisticated designed objects like hammers and violins, all help to shape that cognition. However, computers store it, once the cognition has emerged and is named, and they move back and forth these stored representations in ever more complex combinations. This means that most of todays’ interactive systems in principle assume that the main ‘embodied cognitive work’ has already been done, and that the ‘background’ (Dreyfus, 2007) of embodied meaning is already in place, such that the system can safely use a set of descriptions (Clancey, 1997) as basic building blocks that stand out against this implicit background.

It is instead this ‘embodied cognitive work’ what theories of EC try to get a grip on. With this I mean the process by which insight, or understanding, or creating know-how, is first created in the flow of interaction between a person and his world. This is essentially the enactive process that happens before we can then describe the outcome of such a process in terms of representations that may subsequently be processed and send back and forth as bits of information between people and computational systems. In other words: interactive systems are generally positioned conceptually ‘too late’ regarding embodied cognitive processes: they only come into view as cultural tools once the most important cognitive work has already been accomplished[3]. This means that the kinds of functions and interactions listed in table 8.1, even though they are used to create valuable, perhaps even crucial tools in our everyday life, are not really going to help us in understanding what embodied cognition itself is and how it works. And, based on the interaction between people and such computers, we can certainly not get at the heart of how the physical traces of embodied cognition at some point start to function as representational artifacts (Clancey, 1997). This is because in the way the design is set up, the meanings and relations that define the representational objects in computers are already fixed on beforehand[4].

2. Embodied cognition design: pitfalls

Against the background of the previous discussion, a designer that wishes to create systems in support of embodied cognition easily runs into at least 7 potential pitfalls. I discuss each of them in turn (in the next section, I will discuss opportunities):

2.1. Pitfall 1. Using EC to cover up, rather than transform, disembodied systems

This first pitfall can be summarized as: EC should not be merely a 'Band-Aid', compensating for the fact that a certain system is in its definition still very much Cartesian[5]. The pitfall is hard to avoid in practice, since in many concrete design projects, especially in commercial settings, the 'system function' as defined in the design brief already contains a framing that reflects present-day digital culture, focusing on abstraction, data processing, modeling, information visualization, providing information, and so on. If one then creates a tangible or otherwise 'embodied' interface, this interface may actually cover up, rather than resolve, a more fundamental disembodiment in the system definition. It becomes more a fix of something that already went awry earlier on, than that it truly forms an 'embodied' solution. Of course it ultimately depends on ones philosophical commitments and practical concerns, whether the embodiment of the user's cognition is deemed relevant at all. But if one sets out to design systems with full respect for embodiment, which was at least my objective in this PhD project, then creating embodied interfaces to 'disembodied' system functions, somehow misses the point. Even though this is not easily changed in practice, designers may at least be conscious of this dissonance, and spend some time critically assessing, together with all stakeholders involved, implicit assumptions in the way the system's main function gets defined. In fact, the project of designing embodied interaction can help to reveal on a more fundamental level whether and how the project's aims and scope already contain a detachment from people's embodied practices.

2.2. Pitfall 2: Separating system function and system form.

Closely related to the first pitfall is the pitfall to think that EC design is purely about designing a suitable 'interface', ignoring questions at the functional level of design. EC design always deals with the question of what the device is *for*, what it *does* within the human practice, even if one is designing primarily the concrete level of 'interfacing'. In fact concretely designing for interaction – and testing it - is precisely what is needed order to be able to understand what the function of the system could be. *How* the system is used, *is* what the system is *for*, and vice versa: in the embodied experience of the user, there is no difference. So on the one hand, the designer's observations and explorations take place at the concrete level of the physical, graphical, acoustic, touch, i.e. the concrete forms technology may take that the human body can sense and act on. This is 'where the action is' as Dourish says. But at the same time, what these design interventions are aimed at, what they should do, is to transform the very way a person makes sense of the world, which, in design language, is all about the product's function. The pitfall would be to see interface and function as two separate properties of the design and try to define and design them separately, or even sequentially (first define the function, then design the interface). Instead, one needs to work on both at the same time and consider them as two levels of describing what is, to the user, really just part of one integrated experience[6].

At this point, before going on to the next pitfall, we can relate the discussion so far a bit more explicitly to the theoretical analysis in the previous sections. If we borrow a bit of terminology from Clancey (1997; see chapter 7) we may distinguish between 'descriptive functionality' and 'transactional functionality' of a product. Descriptive functions are functions that are defined 'offline', descriptively that is, by a designer. They can be stated in language. For instance, a video-system may be said to contain certain 'functionalities' like 'play', 'stop', 'fast forward', or 'record', and so on. These functions are defined in the abstract and such a function 'exists' even if nobody ever uses the product. We do not yet know what transactional functionality these functions will have: what active use of the system, in a natural context, will mean for the user. The function of 'recording' may for instance take on a different transactional function in the context of shop-security then it would in the family home setting. I claim it makes little sense to try to connect Embodied Interaction Design to descriptive functionalities. What we need to get at instead is how the system sustains transactional functionalities, and what this means for design. We cannot avoid descriptive functionality, because as soon as we observed that NOOT took on the 'function of tagging a moment' (instead of working along the lines of our earlier descriptive function as a memory scaffold), the soon we put this new observation into words, we have made it into a new descriptive function. This is not problematic in and of itself: what is problematic is leaving no room in the design process for such redefinition to occur at all[7].

2.3. Pitfall 3. Designing embodied metaphor.

Also related to pitfall 1 and repeated throughout this thesis: metaphorically mapping physical form to digital content or operation ignores the essence of embodied cognition. It is the difference between thinking that the NOOT clip 'is' or 'contains' the insight, which can then be accessed by tangible interaction, and the recognition that the tangible clip and its associated audio time-point take on a role within a certain embodied activity that then 'brings forth' the insight in action. What I want to add here, however, is that tangible artifacts in principle enable rich, continuous forms of interaction, giving opportunity for sensorimotor coupling and social mediation. That is, compared to mechanical switchboards and graphical user interfaces, traditional tools, physical objects and physical environments are rich material one may use in designing for EC. As an example, consider for instance that in playing soccer, there is no essential distinction between social interaction, physical skill, or cognition. Physical artifacts used, e.g. the ball, serve to integrate all these levels in integrated instances of interaction. So, a the soccer-player works up to kick the ball, all these aspects come together in one unified moment. The ball, like the hammer and the cane, is therefore an example of a tangible object that is an inherent element in the embodied cognitive process of the soccer player.

The pitfall, however, is to take a tangible object and then not to use its richness, but instead restrict its use to enable a shallow input-output mapping to digital states only (as in e.g. Ishii & Ullmer, 1997; see also chapter 2). In such cases, most of the rich possibilities for interaction that the object initially affords becomes irrelevant as seen in the context of the role that the interactive system has to play in the activity. An anecdotal example is found in a TED-talk by David Merrill from MIT, introducing 'Siftables': small physical blocks with interactive screens and sensing technology[8]. In this movie, the designer's son is seen stacking the Siftables to make a tower. As there is no digital operation connected to 'stacking', the action is cast away as 'irrelevant' by the designer, who states, tongue in cheek: "All he wanted to do is stack the Siftables up. To him, they were just blocks". While recognizing the significant technological and design achievement realized in Siftables, I suggest that in this case the child actually figured out something meaningful about blocks that the designer neglects, both in his design and in his assessment of the child's behavior. In fact, the conclusion should be exactly the opposite: Blocks, physical objects supporting rich social and sensorimotor couplings to the world, are, a to the designer, 'just' interface elements to digital states (Van Dijk et al, 2013).

Figure 8.1. The rich interaction quality of physical blocks, as revealed by the designer's son (left) is in the design concept reduced to 'merely' changing digital states (right). Screen-shots taken from the video, see note vii.

In both NOOT and FLOOR-IT this issue is not fully resolved either. For instance, in NOOT, the design direction for the tangible clips became not to design any form of 'rich interaction' at all (Frens, 2006): instead each NOOT clip became essentially a formless 'dot' and all relevant form was to be found in the context in which a clip would be placed. This position could be defended: the context was the physical space and as such this space played a functional part in the way we conceptualized NOOT. But it did mean that EC theory did not strongly guide the question of what the clip should look like. In FLOOR-IT, the interactions with the images actually were pretty conventional GUI operations, even though operated by foot. Again, the main possibility for embodied interaction was in the context: in the way that people could physically position themselves in relation to each other and the images. As this was part of the design concept (and not some coincidental effect), this could be seen as an important step, but the connection between the embodied aspect of the system and the "GUI-style" operations on individual images remained somewhat of a forced fit.

2.4. Pitfall 4: The illusion of the virtual space

CSCW systems based on detailed ethnographical analyses of human work practices are grounded in the idea of 'social situatedness' (Dourish, 2001; Suchman; 2007; Crabtree & Rodden, 2008). On this view, representational artifacts function as scaffolds for the social negotiation of meaning. This is an essential part of the theory promoted in this thesis. However, in its application to computer systems, designer take a metaphorical leap whereby the actual world in which we are embodied is somehow taken to be 'the same' as the 'digital world' of with which the user interacts. The design question then becomes how to recreate certain known principles of social interaction 'in virtual space'. Even if the idea of social situatedness can be studied and designed to some extent in this way, it cannot address, at least not easily, sensorimotor coupling.

One indication of this lack is that the interface in most CSCW systems is a conventional screen. In TRACES, much more so than in NOOT, this danger lurked in the background: before you know it, we were talking about the design as if people were not acting 'in space, standing on the floor', but 'in the floor, acting on the digital objects'.

It is a mistake to think that we can actually 'be' in the virtual space. It may become, in action, the prime focus of our attention and take up the larger part of our experience (we feel 'as if' we are 'in' the space), and I think this phenomenon needs further investigation and has not been fully cashed out in my own projects (see e.g. Crabtree & Rodden, 2008, for work in this direction). Based on the sensorimotor perspective, however, we must acknowledge that in the end, the activity that underlies the experience of being in virtual space is grounded in the actual body operating in actual space. One part of actual space can be a screen on which pixels transform in real-time, a dynamic to which our eye-saccades and bodily action becomes coupled. And the people one meets 'in' virtual space also have actual bodies situated in actual spaces, on the other end of the wi-fi connection. The totality of our embodied involvement, and not just our dealings with 'the virtual world on the screen', is what sustains embodied cognition. Virtual spaces generally neglect the concrete question of how sensorimotor coupling is part of the interaction with any system, and this prevents further investigation into the ways that the two fundamental aspects, the social and the sensorimotor, relate to one another and form a unity[9].

2.5. Pitfall 5. Designing systems for 'bodily movement' (the more, the better).

We now turn to the other side of the spectrum of pitfalls. In search of embodied interaction there can be a pre-occupation with literal bodily movement. For instance, in the NOOT study we spent quite some time on how the physical action of clipping a sticky-note to the tangible would 'be' the way a person marks a time-point in the audio-file, and what this physical action should look like. The pitfall is in equating EC with physical movement 'per se'. EC says something about the way that sensorimotor couplings evolve, over time. Such couplings do not necessarily involve gross movements of limbs. One eye-saccade can open up an entire world of meaning for a person, and in doing so this person displays embodied cognition at its fullest, even though for many practical purposes the person hasn't moved at all. For instance in NOOT one of the interesting sensorimotor couplings involved would simply be the subtle effect that a person, while in a conversation, would be visually attentive to someone else taking a clip placing it, up for grabs, somewhere on the whiteboard.

However, exploring interactions that involve such gross movements in space may help the designer in getting away from the discrete input-output metaphor (Hummels et al, 2008b). In the TRACES study, in order to get away from thinking in terms of representations of ideas and of people it was useful to start thinking about how one could 'drag along' ones images by walking on a large surface. Conventional interface forms break up bodily movement of the user into discrete 'interactions' that either result in 'activating a system function by selection (e.g. pressing the button)' or 'perceiving the feedback presented by the system (e.g. looking at the graphical display)'.

