Mapping Cultural Frame Shifting in Interaction Design with Blending Theory

Thomas Markussen [1,*] and Peter Gall Krogh [2]

[1] *Designskolen Kolding, Danish Centre for Design Research, Denmark*
[2] *The Alexandra Institute, Åbogade 34, Denmark*

In this paper, we introduce Gilles Fauconnier & Mark Turner's blending theory as a new conceptual framework for explaining 'cultural frame shifting' in interaction design. Cultural frame shifting is when people, through their explorative use of technology, are required imaginatively to reorganize their cultural background knowledge and expectations. In current HCI research it has occasionally been pointed out that a proper understanding of this phenomenon hinges on addressing the relationship between embodied interaction and cultural meaning construction as part of a larger interactive system. However, the given treatments of this relationship are mostly unbalanced. Thus, there is a research bias towards either leaving the question of meaning construction aside, or trying to answer it exclusively in terms of embodiment – often grounded in phenomenology. As a tool of analysis and interpretation we apply the network model of mental spaces from Fauconnier & Turner's blending theory onto video material and interviews from initial qualitative use studies of a design case. In so doing we explore and argue for how meaning formation and embodied cognition coalesce in cultural frame shifting and provide a tool for designers to work with cultural aspects as a constitutive factor of user experience in interaction design.

Keywords - Meaning Construction, Cognitive Semiotics, Blending Theory, Cultural Aspects, User Experience, Interaction Design.

Relevance to Design Practice - The theoretical framework introduced in this paper offers analytical tools that enable designers to evaluate and represent culture's effect on user experiences.

Citation: Markuseen, T., & Krogh, P. G. (2008). Mapping cultural frame shifting in interaction design with blending theory. *International Journal of Design, 2*(2), 5-17.

Introduction

Interaction design is commonly viewed as a recent trend in Human-Computer Interaction (HCI) that focuses on designing user experiences with technology. With the advent of tangible and physical computing, over the last decade or so, new opportunities have emerged for interaction designers to create technological systems or products that engage nearly every aspect of human experience: emotions, vision, movement, gestures, and all sorts of interrelations thereof. As has been pointed out repeatedly, interaction is no longer restricted to viewing and clicking on graphical icons on a screen, but is moving steadily into an augmented reality in-between image, object and the surrounding space (cf. Winograd, 1997).

In addition to this extended user interface, interaction design also represents the embedding of information technology into new territories of our everyday life. As a consequence, the attention of interaction designers is shifting from mere usability and efficiency to playful, explorative and emotional interaction.

Following from this radical design evolution, current HCI research is struggling to increase understanding of the emergent new forms of user interaction. To achieve this, phenomenology is generally called upon as a unifying framework that offers insights into basic elements and principles of human experience. This line of research is commonly referred to as 'Embodied Interaction' or 'Tangible User Interaction' (e.g. Dourish, 2001; Hornecker & Buur, 2006; Larsen, Twenebowa, & Edwards, 2007). However, with the notable exception of Dourish (2001), there is a tendency to treat experiential and aesthetic aspects at the expense of socio-cultural aspects. Even when socio-cultural aspects are considered, they tend to get reduced to questions relating to perceptual and bodily actions of use. This reductionism seems to be motivated by a too simplistic idea of 'embodiment' that is being promoted as the new foundation in HCI, and which stresses material and physical constraints over users social and cultural construction of meaning. For instance, in an account of the interweaving of physical space and social interaction, Hornecker and Buur (2006) claim that geometric, structural qualities like the physical shape and size of objects and their arrangement in space "...predetermine and guide interaction, affecting how space becomes appropriated, inhibited and experienced" (p. 445). In this paper we argue that it is an error to suppose that our behavior in an interactive environment is 'predetermined' exclusively by physical constraints (cf. Giddens, 1985; Dourish, 2001, p. 89). As argued by e.g. McCarthy and Wright (2004) and Petersen, Iversen, Krogh, and Ludvigsen, (2004) we need instead a much more nuanced concept of 'aesthetic

Received March 26, 2008; **Accepted** August 3, 2008; **Published** August 31, 2008

***Corresponding Author:** tm@designskolenkolding.dk

interaction' that, beyond the full engagement of perceptual and bodily skills, recognizes that humans are also capable of working with complex and abstract models for interaction.