Thinking about ways to connect the system's behavior to a continuous flow of movement of the user, and especially analyzing the temporal dynamical structure in movement, such as rhythm, pattern, choreography, may help one to get away from that kind of discreteness (Schiphorst, 1992). At the same time a dogmatic focus on bodily action can become a trap. In the TRACES study, as I wanted to stay clear from more symbolic forms of interaction, I discarded the idea of interacting through hand-gestures or using a pointing-stick and settled on a 'foot-based' interaction. But this meant walking through space became conceptually mixed with 'acting on the pictures' and this problem was never really solved, in the end having the effect that people were afraid to move at all, not wanting to 'step on their pictures'. Generally speaking, if there is some form of free bodily expression involved, there is opportunity to design for embodied cognition. But in essence the use of gross bodily movement is best seen as a process-tool, and not necessarily required for the final solution.

2.6. Pitfall 6: Drifting away from the topic of cognition

This is not so much an actual pitfall as it is a worry that focusing on embodied action only gets strong attention in design projects in contexts where the body and physical action are already important themes to begin with. For instance, in designing an interactive skate-ramp it is to be expected that 'embodied interaction' is relevant[10]. Instead I have tried to investigate the kinds of practices that we would not already in our everyday language describe in 'bodily terms'. In the context of creative meetings I have always focused on the question of how people 'make sense of what they are doing'. This meant for instance that I was not primarily interested in designing for a 'creative atmosphere' using ambient effects and the like, which was in fact what some of the companies were very much interested in. In general, I suggest that it is a mistake to think that people have either embodied skills or cognitive skills (or social skills, and so on) where cognitive skills are then taken to be the classical cognitivist computations over representational models, and embodied interaction is what covers the rest. Cognition to me refers to a range of behavioral routines and practices that together form a certain aspect of human activity that, as a phenomenon, needs to be explained, and the question is then whether we can find interactive systems that both relate to such phenomena and are based on EC theory in their design.[11]

2.7. Pitfall 7: Ignoring context, or, wanting to design the total solution.

This final pitfall ranges broader than just EC-based design, but it played an important part in designing our systems. Both NOOT and TRACES are 'partial' systems. That is, they do not embrace in its entirety the 'task' that they are designed to support. Instead, they were designed to form one useful element in a process that is sustained by many other processes, not under the control of us designers. EC posits that cognition emerges in an 'open' system, one that has no clear-cut boundaries. Practically anything can become part of this system, as a practical consequence of the actions that a person may take, and the new possibilities for perception and action that she thereby discloses. The system one is designing can never be the 'total solution'.

This pitfall was more easily avoided in NOOT than in TRACES. Interactions with NOOT can be combined freely with other activities that users can think of themselves, just like one can use a felt-marker or the whiteboard for all kinds of purposes that arise within the situation. In designing TRACES, there remained a kind of artificial split between the part of the creative session in which 'traces were made' (taking pictures) and the part of the session in which they were part of the social talk between people on the floor[12]. As a result, TRACES was a system that was less flexible, constraining people to follow a rather linear process path. To avoid this pitfall, technologically supporting embodied cognition means one is always creating just one particular element that is going to play its part within an open system of interrelated activities. This means continuously 'zooming out' in reflective activities during the design process, not just looking at 'the product' but also at the larger network of relations – outside of your control span - within which your product will be just one element.

3. *Embodied cognition design: opportunities*

I have sought ways in which interactive systems can support embodied cognition. Let me first summarize once more what embodied cognition is. We start with the idea that people always find themselves already engaged in ongoing embodied activity, situated in a practice. Such activities, we have seen, are inherently socially situated as well as involving sensorimotor couplings. Human beings, in contrast to other animals create expressive traces in the environment. These expressive will over time come to form an inherent scaffolding element sustaining the embodied practice in return. Within this network of relations stabilities arise that form a persons insight into what he is doing. We might call it the emergence of 'knowledge', although know-how may be a better term. The term sense-making (De Jaegher, 2009) may help to appreciate its active nature. This, in short, is embodied cognition. And somewhere within this process, interactive technology can be envisioned to play a supportive role.

The situation we find ourselves feels like a paradox, in which we are trying design supportive structure for EC, using the technology that itself developed from, and has actively helped to shape, for the past 70 years or so, the cognitivist view of mind. Perhaps interactive technology, and especially its information processing aspect, is simply too Cartesian in its very essence, and it makes no sense to try and use it for something else, let alone its opposite.

Is it not true that if we think about how this idea of a fundamental split between body and mind evolved in science and philosophy, we see it went hand in hand with the development of industrialization, science and modernity, leading all the way up to producing modern society, in which the tools and instruments of mind increasingly come to be 'detached' from our embodied practices? Modern technology, it has been said, has long since lost touch with the original ways in which human tools and means for expression were strongly tied into skilled craftsmanship, it times where knowledge and culture had to be continuously reproduced and sustained in ongoing social interactions, in ritual and skill (Verbeek, 2000).

Yet at the same time, this more basic, pre-reflective, pre-descriptive level of relating to the world is not entirely lost to us (Dreyfus, 2002). We see it in music, sports, craftsmanship (Sennett, 2008), in entrepreneurship and professional know-how (Schön, 1983; Gladwell, 2007), in social relations, in our experience of nature, when we are in 'flow', and even in the way we deal with the everyday, mundane affairs, our embodied coping (Dreyfus, 2002). It is all the more exciting then to find that in interactive systems design, one of the most hi-tech, present-day, specializations within the broad field of engineering and computer science, we see in fact a trend going away from Cartesianism, developing artifacts that reconnect to our basic embodied ways of being in the world (Koskinen et al, 2011; Djajadiningrat et al, 2004; Wakkary 2005; Trotto et al, 2011; Hummels et al, 2008b; Klemmer et al, 2006, Robertson, 2002).

How to find a use for modern technology that does justice to the EC perspective? Perhaps just trying as best as possible to avoid any of the seven pitfalls above, will already be as good as a compass to sail on. Even so, I will try to give a few more constructive, or positive directions.

3.1. What digital processes (can) do

Perhaps the hardest question to answer is what an interactive technology may do over and above what it may already do given the fact that the system is also a physical object (or collection of objects), that is, what the role will be for digital processes. For if digital states are no longer the 'storage medium' for the insights formed by the user, and if transforming these states by means of computations is no longer designed to be the way to access, combine, or communicate (to others) such stored insights, then we must rethink the role of these digital processes in the larger whole of the interactive system in its context. Purely re-creating a physical tool using 'digital technology' inside (e.g. a digital clock with analogue hands) does not solve the main problem: for the user, we have just created an analogue device. On the other hand, we are in danger of creating systems that contain a dualism, in which the physical aspect of the system connects to a person's embodied activities, whereas the digital process does not (Imagine a hammer that is also a mobile phone, while the two aspects are not at all integrated. The product might be usable, but really we have two products here: the phone, and the hammer). It is of course the relation between, or rather the integration of the two that we are interested in. As discussed earlier (e.g. chapter 7), relating the physical form to the digital aspect of the system by a designer-defined, metaphorical mapping seems to beg the question as well.

3.2. Technology as material

My suggestion is to conceptualize sensors, feedback components (actuators, screens, light, and so on) as well as digital processes (software), first and foremost as a 'material' to work with, a technological resource, not unlike, and together with, wood, plastics, or any other kind of material. This means we must reject, as much as possible, any implicit conceptual connotations of the material that recasts the design challenge already from the start in terms of information processes. The question is subsequently what one can do with such 'digital' materials within the larger system, a system that contains both digital as well as mechanical aspects, physical form, surface materials, and so on.

The implication here is that designers are asked not to make any in principle distinction between what digital processes do and what the physical form does, or even what a certain aspect of the larger context of which system forms a part does. For a user, there is no difference between what the 'digital' process does and what the 'tangible' part does. If a user does experience a difference, this is because the design has created this distinction, and because the user is asked to respond to the difference, given the way the system works. Embodied interaction with the world, if considered apart from any concrete design, is in principle a unified experience, governed by intentional activity, towards satisfactory couplings with the environment. This means there can also be no principled distinctions between designing the function of the product and designing the interaction, nor between designing the physical form and designing the digital mappings, and so on: one needs to iterate on all these levels in parallel (see also chapter 4 and the pitfalls above).

This relates to an experience we often encountered in our design activities: there were multiple moments where someone would suddenly say: "Yes this feels like a good design move, but hey, we don't need an interactive system to do *that!* We could just use ... (paper, wood, springs, a table, magnets, sand, a pencil, sticky-notes on a wall, a book, etc.)". I have found it to be crucial to take some time to reflect on these moments before casting away the design proposal as irrelevant (on account of the fact that the proposal wouldn't involve interactive technology). Getting to the point where the interactive technology seems no longer needed at all, proved to be a refreshing moment in the design process. In fact, it is precisely these moments, which really force the designer to get clear on what exactly digital computation can contribute to a designed system, as seen from an EC perspective.

3.3. The role of the interactive system in human embodied cognition

Based on the cased discussed in chapter 4,6 and 6, I offer 4 opportunities for interactive systems, which at the same time crucially involve digital processes. Instead of focusing on the representational- and computational capacities of these digital processes however, the focus in all of these contributions is in how the system intervenes in and transforms the cycle of ongoing embodied interaction between a person and his world. That is, these interventions change the sensorimotor loop, and this includes both the way people interact with the physical- as well as the social environment. They are summarized in figure 8.2.

Figure 8.2. Four opportunities for designing interaction for embodied cognition: transforming possibilities for sensing, for acting, for relating socially to others and for creating and using expressive traces.

3.4. SENSE and ACT

SENSE transforms or creates new opportunities for the ways a person may sense the environment. This means creating new, artificial 'sensors' by means of which people can start to respond to aspects of the environment that they hitherto couldn't.

ACT creates new opportunities for physically manipulating the environment. This is not unlike the design of conventional tools (the hammer, the blind-man's cane, and so on).

In the picture I have artificially separated them, which may be useful for finding a concrete starting point for design. As we are intervening in a loop, however, SENSE and ACT are strongly interrelated. Creating a new 'sensor' or a 'tool-for-manipulation' already changes the complete sensorimotor cycle: sensing new things affords new action and new ways of acting in the world creates new ways of perceiving. Ultimately, for that matter, all of these entry-points are strongly interrelated in the way they transform the unified embodied experience of the user as she is interacting with the designed system as a whole.

In principle, many traditional, analogue tools and everyday objects that contain no technology have impact on sensorimotor coupling processes. Heidegger's hammer (Heidegger, 1927) and the blind man's cane mentioned in Merleau-Ponty (1962) are paradigmatic examples. One particular opportunity for digital technology, however, is that it can connect and subsequently bring into view as one whole a collection of disparate events that, purely based on our 'biological' embodiment and mechanical tools, would never become co-located and associated, either spatially or temporally. That is, digital technology can bring together aspects in ones experience that become a whole, in terms of perception and actionability, that is, in terms of what the sensorimotor loop couples to. For example, NOOT makes available a series of 'conversation moments of the past' in one spatial setting, as a collection of physical elements on the wall that are synchronously available for action in the here-and-now, together with the ongoing conversation in the here and now. Likewise, FLOOR-IT brings together a person's embodied social activity and a trace of the expressive artifacts this person has been particularly engaged with earlier. Other participants in the social exchange can now perceive and act on the person and her traces as one meaningful whole. This enables participants to 'see' other participants in a context that would not have been possible by means of participants' ordinary dealings with sticky-notes in a brainstorm space. In conclusion, the active dynamic behavior of interactive technology that transcends ordinary constraints of space and time can support sensorimotor couplings that would not be possible in interaction with 'passive', physical objects.

3.5. RELATE

This means transformation of social scaffolding in embodied space, or in other words, providing for new ways of social interaction with other people in face-to-face contact.

Much relevant research has already been done on the role of digital technology in connecting people and mediating social interaction (Dourish, 2001). My suggestion would be to build on those insights, but to try moreover to situate it explicitly in actual, embodied space. This means, for one thing, less of a focus on language and communication of messages. People are primarily relating to one another in action, using their bodies, seeking a satisfactory position to take in the social situation. Sending linguistic messages back and forth is just one part of that, not the prime focus. Interactive systems may help to support sensorimotor couplings between people, which, as a start, connect primarily to nonverbal communication, such as bodily inter-positioning and gesture (Goodwin, 2000). In other words, instead of using descriptions of what people communicate to each other as the basic building blocks for the interactive tool, the system should connect to the embodied, communicative activity of people, that is: support how people maintain social relations.

3.6. TRACE

This entails enabling the creation and use of expressive traces. While sensorimotor couplings and situated social interactions form the basis of embodied cognition, human beings also create external representations, through their sensorimotor activity, in the social context. In this thesis, I have chosen to call these 'expressive traces', with the aim of keeping the analysis of the possible roles of such objects as close as possible to the underlying sensorimotor couplings and social situation. Such traces then come to function themselves as elements in the socio-sensorimotor couplings (see chapter 7).

Interactive technology can provide for new ways of creating expressive traces in the environment with which one, in creating and using them, forms meaningful couplings.

Of course, any particular system will probably implement a combination of these four opportunities. The overview is meant to provide four different entry-points for a design process. Perhaps digital technologies will be able to create highly dynamical, fluid sorts of objects that we at present cannot readily understand as either directly intervening in sensorimotor couplings or as creating endurable traces in the environment; or as enabling social interaction, but which exist as new hybrids somewhere in between. Perhaps the images projected around the body in FLOOR-it can already be seen to possess something of that hybrid nature, as the images around the body can be seen as transforming a person's way for perceiving others, but also as a residual of ones evolving thought process, left as a trace in the physical space. What digital computation may eventually afford in any concrete project is an open question, not only since the specific case will yield specific kinds of conceptualizations that we cannot predict on beforehand, but also since technological developments are evolving so rapidly that we can hardly foresee what new opportunities may arise in the near future (e.g. see Ishii et al, 2012 and for a critical response, Van Dijk et al, 2013).

4. Transformative design with respect for embodiment

In this final section, I offer some ideas as to where all of this may lead us in the future.

This chapter has discussed how to make todays' interactive systems, which contain a lingering Cartesianism, 'more embodied'. Is this actually a legitimate question to ask? From a cognitive science perspective on human embodied cognition, designed technology does not make human activity more or less embodied: cognition is embodied all along, whether the user is interacting with a tangible media system, or pondering over some horrendous command-line interface from the previous century, or hiking in a forest. So what is it that I ask, in asking for a more 'embodied' design?

Then again, if people are truly embodied cognitive systems, as the theory states, part of what constitutes their cognition is the structure of the environment. And a large part of that environment, at least in our Western society, is designed. And an increasingly large part of that designed environment is digital technology, accessed via pixels on screens. So, one question is what happens with a person's embodied cognition once this person is situated in a technological environment that is itself strongly influenced by cognitivist concepts. Winograd & Flores worry about this when they say:

"Computers designed on the basis of this misconception [of human cognition] provide only impoverished possibilities for modeling and enlarging the scope of human understanding."

(Winograd & Flores, 1986)

In a way, the Cartesian model of cognition may actually have become a reality, not because it was true all along, as a fact of human nature, but ironically enough because our embodied way of being in the world has brought forth a certain cultural environment that is very much Cartesian, which in turn has scaffolded our everyday life and experience, be it in science, engineering, education, or otherwise. The EC theorists may be right in stating that human being is fundamentally embodied and situated, but given that our environment is filled with 'Cartesian' machines, what will happen? Can we escape this? Can we return to our own embodied selves, if the environment we live in pushes us away from it, into representations, abstractions, data? Have we truly become 'post-human', lost in a digital representation of ourselves, with nothing to be done about it (Hayles, 1999)[13]?

For a designer, there is all the more reason to step right into any of the cultural worlds of today, these everyday practices and contexts we live in, and start transforming them into desired directions (Trotto et al, 2011; Stienstra et al, 2012, Hummels, 2012). This in fact involves taking responsibility and taking concrete action within the given structures and conventions, however without uncritically accepting them. By designing and building concrete systems we may provide alternatives and new ways of seeing and conceiving that may help us gradually turn developments into desired directions (Verbeek, 2000).

In that sense, then, it does make sense to ask how interactive systems can be more 'embodied'. Asking this question as I have done in this thesis does not mean that I ask for a system to 'be' itself an embodied cognitive system, as traditionally is the design question in Artificial Intelligence (Brooks, 1991; Beer, 2008). It is also not about copying the patterns by which people relate to each other and recreate them in the machine, such that the machine responds to us as we would to each other. It certainly does not mean that interactive systems either do, or do not, 'have' embodied interaction as one of their features. In my reading of it, the term 'embodied interaction' refers to what human beings do, not to a certain category of designs. All artifacts connect to human cognition and all human cognition is essentially embodied cognition.

However, as the same theory shows, human beings bring forth in their environment artificial structure that in turns constrains our activities, and paradoxically it can structure our activities in such a way that we turn out to act pretty much as cognitivist machines (and sometimes hardly being able to act otherwise). If this is not what we want, then the design question is whether and how we can help ourselves going in other directions – by designing the suitable kinds of environments and tools - in recruiting our fundamental embodied mode of being, drawing on skilled action, know-how, social situatedness, and so on, in as many concrete practices as we think are relevant.

4.1. How to connect to existing contexts of practice

For any concrete design project, given a certain existing context of practice, one starting point would be close to the conventional way in which information technology is understood: as a means in which people store knowledge within a socio-cultural practice. One way to connect this to EC design is to reframe external knowledge in terms of a situated practice of creating and using expressive traces. This is in fact the approach taken in both NOOT and TRACES. We investigated how existing practices that already figures representational artifacts, such as the sticky-note, and we reframed these as expressive traces over the course of designing added value to the practice by means of digital technology. The big challenge, starting from this end, is how to incorporate the sensorimotor loop. NOOT and TRACES can be seen as first steps in this direction. Yet both projects also reveal how difficult it is to really get the sensorimotor loop 'in'. One step into this direction is to see how social interaction involves expressive traces, and how this always takes place in a concrete space, where people interact with each other and physically with the trace itself (Goodwin, 2000). Working from that end, skill, affordance, body position, nonverbal interaction, expressive acts, and so on, can start to become part of the design concept as well.

Another starting point would be to try and first create a technological system explicitly in service of a sensorimotor skill. The interactive system then functions like an embodied tool, which becomes part of your body. The challenge, starting from this end, is how to connect these sensorimotor enhancements to the more 'cognitive' sorts of activities, as embedded in social practices. Again, one option is to extend the enhanced sensorimotor loop with expressive traces, which enables some form of 'external representation' to enter the scene that endures in the physical environment over and above the immediate influence of ongoing sensorimotor interaction. To give an example, recall Stienstra's augmented speed-skate (chapter 2; Stienstra, 2012). Suppose that over and above of the real-time feedback loop, which maps skate actions to sounds over headphones, this loop would also create visible traces on the ice-rank as well. These traces would reflect, in a more endurable, expressive fashion, what the skater is doing. The patterns could over time come to signify meaningful aspects of the skater's performance, e.g. the skater's weak-spots on the track, or what part of the race would need extra attention, or what is the best point to accelerate, and so on. If initially these traces would come to bear meaning for the skater herself, the fact that they are public would open up opportunities for social interaction between multiple skaters as well[14].

4.2. Questioning practices through design

Grounding design in Embodied Cognition will not just create new kinds of tools that have new kinds of interactive effects on people, or yield new functionalities. Undoubtedly, the process of designing EC-based tools for a particular context of practice will lead to critically addressing the practice itself and question the foundations on which it rests. In fact, NOOT and TRACES did not just provide directions for solving existing problems in brainstorm rooms, but also critically questioned the practice itself. Why are creative practitioners so focused on recording and storing the 'outcome' of a session, while at the same time they state that the true value of a session lies in the transformation of the people themselves, not in the notes or flip-charts one takes home afterwards (See also the reflections in chapter 5 and the intermezzo)?

Both NOOT and TRACES (the resulting designs, but also the design process itself, in as much as it involved the practice in co-design settings) offer the potential for transforming these practices. They can make practitioners and participants of creative sessions more sensitive to the effect of sensorimotor dynamics as well as to the underlying social relations that ground the creation of ideas and insights during a creative session.

They underscore once more that ‘making notes of it’ does not mean one has ‘stored the shared insight’, as shared insight is ultimately something that is enacted, and sustained, in interaction. In the same way, other practices, in formal education, in health-care, in politics, in institutional management, in engineering, all these practices where implicit forms of Cognitivism can be found, may be critically questioned and opened up for change through transformative EC design projects, asking renewed interest and respect for our inherently embodied ways of making sense of the world.

1 "Human beings, on this view, are themselves technical entities who serve as components of organizational systems: their bodies are machines and their minds are nodes in a hierarchical command-and-control network based on rational analysis and optimization. Edwards refers to the system of practices around this idea as 'cyborg discourse'." (Agre, 1997, p. 3.) To reiterate, this is the reason why notions of DRC are not necessarily helping us in getting beyond the lingering Cartesianism in todays' design practices (See also chapter 7).

2 There is a fourth kind of design pattern aimed at creating an 'artificial intelligent agent', which is in fact the usual approach of investigation in Cognitive Science. In contrast, I have only considered interactive systems as tools or aspects of environment, i.e. artificial interventions scaffolding human cognition. In Interactive Systems Design, a part of a design project often involves envisioning an 'artificial intelligence', as when some interactive system is assumed to interact with the user 'as if it were a real person', or as when the system is supposed to 'know about' and 'learn from' its environment. EC theory however contains a number of strong and quite fundamental arguments against the classical attempts at creating AI (Haselager, 1997; Brooks, 1991; Ziemke & Sharkey, 2001) as well as an overall skepticism concerning the possibility of creating it at all (Dreyfus, 2007). For this Phd project, I decided right from the outset to avoid any goal of creating Artificial Intelligence, i.e. to design 'anthropomorphic behavior' in the interactive system. See (Suchman, 2011), and (Deckers et al, 2011) for EC-inspired work that does.

3 And conventional 'user centered design' comes even after that, in trying to re-connect the already defined system of representations back to the user's actions.

4 We can get insight from observing how representational artifacts, e.g. interactive computer systems, are actually used in practice, regardless from their design, and gain insight into embodied practice from that (Dourish, 2001; Redström, 2008; Wakkary & Maestri, 2007). The present discussion asks how designing systems relates to EC.

5 Perhaps this pitfall can be traced back to a problem that may be part of the basic call for 'usability' as is common practice in UCD. One may argue that usability really functions to 'repair' (cover up) some existing difficulty of connecting the main functionality of the system to the user practice, while at the same time the question of why that functionality is not already naturally connecting to that practice is itself not answered.

6 The point here is not to claim that there are only two relevant levels of description in interactive systems. There may be many levels of organization that all have to be taken into account in the design process. Such multi-level analysis is elaborated in Cognitive Work Analysis (Vicente, 1999), an approach specifically aimed to respect the complexity of actual work situations, in line with what I call a Socially Situated Practice view and connecting to Ecological psychology (Gibson, 1979). The point here is however to show how, given any two levels of description, EC emphasizes 'emergent' meaning at the higher level, from self-organizing interactions at the lower level (Kelso, 1995; Haken, 1999). As I discuss it here, this means that the artifact's function emerges from the way the concrete properties of the 'interface' afford certain sensorimotor couplings, sustained in ongoing action, and that therefore one needs to design and research at the level of concrete embodied interaction in order to get a grip on the 'function' system, as it is experienced by the user. Contrast this with Vicente (1999), who writes: "Understanding of the system increases by crossing levels. By moving up the hierarchy [of levels] we obtain deeper understanding of the system significance with regard to the purposes that are to be achieved, whereas in moving down, we obtain a more detailed explanation of the [manner in which] those purposes can be carried out" (Vicente, 1999, p. 172). This seems instead to assume a top-down process, in which 'purposes' first exist, and then are 'carried out' at lower levels. Instead, radical versions of EC hold that the most basic ('primordial') level is that of actual embodied interaction, and purpose emerges from it as self-organizing couplings (e.g. Heidegger 1927; Chemero, 2009, Varela et al, 1991; Kelso, 1995; Suchman, 2007).

7 Perhaps this is what Dourish (2001) means by: "although a designer can suggest a coupling, only the user can make one". Yet in my reading the coupling is co-shaped as the design interacts with the user-in-context.

8 http://www.youtube.com/watch?v=JP0w9lZoLwU (00:03.41)

9 Interestingly, in recent years CSCW is getting nearer to being able to ask that latter question since many GUI-based collaborative tools will now be implemented as Apps on a hand-held device. This means that information on the screen may become 'public' not just inside a virtual space in concrete reference to the physical positioning of people and the hand-held device in some physical context. This enables the kinds of analyses that Goodwin performs on the way people work in professional settings (Goodwin, 2000).

10 Which does not mean, that these activities do not involve cognition, but merely that it is not always the aspect of the activity that is on the foreground of the design intention.

11 If we would use 'cognition' as the technical term associated only with cognitivist models of mind, then we must find another word for the kind of sense-making that is more fundamental, and in which even explicitly computational-representational routines are ultimately grounded.

12 Similarly it would be a mistake to assume that people will only communicate through your online collaborative tool, and not for instance just call each other up by telephone (probably even at the same time as they are using the tool). This means a lot of what is happening in communication is not accessible by the tool at all, and if the design demands that the tool should have this access to the process (if it is designed on that assumption), then the tool will fail at some point (Suchman, 2007 discusses the same point, showing the limited information a copy-machine has access to, concerning the embodied sense-making processes of its users).

13 Hayles argues that on the one hand, based on digital culture and modern technology, we have become post-human. Yet there is space for embodied engagement within it (Hayles, 1999).

14 And finally, over time, skaters would come to give names to particular kinds of traces, thereby creating a descriptions of the way they already share an experience within which these external traces are meaningful to them in guiding skate action (Clancey, 1997).

Thesis Summary

Introduction

This investigation explores relations between 1) a *theory* of human cognition, called *Embodied Cognition*, 2) the *design* of interactive systems and 3) the practice of 'creative group meetings' (of which the so-called 'brainstorm' is perhaps the best-known example). The investigation is one of Research-through-Design (Overbeeke et al., 2006). This means that, together with students and external stakeholders, I designed two interactive prototypes. Both systems contain a 'mix' of both physical and digital forms. Both are designed to be tools in *creative meeting sessions*, or brainstorms. The tools are meant to form a natural, element in the physical meeting space. The function of these devices is to support the formation of *shared insight*: that is, the tools should support the process by which participants together, during the activity, get a better grip on the design challenge that they are faced with. Over a series of iterations I reflected on the design process and outcome, and investigated how users interacted with the prototypes.

Creative meeting practices

In creative meetings, participants do not always have a clear understanding of their creative challenge right from the start. Part of the problem is that each participant may understand the challenge, as it is initially introduced by the problem-owner, differently. In general, many creative challenges are complex, ill-defined problems to begin with (aka 'wicked problems'). Especially when multiple stakeholders are involved, each with their own interpretation of what the challenge is 'really' all about, a better insight into 'what the problem really is' needs some time to evolve. In practice, shared insight into the creative challenge *co-evolves* with the team's practical activities towards addressing the challenge. In current practice, people use all kinds of physical tools to develop this shared insight, such as: sticky-notes, whiteboard and markers, sketching paper, prototyping materials, photographs brought from home, and so on. The question is whether we can augment these physical tools using interactive technology in a meaningful way, without disrupting the creative flow, or the natural, improvised and flexible ways by which people currently interact with each other and their physical artifacts.

Embodied Cognition

A theory that might be helpful for designing such integrated technological tools, as part of the creative space, might be Embodied Cognition. This is a theory about the basic way in which people are able to think and act. It claims that what we call cognition is fundamentally dependent on our ongoing *embodied activity*. Bluntly speaking: no active body, no thoughts. The theory argues against the classic idea that thinking is something that happens purely 'internal' to us. It rejects the idea that the mind is the 'software' running on the 'hardware' of the brain. Thinking, instead, *emerges in action*, out of continuous embodied interactions between brain, our body and the way our body is 'situated' in a physical- and social context. According to Embodied Cognition, cognition is best seen as a dynamic *coupling* (Clark, 1997; Dourish, 2001), or a process of *coordination* (Suchman, 2007; Clancey, 1997), or, as phenomenologists call it, as getting 'grip', through skilled action (Dreyfus, 2002; Merleau-Ponty, 1963). Artifacts, such as the sticky-note in a brainstorm session, play an important part in the embodied cognitive process. As Kirsh (2010) states, physical artifacts are 'things to think with'. They help people to 'offload' thinking to the environment, to coordinate their own activities with those of others, and to create and hold active online couplings in the continuous feedback loop between action and perception.

Interactive systems

One reason Embodied Cognition may be useful is because the field of interactive systems design shows a growing trend towards trying to integrate physical form and digital process. Looking at it from the perspective of Industrial Design, this entails adding interactive behaviors to physical products, using sensors, actuators, and the like. From the perspective of computer science, it means creating so-called 'tangible' interfaces, where various physical objects can be used to control digital information, a follow-up on the familiar 'graphical' interface. A related trend is that of 'contextual' interfaces that depend crucially on available cues in the local environment. These developments go under such headings as *ubiquitous computing*, *tangible interaction*, *wearable computing*, *augmented reality*, and so on. The bulk of this design work has yet to find its way to the commercial markets, but the prospect is that in the near future this will certainly happen. The current popularity of interacting via mobile devices, such as the smartphone or tablet, with Apps making use of GPS location, the accelerometer, and so on, signals a development that moves away from the classical 'desktop interface'. One may say it moves interaction with digital processes 'back into the real world', mixing it seamlessly with physical objects, environments, and social contexts.

Research objectives

Through designing and researching two concrete interactive prototypes I explored the following research question:

RQ 1. How may we design interactive systems in support of embodied cognition?

The main objective of my investigation has been to *reframe* our conceptualization of interactive systems design, such that designers may start to think in new ways about what it is they are trying to do, based on Embodied Cognition theory. At the same time, the practical attempt of the theory to design also brings insight the theory itself, which defines my second research question:

RQ 2. How does (the practical attempt at) designing interactive systems supporting shared insight in creative meetings, inform the theory of Embodied Cognition?

Approach

In a series of design iterations I undertook the following activities: 1) detailed observational studies of naturally occurring human practices (either with our without our prototypes); 2) participatory workshops involving potential users from several creative companies and organizations, executed at the site-of-practice, including situated interviews and 'acting-out' design concepts; 3) design explorations and prototyping, and reflecting on these in reference to the theoretical framework; 4) detailed observations of human activity in response to an experimental manipulation, using two variations on a prototype as conditions, and 5) general theoretical reflections. Together, these research activities enabled me to answer my research questions.

Findings

The designs: NOOT and FLOOR-IT

NOOT, in its final form, consists of a system of tangible clips with which one can create time-markings in a continuous audio-recording of the creative session. The tangible clips can be placed everywhere in the physical space, e.g. on the wall, on the table, on sketches or annotations, or on a mock-up or prototype. With a physical horn one can activate audio-playback that allows one to listen to the part of the conversation that was going on when the clip was first activated. In this way NOOT provides small segments of 'history' of the conversation, attached to meaningful physical items in the space, which can be fed back into the current conversation. In the final reflection I offered that NOOT couples *individual moments of reflection-in-action* to the overall group conversation, thereby supporting the formation of shared insight.

FLOOR-IT enables people to create digital photographs of any of the sketches or written texts (or other visual elements) created during the session. The series of personal snapshots form a 'trace', reflecting one's evolving line-of-thought. Each person's personal 'trace' is physically projected as a circle of digital images around the body, on the floor. On that floor, which is quite large (six projectors were used to create the canvas), small groups of people engage in a creative conversation, while their traces are publicly visible as projected around their bodies. The traces form a conversational 'scaffold', to which people can point and refer during the talk. Furthermore, by using foot gestures, images may copied from one trace to the other, and they may be combined to form new clusters, new traces, which stay fixed on the floor. The emerging, overall trace on the floor represents the growing 'shared insight' of the team as a whole which continues to support the ongoing interactions of the creative team. In a user study, comparing FLOOR-IT with a variation that projected the pictures on a shared wall, it was discovered that such traces function to help people position themselves socially in relation to others. Referring to ones personal trace during ongoing talk helps not so much to share factual information rather than that it serves to present yourself as a valuable partner in the activity, and to invite others to do so as well.

Consequences for theory

Embodied Cognition is a broad field of inquiry, with roots in quite disparate research traditions. Based on my reflections on the design iterations, I was able to discern four variations of the theory that each have their own particular consequences for design. I call these the 1) distributed representation and computation perspective, 2) the socially situated practice perspective and 3) the sensorimotor & enactment perspective.

The distributed representation and computation perspective is perhaps most easily understood by those familiar with computational principles and it has proven to be a useful and relevant set of principles for interaction designers. Yet it actually hinders interaction designers in getting to the heart of the notion of embodiment. Instead, based on my design investigations I offer that the prime ingredients needed for understanding how my prototypes support shared insight are 1) the *sensorimotor* aspect of cognition (how insight emerges from real-time coupling of perception and action) and 2) the *social situatedness* of cognition (how cognition is socially coordinated between people). Moreover, sensorimotor coupling and social situatedness are strongly integrated in one unified embodied activity (Goodwin, 2000). In particular, the studies revealed how people would create *expressive traces* in the environment. Expressive traces, e.g. a physical sticky-note, a NOOT clip, or a trace in FLOOR-IT, are both the outcome of people's earlier actions, as well guiding further action. That is, traces become part of people's sensorimotor couplings. At the same time, expressive traces are also social artifacts, created in and for a social context, publicly available and socially accountable. They function to coordinate people's social positioning in the physical space. Expressive traces form the linking pins between social interaction and sensorimotor coupling, thereby supporting the emergence of shared insight.

Conclusions for design

I offer a number of pitfalls and opportunities for designers that want to ground design in embodied cognition theory. I start with the claim that the classic interface concepts, which rely on information processing metaphors, are best explained with a 'Distributed Representation and Computation' version of Embodied Cognition. This goes also for many of the so-called 'tangible media systems', where tangible objects essentially 'encode' digital information in physical form. However useful, they stand in the way of designing for a more fundamental form of Embodied Cognition, as they too easily draw us back into 'Cartesian thought'.

Based on Socially Situated Practices and Sensorimotor Coupling and Enactment, I propose a more fundamental form of Embodied Cognition Design. Embodied Cognition Design brings forth interactive systems that transform our ways of perceiving, our possibilities for acting, our ways of interacting socially with others, and it helps us to create endurable ‘expressive traces’ in the environment. In any concrete product proposal, all of these aspects will be part of the unified experience of the user. Through Embodied Cognition Design we may search for completely new roles for digital computing technology in human practices. This means going beyond the classical, Cartesian functions of storing, processing and presenting representational data. One consequence of this vision is that the ‘function’ of an artifact can no longer be predefined before one starts designing the ‘interface’: in Embodied Cognition Design, concrete interactions between the user and the system bring forth, or ‘enact’ the meaning that the system has for the user. This means one has to design the interactive behavior and ‘what the system is for’, both at the same time, with no a priori distinction between the digital- and the physical aspect, nor even the embedding context. One may for example design in iterative fashion, building series of functioning prototypes, which can be tried out such as to stay in close contact with the user and his context of practice throughout the entire project.

References

Agre, P.E. and Chapman., D. (1990). What are plans for? Robotics and Autonomous Systems, 6(1-2), 17-34.

Agre, P. & Horswill, I. (1997). Lifeworld analysis. Journal of artificial intelligence research, 6, 111-145.

Agre, P.E. (1997). Toward a Critical Technical Practice: Lessons Learned in Trying to Reform AI. In: G. Bowker, L. Gasser, L. Star, and B. Turner, eds, Bridging the Great Divide: Social Science, Technical Systems, and Cooperative Work, Mahwah: Laurence Erlbaum, 1997.

Allison, B., Owen, A., Rothwell, A., O'Sullivan, T., Saundes C. & Rice, J. (1996). Research Skills For Students, London: Kogan Page.

Anderson, M.L. (2003). Embodied cognition: a field-guide. Artificial Intelligence, 149 (1), 91-130.

Archer, B. (1995). The Nature of Research. Co-Design Journal, pp. 6-13.

Arias, E., Eden, H., Fischer, G., Gorman, A., Scharff, E. (2000). Transcending the individual human mind—creating shared understanding through collaborative design. Transactions on Computer-Human Interaction 7 (1). 84-112

Bach-y-Rita P. (1972). Brain Mechanisms in Sensory Substitution, New York: Academic Press.

Ballard, D., Hayhoe, M., Pook, P., & Rao, R. (1997). Deictic codes for the embodiment of cognition. Behavioral and Brain Sciences, 20, 723-767.

Bateson, G. (1972). Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology. Chicago: University Press.

Beer, R.D. (2008). Dynamical systems and embedded cognition. To appear in K. Frankish and W. Ramsey (Eds.), The Cambridge Handbook of Artificial Intelligence. Cambridge University Press.

Binder, T. (2007). Why design: labs. Proceedings of 'Design Inquiries', the 2nd Nordic Design Research Conference. Retrieved from: http://www.dkds.dk/Forskning/Personer/Thomas_Binder, March, 9, 2013.

Brooks, R.A., (1991) Intelligence without representation, Artificial Intelligence 47, 139–159.

Bruns, A. M., Keyson, D.V. and Hummels, C.C.M. (2008). Squeeze, rock and roll; can tangible interaction with affective products produce stress reduction? Tangible and embedded interaction. Proceedings of the 2nd international conference on Tangible and Embedded interaction.

Bruns, M., Hummels, C.C.M., Keyson, D.V. & Hekkert, P.P.M. (2012). Measuring and adapting behavior during product interaction to influence affect. Personal and Ubiquitous Computing, 10(2-3), 163-165.

Bucciarelli, L.L., (1996). Designing Engineers. MIT Press, Cambridge, MA.

Buur, J., M.V. Jensen, and T. Djajadiningrat (2004). Hands-Only Scenarios and Video Action Walls – Novel Methods for Tangible User Interaction Design. Proceedings of DIS Cambridge MA, USA, p. 185 – 192.

Buur, J. & Matthews, B. (2008). Participatory innovation, a research agenda. Proceedings of the Tenth Anniversary Conference on Participatory Design 2008 (PDC '08). Indiana University, Indianapolis, IN, USA, 186-189.

Calvo, P. & Gomila, A. (Eds.) (2008). Handbook of cognitive science: An embodied approach. Amsterdam: Elsevier.

Caroll, J.M. (1997). Human computer interaction: psychology as a science of design. International Journal of Human-Computer Studies, 46, 501-522.

Ceci, S. J., and A. Roazzi. (1994). The effects of context on cognition: Postcards from Brazil. In R. J. Sternberg and R. K. Wagner, (Eds.). Mind in Context. New York: Cambridge University Press, pp. 74-101.

Chemero, A. (1998) A Stroll Through the Worlds of Animats and Humans: Review of Being There: Putting Brain, Body and World Together Again.

Chemero, T. (2009). Radical embodied cognitive science. Cambridge, MA: MIT Press.

Clancey, W.J. (1993). Situation action: a neuropsychological interpretation. Response to Vera and Simon. Cognitive Science, 17, 87-116.

Clancey, W. J. (1997). Situated cognition : On human knowledge and computer representation. Cambridge, MA: Cambridge University Press.

Clark, A. (1997) Being there: Putting brain, body and world together again. Cambridge, MA: MIT Press.

Clark, A. & Chalmers D.J. (1998) The extended mind. Analysis, 58, 10-23.

Clark, A. (2008) Pressing the flesh: a tension in the study of the embodied, embedded mind? Philosophy and phenomenological research 76 (1), 37-59.

Crabtree, A. & Rodden, T. (2008) Hybrid ecologies: understanding cooperative interaction in emerging physical-digital environments. Personal & Ubiquitous Computing, 12, 481–493.

Crilly, N., Maier, A., & Clarkson, P. (2008). Representing Artefacts as Media: Modelling the Relationship Between Designer Intent and Consumer Experience. International Journal of Design [Online] 2(3). Retrieved from: http://www.ijdesign.org/

Cross, N. (2007). Designerly Ways of Knowing. Basel: Birkhäuser.

Damasio, A. R. (1994). Descartes' error: Emotion, reason, and the human brain. New York: Putnam.

Dewey, J., & Bentley, A.F. (1949). Knowing and the known. Boston: Beacon Press.

Dewey, J. (1910). How we think. Boston: D.C. Heath & Co.

Deckers, E. Wensveen, S. Ahn, R. and Overbeeke, C.J. (2011) Designing for perceptual crossing to improve user involvement. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11). ACM, New York, NY, USA, 1929-1938.

Djajadiningrat, J.P., Overbeeke, C.J., and Wensveen, S.A.G. (2002). But how, Donald, tell us how? On the Meaning in Interaction Design through Feedforward and Inherent Feedback. Proceedings of DIS2002, pp.285-291.

Djajadiningrat, J.P., Wensveen, S.A.G., Frens, J.W. and Overbeeke, C.J. (2004). Tangible products: redressing the balance between appearance and action. Personal and Ubiquitous Computing, 8 (5), 294-309.

Dourish, P. (2001) Where the Action Is: The Foundations of Embodied Interaction. Cambridge, MA: MIT Press.

Dourish, P. (2006). Implications for Design. Proc. ACM Conf. Human Factors in Computing Systems CHI 2006 (Montreal, Canada), 541-550.

Dreyfus, Hubert (1972). What Computers Can't Do, New York: MIT Press

Dreyfus, H.L. (2002). Intelligence without representation: Merleau-ponty's critique of mental representation. Phenomenology and the Cognitive Sciences, 1, 367-83

Dreyfus, H.L. (2007) Why Heideggerian AI failed and how fixing it would require making it more Heideggerian. Philosophical Psychology. 20. 247-268.

Van Dijk, J., Kerkhofs, R., van Rooij, I., and Haselager, W.F.G. (2008). Can there be such a thing as embodied embedded cognitive neuroscience? Theory & Psychology, 13(8), 297-316.

Edelman, G. M. (1992). Brilliant Air, Brilliant Fire: On the Matter of Mind. New York: Basic Books.

Ehn, P. (2008). Participation in Design Things. In Proceedings of the Tenth Anniversary Conference on Participatory Design 2008 (PDC '08). Indiana University, Indianapolis, IN, USA, 92-101

Ehn, P. (2011). Design Things: Drawing things together and making things public. Technoscienza. Italian Journal of Science and Technology Studies, 2(1), 31-52.

Fernaeus, Y., Tholander, J., & Jonsson, M. (2008). Toward a new set of ideals: consequences of the practice turn in tangible interaction. Proc of 2nd international conference on tangible and embedded interaction (TEI'08) Feb 18-20, Bonn, Germany, 223-230.

Feyerabend, P. (1975). Against Method: Outline of an Anarchistic Theory of Knowledge. Londen: Verso.

Fitzmaurice, G., Ishii, H., and Buxton, W. (1995) Bricks: Laying the foundations for graspable user interfaces. In Proceedings of Computer-Human Interaction 1995. 442–449.

Fodor, J. (1983). The modularity of mind. Cambridge, MA: MIT Press.

Frens, J. (2006). Designing for Rich Interaction. Integrating Form, Interaction, and Function. Eindhoven: Department of Industrial Design.

Gallagher, S. & Zahavi, D. (2007) The Phenomenological Mind: An Introduction to Philosophy of Mind and Cognitive Science. New York: Routledge

Garfinkel, H. and Sacks. H. (1970). Formal Structures of Practical Action. In J. C. McKinney and E. A. Tiryakian (Eds.), Theoretical Sociology, New York: Appleton Century Crofts.

Gaver, W. Bowers, J., Boucher, A., Law, A., Pennington, S., Villar, N. (2006). History Tablecloth: Illuminating Domestic Activity. Proc of DIS, '06, 199-208.

Geyer, Florian; Budzinski, Jochen; Reiterer, Harald (2012). IdeaVis: A Hybrid Workspace and Interactive Visualization for Paper-based Collaborative Sketching Sessions Proceedings of the Nordic Conference on Human-Computer Interaction NordiCHI 2012, Copenhagen, Denmark, ACM Press, Oct 2012

Geertz, C. (1973). The interpretation of cultures: selected essays. New York: Basic Books. (pp. 3-30).

Gibson, J.J. (1979). The Ecological Approach to Visual Perception, Houghton Mifflin, Boston.

Gladwell, M. (2007). Blink. Back Bay Books.

Goodwin (2000). Action and embodiment within situated human interaction. Journal of pragmatics, 32, 1489-1522.

Goodwin, C. (2003). The semiotic body in its environment. In J. Coupland & R. Gwyn (Eds.) Discourses of the Body (pp. 19-42). New York, NY, US: Palgrave/Macmillan.

Haken, H. (1999). Synergetics and some applications to psychology, in W. Tschacher & P.-P. Daualder, eds., Dynamics, synergetics, autonomous agents. London: World Scientific.

Haselager, W.F.G. (1997). Cognitive science and folk psychology: The right frame of mind. London: Sage.

Haselager, W. F. G., Bongers, R. M., & van Rooij, I. (2003). Cognitive science, representations and dynamical systems theory. In W. Tschacher & J.-P. Dauwalder (Eds.), The Dynamical Systems Approach to Cognition (pp. 229–242). Singapore: World Scientific.

Hayles, N.K. (1999). How we became posthuman. Virtual bodies in cybernetics, literature and informatics. Chicago: University Press.

Heath, C., & Luff, P. (1991). Collaborative activity and technological design: Task coordination in London Underground control rooms. Proceedings of ECSCW 91, 65-80. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Heath C. & Luff, P. (2000) Technology in action. Cambridge University Press.

Heidegger, M. (1927). Sein und Zeit. Tübingen: Max Niemeyer Verlag. Reprinted in 1986.

Heidegger, M. (1976). Gesamtausgabe: Vol. 21. Logik: die Frage nach der Wahrheit. Frankfurt am Main: Vittorio Klostermann.

Heinemann, T., R. Mitchell, et al. (2010). Co-constructing meaning with materials in innovation workshops. Objects & Communication MEI 30-31: 289-303.

Helmes, J., Hummels, C. and Sellen, A. (2009). The Other Brother: Re-experiencing Spontaneous Moments from Domestic Life. In: Proceedings of the Third International Conference on Tangible and Embedded Interaction, (Cambridge, UK, February 2009, pp. 233- 240.) New York: ACM.

Hengeveld, B.J. (2011). Designing LinguaBytes : a tangible language learning system for non- or hardly speaking toddlers. Eindhoven: Technische Universiteit Eindhoven.

Hollan, J., Hutchins, E. and Kirsh, D. (2000). Distributed Cognition: Toward a new Foundation for Human-Computer interaction research. ACM Transactions on Computer-Human Interaction, Vol. 7, No. 2, Pages 174–196.

Holland, O. and Melhuish, C. (2000) Stigmergy, self-organisation, and sorting in collective robotics. Artificial Life, 5(2).

Holzblatt, K., and Jones, S. (1993). Contextual inquiry: A participatory technique for system design. In Schuler and Namioka (op. cit.), pp. 177-210.

Hornecker, E. and Buur, J. (2006). Getting a grip on tangible interaction: a framework on physical space and social interaction. In R. Grinter, T. Rodden, P. Aoki, E. Cutrell, R. Jeffries, and G. Olson (Eds.) , Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Montréal, Québec, Canada, April 22 - 27, 2006, pp. 437-446.). New York: ACM

Van der Hoven, E. and Eggen, B. (2008). Informing augmented memory system design through autobiographical memory theory. Personal and Ubiquitous Computing, 12, 433–443.

Hummels, C.C.M. (2012) Matter of transformation. Sculpting a valuable tomorrow. Inaugural lecture. Eindhoven: University Press.

Hummels, C.C.M., Frens, J. (2008) Designing for the unknown: A design process for the future generation - of highly interactive systems and products. In: Proceedings Conference on EPDE, 4-5 September, Barcalona, Spain, 204-209

Hummels, C.C.M., Overbeeke, C.J., Appleby, R.S., Frens, J.W. & Wensveen, S.A.G. (2008). The power of embodiment for design and vice versa. Form + Zweck, 22, 6-11.

Hummels, C.C.M., Overbeeke, C.J. & Klooster, S. (2007) Move to get moved. Personal Ubiquitous Computing, 11:677–690.

Hummels, C.C.M. and van der Helm, A. (2004). ISH and the search for resonant tangible interaction. Personal and Ubiquitous Computing 8(5): 385-388.

Hutchins, E. (1995) Cognition in the wild. Cambridge: MIT Press.

Hurley, S.L. (1998). Vehicles, contents, conceptual structure and externalism. Analysis, 58 (1), 1-6.

Ingold, T (2005). "On Movement, Skill and Design of User Interfaces". University of Southern Denmark. January 18.

Ingold, T. (2006). 'Walking the plank: meditations on a process of skill'. J Dakers (ed.), in: Defining technological literacy: towards an epistemological framework. Palgrave Macmillan, Palgrave Macmillan, New York, pp. 65-80.

Ingold, T. (1995). 'Tools, Language and Cognition'. Journal of the Royal Anthropological Institute (N.S.), vol 1, no. 2, pp. 396-398.

Ingold, T. (2000). Making culture and weaving the world. In Matter, Materiality and Modern Culture, ed. P. M. Graves-Brown. London: Routledge, pp. 50-71.

Ishii, H., and Ullmer, B. (1997). Tangible Bits: Towards Seamless Interfaces between People, Bits, and Atoms. Proc. of CHI'97, pp. 234-241.

Ishii, H. (2008) Tangible bits: Beyond pixels. In: Proceedings of the Second International Conference on Tangible and Embedded Interaction, (Bonn, Feb 2008, pp. XV-XXV). New York: ACM.

Ishii, H., Lakatos, D., Bonanni, L. and Labrune, J.B. (2012) Radical Atoms: Beyond tangible bits, toward transformable materials. Interactions 19(1).

Isomursu, M., Kuutti, K., and Väinämö, S. (2004). Experience Clip: Method for User Participation and Evaluation of Mobile Concepts. In: Proceedings of the Participatory Design Conference, (Toronto, Canada, 2008, pp. 83-92.) New York: ACM.

Jensen, M.V., Buur, J., Djajadiningrat, T. (2005), Designing the user actions in tangible interaction. In Critical Computing, 9-18

Jordà, S., Geiger, G., Alonso, M., and Kaltenbrunner, M. (2007). The reacTable: exploring the synergy between live music performance and tabletop tangible interfaces. In: Proceedings of the 1st International Conference on Tangible and Embedded Interaction 2007. pp. 139-146.

De Jaegher, H. and Di Paolo, E. (2007). Participatory sense-making: An enactive approach to social cognition. Phenomenology and the Cognitive Sciences, 6(4), 485-507.

De Jaegher (2009). Social understanding through direct perception? Yes, by interacting. Consciousness and Cognition, 18, 535–542.

Kaptelinin, V. and Nardi, B. (2006). Acting with Technology: Activity Theory and Interaction Design. Cambridge: MIT Press.

Keller, A. I. (2005). For inspiration only: Designer interaction with informal collections of visual material [Doctoral dissertation]. Delft, the Netherlands: Delft University.

Kelso, J.A.S. (1995). Dynamic patterns: the self-organization of brain and behavior. Cambridge, MA, MIT Press

Kirsh, D. & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. Cognitive Science, 18, 513-549.

Kirsh, D. Problem Solving and Situated Cognition. (2009) In, Philip Robbins & M. Aydede (Eds.) The Cambridge Handbook of Situated Cognition. Cambridge: Cambridge University Press. (pp. 264-306)

Kirsh, D. (2010). Thinking with external representations. AI & Society, 25, pp. 441-454.

Kleinsmann, M. (2008). Barriers and enablers for creating shared understanding in co-design projects. Design Studies, 29 (4), 369-386.

Klemmer, S.R., Hartman, B. and Takayama, L. (2006). How bodies matter: five themes for interaction design. In: DIS 2006, ACM Conference on designing interactive systems, (June 26–28, University Park, Pennsylvania, USA, pp. 140-149), New York: ACM.

Koskinen, I., Zimmerman, J., Binder, T., Redstrom, J., & Wensveen, S. (2011). Design research through practice: From the lab, field and showroom. Waltham (MA): Morgan-Kaufmann.

Lakoff, G. & M. Johnson. (1999). Philosophy In The Flesh: The Embodied Mind and Its Challenge to Western Thought. New York: Basic Books.

Lave, J., (1988). Cognition in Practice. Mind, mathematics and culture in everyday life. Cambridge University Press.

Lave, J., and E. Wenger. (1991). Situated Learning: Legitimate Peripheral Participation. Cambridge: Cambridge University Press.

Loftus, E.F. and Hoffman, H.G. (1989). Misinformation and memory, the creation of new memories. Journal of Experimental Psychology: General 118(1): 100-104.

Lucero, A., Vaajakallio, K. and Dalsgaard, P. (2011). The dialogue-labs method: process, space and materials as structuring elements to spark dialogue in co-design events. CoDesign, Taylor & Francis, 1-23.

Lugt, R van der (2005). How sketching can affect the idea generation process in design group meetings. Design studies, 26(2), 101-122.

Maier, A. M., Kreimeyer, M., Lindemann, U., Clarkson, P. J. (2009). Reflecting communication: a key factor for successful collaboration between embodiment design and simulation. Journal of Engineering Design, 20 (3), 265-287

Mascolo, M. F. (2005). Change processes in development: The concept of coactive scaffolding. New Ideas in Psychology, 23, 185-196.

Matari₵ M.J. (1996) Studying the Role of Embodiment in Cognition. Working Notes of the AAAI Fall Symposium on Embodied Cognition and Action, MIT, Nov 9-11, 1996.

Maturana, H. and Varela, F.J. (1984). The tree of knowledge. Biological basis of human understanding. Boston: Shambhala.

Merleau-Ponty, M. (1962). Phenomenology of perception. New York: Routledge.

Miller, G. (2003). The cognitive revolution: a historical perspective. Trends in Cognitive Sciences Vol.7 No.3 March 2003 141-144.

Myin, E. & Hutto, D. (2013). Radicalizing Enactivism. Basic Minds without Content, Cambridge: MIT Press.

McCoy, J., and G.W. Evans (2002). The potential role of the physical environment in fostering creativity. Creativity Research Journal, vol. 14, no. 3/4, pp. 409-426.

Morris, D. (2010). Empirical and Phenomenological Studies of Embodied Cognition. In S. Gallagher & D. Schmicking (Eds.) The Handbook of Phenomenology and Cognitive Science. 235-252. London: Springer Verlag.

Neth, H., Carlson, R. A., Gray, W. D., Kirlik, A., Kirsh, D., & Payne, S. J. (2007). Immediate Interactive Behavior: How Embodied and Embedded Cognition Uses and Changes the World to Achieve its Goals. In D. S. McNamara & J. G. Trafton (Eds.), Proceedings of the 29th Annual Conference of the Cognitive Science Society (pp. 33–34). Nashville, TN: Cognitive Science Society.

Newell, A. & Card, S. K. (1985). The prospects for psychological science in human-computer interaction. Human-Computer Interaction. 1 (3): 209-242.

Newell, A., and Simon, H.A., (1972). Human problem solving. Englewood Cliffs, NJ: Prentice Hall.

Noe, A. (2004). Action in perception. Cambridge: MIT Press.

Norman, D.A. (2002). The design of everyday things. New York: Basic Books.

Pfeifer, R & Scheier, C. (1999) Understanding Intelligence, MIT Press, Cambridge, MA.

Pye, D. (1968). The Nature and Art of Workmanship. Cambridge: Cambridge University Press.

O›Donoghue, T., Punch K. (2003). Qualitative Educational Research in Action: Doing and Reflecting. Routledge.

Osborn, A.F. (1963) Applied Imagination. New York: Scribner's.

Overbeeke, C.J., Wensveen, S. and Hummels, C.C.M. (2006). Design Research: Generating Knowledge through Doing. In Swiss Design Network. Drawing New Territories. State of the Art and Perspectives. Third Symposium of Design Research, 17-18 Nov, Geneva. Geneva: Swiss Design Network.

Overbeeke, C.J. and Wensveen, S.A.G. (2003). From Perception to Experience, from Affordances to Irresistibles. Proceedings of DPPI›03, June 23-26, 2003, Pittsburgh, Pennsylvania, USA.92-97.

Randall, D., Hughes, J., & Shapiro, D. (1991). Systems development – the fourth dimension: perspectives on the social organisation of work, SPRU/PICT Workshop on Policy issues in systems and software development (Brighton, Juli 18-19).

Redström, J. (2008). Re: definitions of use. Design Studies, 29, 410-423.

Rittel, H., & Webber, M. M., (1984) Planning Problems are Wicked Problems. In N. Cross (Ed.), Developments in Design Methodology, 135-144. John Wiley & Sons: New York.

Rietveld, E, De Haan, S. & Denys, D. (2012). Social affordances in context: What is it that we are bodily responsive to? Behavioral and Brain Sciences.

Robbins, P. & Adydede, M. (Eds.) (2009). The Cambridge Handbook of Situated Cognition. New York: Cambridge University Press.

Robertson, T. (1997). Cooperative Work and Lived Cognition: A Taxonomy of Embodied Actions. In: Proc Fifth ECCSCW Dordrecht: Kluwer Academic Publishers, 205-220.

Robertson, T. (2002). The public availability of actions and artefacts. Computer Supported Cooperative Work, 11: 299-316.

van Rooij, I., Bongers, R. M., & Haselager, W. F. G. (2002). A non-representational approach to imagined action. Cognitive Science, 26(3), 345-375.

Ross, P. R., & Wensveen, S. A. G. (2010). Designing aesthetics of behavior in interaction: Using aesthetic experience as a mechanism for design. International Journal of Design, 4(2), 3-13

Ryle, G. (1949). The Concept of Mind. New York: Barnes &Noble.

Sanders, E. B.-N. (2000). Generative Tools for CoDesigning. In Scrivener, Ball, and Woodcock (Eds.) Collaborative Design. London: Springer-Verlag.

Schegloff, E.A. (1991) Conversation Analysis and Socially Shared Cognition. In L. Resnick, J. Levine and S. Teasley (eds.), Perspectives on Socially Shared Cognition. Washington, D.C.: APA, 150-171.

Schiphorst, T. (1992). The Choreography Machine: A Design Tool For Character and Human Movement, CyberArts: Exploring Art and Technology, Miller Freeman Inc., Book Division, San Francisco, CA, pp 147-154.

Schön, D.A., 1983, The reflective practitioner - how professionals think in action. New York: Basic Books.

Schuler, D., and Namioka, A. (1993). Participatory design: Principles and practices. Hillsdale, NJ: Lawrence Erlbaum.

Sennett, R. (2008). The Craftsman, London: Penguin.

Simon, H. (1996). The Sciences of the Artificial. Cambridge, MA: MIT. 3rd edition.

Skarda, C. A., & Freeman, W. J. (1987). How brains make chaos to make sense of the world. The Behavioral and Brain Sciences, 10, 161–195.

Sleeswijk Visser, F., van der Lugt, R., Stappers, P.J. (2007). Sharing user experiences in the product innovation process: Participatory design needs participatory communication. Journal of Creativity and Innovation Management, 16(1), 35-45.

Spradley, J.P. (1979). The Ethnographic Interview. Harcourt, Brace, Jovanovich

Stappers, P.J. (2007). Doing Design as a Part of Doing Research. In R. Michel, (Ed). Design Research Now. Basel, Switzerland: Birkhäuser. Pp. 81-91.

Stienstra, J.T., Overbeeke, C.J. & Wensveen, S.A.G. (2011). Embodying complexity through movement sonification : case study on empowering the speed-skater. Proceedings of the 9th ACM SIGCHI Italian Chapter International Conference on Computer-Human Interaction: Facing Complexity, 13-16 September 2011, Alghero, Italy. (pp. 39-44). New York: ACM.

Stienstra, J.T., Bruns, M., Wensveen, S.A.G. & Kuenen, C.D. (2012). How to design for transformation of behavior through interactive materiality. Proceedings of the 7th Nordic Conference on Human-Computer Interaction (NordiCHI 2012), October 14-17, Copenhagen, Denmark, New York: ACM.

Stolterman, E. (2008). The nature of design practice and implications for interaction design research. International Journal of Design, 2(1), 55-65.

Steen, M (2012). Human-centred design as a fragile encounter, Design Issues, 28, 1, 72-80.

Suchman, L.A. (2007). Human-Machine Reconfigurations: Plans and Situated Actions 2nd expanded edition. New York and Cambridge UK: Cambridge University Press.

Suchman, L.A. (1987). Plans and situated actions. The problem of human-machine communication. New York: Cambridge University Press.

Suchman, L. (2011). Subject Objects. Feminist Theory, 12 (2): 119-145.

Thelen, E., & Smith, L. B. (1994). A dynamic systems approach to the development of cognition and action. Cambridge. MA, USA: MIT-Press.

Torrance, S. (2006). In search of the enactive. Phenomenology and the Cognitive Sciences (2006) 4: 357–368.

Theraulaz & Bonabeau (1999). A brief history of stigmergy. Artificial Life, 5, 97-116.

Trotto, A., Hummels, C.C.M. & Cruz Restrepo, M. (2011). Towards design-driven innovation: designing for points of view, using intuition through skills. Proceedings of the Designing Pleasurable Products and Interfaces Conference 2011 (DPPI 2011), 22-25 June 2011, Milan, Italy, (pp. 3-9). Milan: Politecnico di Milano.

Ullmer, B. and Ishii, H. (2000). Emerging Frameworks for Tangible User Interfaces. IBM Systems Journal, 39, 915-931.

Underkoffler, J. & Ishii, H. (1998). Illuminating light: an optical design tool with a luminous-tangible interface. In C. Karat, A. Lund, J. Coutaz, and J. Karat, Eds. Conference on Human Factors in Computing Systems (542-549). New York, NY: ACM Press/ Addison-Wesley Publishing Co.

Varela, F. J., Thompson, E., & Rosch, E. (1991). The embodied mind. Cambridge, MA, USA: MIT.

Verbeek, P.P. (2000). De daadkracht der dingen (What things can do). Amsterdam: Boom.

Vicente, K.J. (1999). Cognitive Work Analysis. Mahwah, NJ: Lawrence Erlbaum Associates.

Von Uexkull, J. (1934). A stroll through the worlds of animals and men. In: K. Lashley, (Ed). Instinctive behavior. New York: International Press.

Vygotsky, L. S. (1956). Thought and Language. Cambridge (Mass): MIT Press.

Wilson, M. (2002). Six views of embodied cognition. Psychonomic Bulletin & Review, 9, 625–636.

Wakkary, R. and Maestri, L. (2007). The resourcefulness of everyday design. In Proceedings of the 6th ACM SIGCHI Conference on Creativity & Cognition, Washington, DC, USA, June 13 - 15, 2007. New York: ACM, 163-172.

Wakkary, R. (2005). Framing Complexity, Design and Experience: A Reflective Analysis, Digital Creativity, Volume 16, (2), 65-78.

Wensveen, S. A. G. (2005). Designing for emotionally rich interaction. Unpublished doctoral dissertation. Delft University of Technology, Delft, The Netherlands.

Wegner, D.M. (2002). The illusion of conscious will. Cambridge (MA): MIT Press.

Wiener, N. (1948). Cybernetics: Or Control and Communication in the Animal and the Machine. Cambridge (MA): MIT Press.

Winograd, T. and Flores, F. (1986). Understanding Computers and Cognition: A new foundation for Design. California: Addisson-Wesley

Ylirisku S, Halttunen, V. Nuojua, H &. Juustila, A. (2009). Framing Design in the Third Paradigm. Proceedings Of CHI'09, April 7th, Boston, MA, USA, 1131- 1140.

Ziemke, T. and Sharkey, N. E. (2001) A stroll through the worlds of robots and animals: Applying Jakob von Uexküll's theory of meaning to adaptive robots and artificial life. Semiotica, 134(1-4):653-694.

Zimmerman, J, Forlizzi, J. Evenson, S. (2007). Research Through Design as a Method for Interaction Design Research in HCI. Proc. CHI 2007, April 28– May 3, 2007, San Jose, California, USA.

Appendices

A. Publications from this thesis

Van Dijk, J. (2009) Cognition is not what it used to be. Reconsidering usability from an embodied embedded cognition perspective. Human Technology, Volume 5, Number 1, May 2009, pp. 29-46

Van der Sluijs, J.M. and Van Dijk, J. (2009) Noot: A Tangible Interaction Tool Supporting Memory In Creative Practices. Proceedings of CHI-NL, 2009, June 11, Leiden.

Van Dijk, J., van der Lugt, R. and Overbeeke, C.J. (2009). Let's take this conversation outside: Supporting embodied embedded memory. in: Conf. Proceedings of DPPI'09, October 13-16, Compiegne, France. Pp. 144-151. Universite de Technologie de Compiegne.

Van Dijk, J. and Brouwer, C.E. (2011) Making sense of brainstorms: some NOOTs to reflect on. Participatory Innovation Conference (PINC'11), Sonderborg, Danmark.

Brouwer, C.E. and Van Dijk, J. (2011) Brainstorming: Talk and the representation of ideas and insights. Participatory Innovation Conference (PINC'11), Sonderborg, Danmark.

Van Dijk, J. Van der Lugt, R. and Overbeeke, C.J. (2011) Marking the moment: Coupling NOOT to the situated practice of creative sessions. Work-in-Progress Workshop, Tangible, Embodied & Embedded Interaction, 23-16 jan, Funchal, Portugal.

Van Dijk, J. Van der Roest, J. and Messager, E. (2011) NOOT: Tangible tags supporting reflection in brainstorms. CHI-Sparks, June, Arnhem, Netherlands, (Including demo).

Van Dijk, Van der Roest, J., Van der, Lugt, R. and Overbeeke, C.J. (2011) NOOT: A tool for sharing moments of reflection during creative meetings. C&C'11, November 3–6, 2011, Atlanta, Georgia, USA. [Honorable mention 2011 Emmy Candy Award best contribution to creative communication]

Van Dijk, J. and Vos, G.W. (2011) Traces in Creative Spaces. C&C'11, November 3–6, 2011, Atlanta, Georgia, USA.

Vos, G.W. and Van Dijk, J. (2011) Traces in Creative Spaces. CHI- Sparks, June, Arnhem, Netherlands, (Including demo).

Van Dijk, J. and Frens, J.W. Being there, doing it: the challenge of embodied cognition for design. Workshop *at CHI-sparks, june, Arnhem, Netherlands.*

Van Dijk, J. and Frens, J.W. Being there, doing it: the challenge of embodied cognition for design. Workshop at Creativity and Cognition '11, November 3–6, 2011, Atlanta, Georgia, USA.

Van Dijk, J., Van der Lugt, R. and Hummels, C.J. (2013) Tracing shared insight. Work-in-Progress Workshop, Tangible, Embodied & Embedded Interaction, Feb 10-13, 2013, Barcelona, Spain.

Dijk, J., Moussette, C., Kuenen, S. and Hummels, C. (2013). Radical Clashes: What Tangible Interaction is Made of. Proceedings of Tangible, Embodied and Embedded interaction (TEI'13), Feb 10-13, 2013, Barcelona, Spain.

Dijk, J. and Van der Lugt, R. (2013) Scaffolds for shared understanding. Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 27, 107–117.

B. Initial design explorations for FLOOR-IT (chapter 5)

In figure A.1. one finds the visual materials with which nine initial ideas, developed in the first design exploration by student G.W. Vos and myself. These pictures were presented with verbal explanation in the kick-off meeting of each of the three InCompanyLabs.

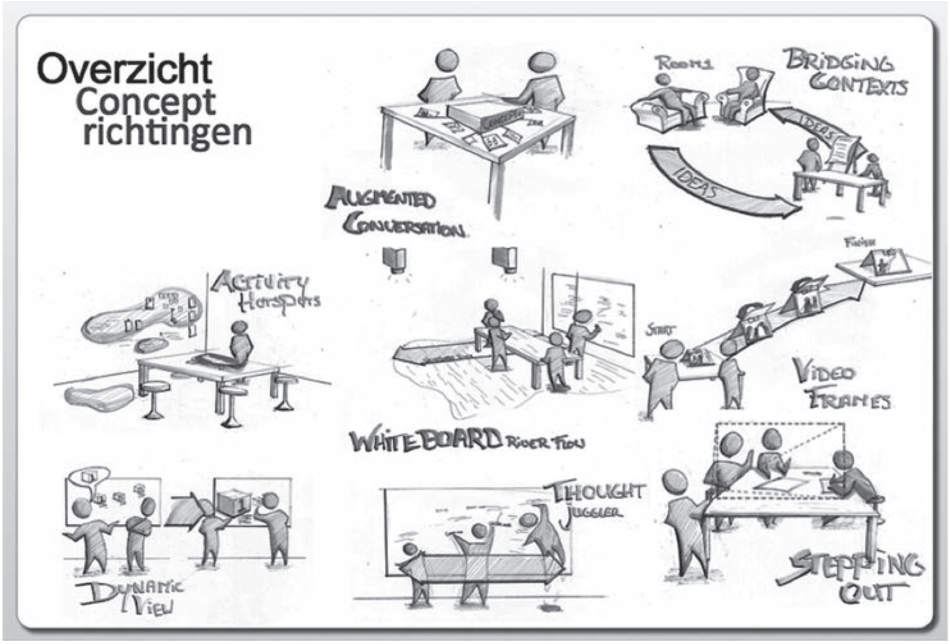


Figure A.1. The nine initial design ideas used as input to the In Company Labs

To get a feel of the kinds of ideas we envisioned based on the principle of 'traces', I elaborate on three of these ideas here:

Augmented Conversation

This idea supports a process by which people can add annotations on an interactive table-top projection and connect them to a mock-up or prototype or other physical object that is being discussed at that moment in the session. Below one can see that in the reflections it was added by the student that this tool would enable to have comments of people 'have it's effect' later on in the session, a function very much like that of NOOT (see chapter 4). I added the comment that this idea illustrates principles of distributed cognition, in the sense of Don Norman's 'knowledge in the world' (Norman, 2002).

Video-frames

This idea enables people to stack personal reflection on personal reflection and create 'trace' of video-fragments of this stacking process. The goal is that each person's reflective ‘point of view’ becomes iteratively integrated with that of others, working towards a shared insight. Using a special camera/display device, someone gives live commentary on what is happening while filming the situation. The next person then sees that original scene and then hears the person giving the reflective commentary. This second person now also gives her reflective commentary, which is also recorded. The third person sees the original scene, the first commentary, and the second one (with the ability to flip and scroll through the material, as one does browsing through a list of youtube movies) and then also can give a commentary. And so on for all participants involved. This means each new commentary is influenced by other people’s commentaries and the system as a whole records a history of iteratively aligning these individual viewpoints. This idea connects to Schön’s theory of reflection in- and on action (1983), connecting to social coordination (Suchman, 2007).

Dynamic View & Thought Juggler

These ideas connected to people’s physical movement and perceptual activity in the space. Dynamic view changes the size of the annotations people have created on interactive whiteboards, such that some these traces are at times better visible than others. This dynamic manipulates the particular scaffolding structure that people use ‘in action’ to guide their insight-generating process, continuously changing what materials are ‘ready-to-hand’ (Heidegger, 1927; Verbeek, 2000) and what isn’t. Thought-juggler was based on the idea that one needs to actively keep traces visible e.g. by pushing them up or even by jumping in front of them. If one does not actively move, the traces will slowly fade away, which means one needs to be literarally ‘bodily involved’ (Klemmer et al, 2006) with these traces in order to keep them available.

A final reflection step in which both design student G.W. Vos and I reflected on the ideas, asking design questions and relating to theory (see figure A.2), formed our background conceptual frame just before going into the In Company Labs.

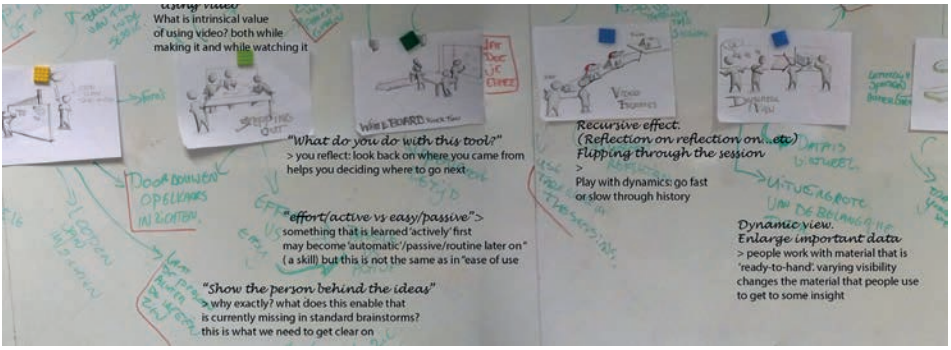


Figure A.2. Snapshot of our ‘reflective traces’, resulting from our reflections on the nine initial ideas.

C. Detailed set up of the InCompanyLabs (Chapter 5)

Each Incompany Lab lasted 3 to 4 days, within one week. In what follows next, I describe in some detail the structure of the activities in that week:

Day 1: Problem definition

The first day of the actual week involved a kick-off meeting (1.5 hours) with employees ranging from 4 to 12 people, mapping a general design question to the specifics of the context of practice.

The structure of the kick-off meeting itself was as follows:

1. Introduction with short presentation of overall design & research questions.
2. Introduction into the theory of embodied cognition with practical examples of everyday life.
3. In sub-groups: mapping the physical space and artifacts in it.
4. Plenary: Introduction to our idea sketches.
5. In sub-groups: elaborate on idea-sketches, transforming them into new ideas fitting the user practice and needs.
6. Plenary: pitching results; general discussion and reflections.

Analysis

The next few days involved both design explorations and further research into the practice by means of contextual interviews and the observation of (at least one) 'naturally occuring' creative session taking place at the work-site:

1. Design explorations involved sketching, discussing and organizing informative materials on a centrally placed wall that was publicly observable by employees, for example next to the coffee-machine or in the shared work-space. Employees were actively invited to join in on the process or give comments to the materials displayed.
2. Casual ethnographical observations were made of routines and events at the work-site.
3. Probe-cards were created based on the themes opened up in the kick-off meetings that we disseminated amongst employees in physical form and via email The feedback on these probe-cards was used as input to the design process.
4. At each site of practice we observed a creative session, of which we took field notes and recorded in audio, as well as taking pictures. We analyzed data searching for relevant patterns in people's behavioral routines, use of artifacts and tools and social interactions.
5. At each site of practice we also conducted two to three contextual interviews with key-employees in the organization, for example brainstorm facilitators.

Prototyping:
Mock-up experience prototypes were created of the final design concept for each of the three labs. On the final day, a closing workshop was organized with company employees.
Evaluation:
The employees were asked to act-out the prototype. An artist live sketched a storyboard scenario on the basis of this acting out exercise. This storyboard was then further discussed, and last changes to the concept could be proposed, again immediately processed by the artist in his storyboard sketch. After the co-design week we had another meeting with the artist to decide on the final details of the storyboard images.

After the InCompany Labs, towards the final prototype

The three labs were followed by a second innovation meeting asking feedback from stakeholders on the three concepts. In a subsequent workshop with expert designers, the three concepts served as the basis for one coherent design proposal, using acting-out and tinkering materials as basic design techniques. The designer workshop started with an introduction into EC theory and some elaboration on the main design question. The design team members who had been part of the InCompanyLabs took the role of participant-observers, that is, we actively participated in the process while at the same time keeping a reflective eye on the evolution of the session, as well as making notes and audio-recordings that could later be inspected. The goal of this session was not only to integrate the three ideas into one concept, but also to investigate in what way a group of professional designers comes to combine practice-inspired ideas with the theory of EC into one coherent proposal. In other words, we were interested in finding out how a group of skilled designers would concretely map EC theory onto this particular part of the design process. From this session emerged an idea that was further detailed and subsequently prototyped in a Wizard of Oz set-up. In a final innovation session with the larger group of stakeholders people were asked to try out the Wizard of Oz and give feedback once more.

Practitioners and their companies involved in the InCompanyLabs:

In order for the study to succeed a close collaboration with the employees of the company was required. The focus was on the facilitators who are in general the employees that are in contact with participants of workshops and brainstorm sessions. The amount of people for each session and gender depended on the different companies and therefore could not be determined up front.

YOUMEET

From the website: “A facility for result-oriented meeting in inspiring spaces, with a creative approach by professional coaches” (www.youmeet.nl)
We involved the following people:

- 3 practitioners joined the starting and final co-design session
- 3 (other) practitioners were interviewed in situ about the practice (two facilitators and
- 1 managing directors)

- 1 commercial session of an external client was observed
- 2 designer-researchers created the prototype
- 1 artist sketched the final storyboard

Our main contact throughout the week was the owner of the company who also functioned as the central 'host' for visitors.

Van Berlo

From the website: Van Berlo is an international design company based in Eindhoven ... over the last 30 years ... one of Europe's cutting-edge companies in the area of strategy, design and implementation. This includes both product development and engineering as well as brand implementation. (www.vanberlo.nl)

The following people were involved:

- 8 Practitioners joined both the start- and the final co-design workshop.
- 4 practitioners were interviewed in situ about their practice (one of which a director of the company)
- 1 regular design meeting was observed figuring 3 practitioners discussing a design project.
- 3 design-researchers worked on the design concept and the prototype
- 1 artist sketched the final storyboard

Our main contact in the organization throughout the week was one of the lead-designers/ head of department.

LEF future centre

From the website: "The power of LEF ... take people out of their environment and in a completely different environment have them look at the challenge. With this a breakthrough can be achieved. .. a symbiosis...: the question, the team, the facilitator with his/her methods and the physical environment that we configure especially in support of the process. (http://www.rijkswaterstaat.nl/over_ons/lef_future_center/)

We involved the following people:

- 5 Practitioners joined the starting and final co-design workshop
- 2 practitioners were interviewed
- 1 session involving 30+ participants an several sub-sessions, lasting one day, was observed
- 3 design-researchers worked on the concept and the final prototype, with help of 2 technical assistents employed by LEF.
- 1 artist sketched the final storyboard

Our main contacts throughout the week were the teamleader of the team of facilitators and an account-manager within that team.

D: Quantitative analysis and results (chapter 6)

In this section I describe the initial attempt at a quantitative analysis of the video-data discussed in chapter 6, the problems I encountered, and the reasons for focusing fully on the qualitative analysis instead. The basic set-up and conditions of the study are described in detail in chapter 6.

Data analysis

Three observers (two assistants who had not been part of the design team and myself) went through all video-materials in detail.

Overt behavioral actions involving the prototype were scored: the data did not allow to score e.g. eye-saccades. Focus was on behavior relevant to differences in interaction designs, which involved overt actions (e.g. rotating a picture, scaling it, and so on). We included 'pointing at an image', which is not detected by the system itself, but publicly visible by the other participants as 'in reference to' to the system. We scored all *conversational moments* in which one or more images would be used *as a scaffold for communication*. E.g. one person would state "We had this idea....", and point at, or manipulate, an image while talking, and another person would say "hm hm".

We included moments in which one person would say something and another person would give some kind of relevant response (a 'hm' or 'yes' would be the minimum) *while* one of these people or both would be interacting with the image as part of that moment. We excluded moments where the image would contain a text that would literally be 'read of': i.e. moments where a person would point at a image with the word "Cow" and then simply say: "Ok 'cow', that was our first idea ...." However, a image of a cow that would be named "cow" would be included. The criterion was whether referencing the image could assumed to have an added value to the verbal utterance. There were many more detailed criteria for inclusion or exclusion, but we will not discuss them here.

We included three sub-categories: EXPLAIN "use an image to explain", REACT "use an image to react", CONNECT "both people use the same image in one moment". This included instances where the image would be used multiple times by two people, going back and forth with the same image as a central point of reference.

In a second meeting we added two more categories: INDIVIDUAL "Use a picture for a personal reflection, not connected to a conversation moment". Such individual moments were in many cases clearly visible, but as they involved no conversation moment, the boundary of this category was actually difficult to define. CLUSTER was a category that *only* existed in WALL. In most of the WALL sessions people would at some point start organizing images on the wall within the grid. During that activity, there were many conversational moments, but these could no longer be related to the topic of the brainstorm, even though they were of course in some way related to it. The typical utterance would be "Yes, and that one there", "Here?","No, next to that one", "O, here", "Yes". Even though this talk was clearly related to the overall task of creating a concept proposal, it was so different from the other conversational moments that we decided to make it a separate category.

Results

Type	*Total*	*FLOOR*	*WALL*
Communication Using Scaffold	*368*	*194*	*174*
Sub-category: explain	*234*	*132*	*102*
Sub-category: react	*64*	*32*	*32*
Sub-category: connect	*70*	*30*	*40*
Individual use	*51*	*37*	*14*
'Cluster'-talk	*77*	*0*	*77*
Other	*9*	*2*	*7*

Table 6.2: Quantitative results

In table 6.2 we see that in FLOOR images are used more than WALL in direct communication. If we look at communication using scaffold, there is a difference between WALL and FLOOR, but if we include the sub-categories (EXPLAIN, REACT, CONNECT) there are no significant effects using a X^2 measure. The main difference that overruled all other patterns in the distribution of counts was the difference in 'clustertalk', which was pervasive in WALL and absent in FLOOR.

Discussion

Regardless of the statistics, the data are in any case hard to interpret because of the confounding category of 'cluster-talk'. If we include 'cluster-talk' as part of 'communication using scaffold', then images are used in communication more in WALL than in FLOOR. Individual use of images seems to be taking place more in FLOOR than in WALL, but in the WALL situation we 'just looking' at the wall from a distance may be enough for individual scaffolding, and that kind of 'interaction' we could not measure in our data. So although there is a strong qualitative difference between conditions, represented by 'cluster talk', the quantitative data as such remain inconclusive. We have not attempted the alternative coding strategy of coding every 5 seconds with one label. NB, by scoring 'each moment in which people interacted in the conversation, while using the prototype', a 3 second episode could already have multiple such 'moments', while at other times a 3 minute episode would have no moments at all.

All-in all, the *process* of going through all the video-data and scoring each moment of interaction with the prototype provided a very detailed insight into the observation materials, and worked as a thorough first pass going towards a qualitative analysis. One question for a qualitative analysis of the video would be to find out what this 'cluster-talk' is really all about, and what this may say about the difference between WALL and FLOOR. Next to that are a number of other phenomena emerged that we will look into. In the remainder of this chapter we will therefore focus on the qualitative analysis.

Curriculum Vitae

Jelle van Dijk (Utrecht, Netherlands, 1975) holds a masters degree in Cognitive Science from the Radboud University Nijmegen. He has experience in computational modeling and neuroimaging research. In recent years he conducted design-based research on embodied cognition in the context of designing tangible and embedded interactive systems. His general interests include cognitive theory and philosophy, phenomenology, learning and development, interactive systems design, situated know-how and skill, technology in human practice, and the role of design, creativity and prototypes in scientific inquiry. He conducted his PhD research as part of the Designing Quality in Interaction Group at the department of Industrial Design at Eindhoven Technical University, under supervision of Prof. Caroline Hummels. He works in the research group co-design headed by Prof Remko van der Lugt at the department of Applied Science and Engineering at Utrecht University of Applied Sciences. Next to his research Jelle teaches courses in Human Centered Design at Utrecht University of Applied Sciences, Utrecht. He developed and coordinates the multidisciplinary minor programme Interactive Media Products. Jelle lives in Utrecht with his wife and two sons.

A je to!
That's it!
Voor mekaar!

268

A je to!
That's it!
Voor mekaar!