Traditional HCI and product semantics has a long history of studying the nature of such models and how they help users cognitively to interpret the intended function of artifacts according to their material form, previous knowledge and experience of the user, and varying socio-cultural contexts of use. This is comprised by the theory of affordances, which Norman (1988) and Krippendorff (1995) originally brought into design from Gibson's ecological theory of vision (Gibson, 1979). However, affordance theory only provides us with a limited understanding of how affordances in interaction design involve a dynamic and mutual interplay of socio-cultural factors, mental models and embodied skills. First, it is 'ocularcentric' (Crary, 1990; Jay, 1993) in the sense that it treats user experience as a disembodied visual experience. Second, even though it recognizes that users' socio-cultural background predominantly influences their interpretation of products, affordance theory treats these aspects as being merely fixed and stable constraints. It does not consider how people's interpretations about the use of technology change dynamically as the socio-cultural context of the technology changes (cf. Bærentsen & Trettvik, 2002; Vyas, Chisalita, & van der Veer, 2006).

In this paper we use the term 'cultural frame shifting' to refer to this dynamic process of cultural knowledge transformation. In the following section we give a general description of this phenomenon: What is it, and how does it work. Unfortunately, the above-mentioned research paradigms offer an inadequate account for it. Whereas Embodied Interaction does not have a proper theory of the socio-cultural aspects of knowledge transformation, HCI consider users background knowledge as distinct from embodied interaction and cultural change. Faced with these shortcomings, we explore instead how Gilles Fauconnier & and Mark Turner's blending theory (Fauconnier & Turner, 1998, 2002) might serve as a new conceptual framework for describing cultural frame shifting.

Except from Imaz and Benyon (2007) and Markussen (in press), Fauconnier & Turner's blending theory has received only little attention in interaction design. To illustrate the potential strengths of blending theory we apply Fauconnier & Turner's network model in our evaluation of cultural frame shifting as it is enacted in the use of an interactive exhibition hydroscope evaluated at a Danish public aquarium. The evaluation consisted of users' uninstructed exploratory use of the prototype documented in video and semistructured interviews carried out during use sessions (Dindler et al., 2007). On the basis of this we explore and argue for how meaning formation and embodied cognition coalesce in cultural frame shifting and provide a tool for designers to work with cultural aspects as a constitutive factor of user experience in interaction design.

Thomas Markussen (b. 1973) holds a MA-degree in comparative literature and semiotics from the University of Aarhus (DK). He is currently affiliated to Kolding Design School (DK) where he's working on a PhD research project dedicated to the developing of a cognitive semiotic framework for understanding the interweaving of aesthetic experience and meaning construction in interaction design. In his earlier work, which includes lecturing, writings and media productions, Markussen has been focusing on the impact of technology use within art, architecture and design. He continually pursues these research interests as a member of the editorial committees behind the international journals Fibreculture and Inflexions.

Peter Gall Krogh (b. 1968) Holds a MA in architecture and is Associate Professor and Innovation Manager in Interaction design at the Alexandra Institute Denmark. He has participated in and led a range of educational programs and research projects with the focus of integrating services, IT and physical artifacts and spaces. The current activities evolve around the research centre for Interactive Spaces. Research interests include Interaction Design, Augmented Reality, Pervasive Computing and Aesthetic Interaction and Participatory Design processes. For further info: www.interactivespaces.net

Cultural Frame Shifting in Interaction Design

The notion of frame has been used over the years in various fields such as psychology, computer science, anthropology and linguistics (Cienki, 2007). Basically, a frame is conceived across these fields as referring to the cultural background knowledge and beliefs that people unconsciously draw upon when using language and thinking and acting in the world (Kövecses, 2006, p. 69). Charles Fillmore, the founder of *frame semantics*, has for instance demonstrated that people cannot understand the meaning of words in a sentence, unless they understand the cultural beliefs and social institutions in which the concrete speech act in embedded (Fillmore, 1975).

Recent developments in cognitive linguistics have however focused more on the phenomenon of 'frame shifting'. By 'frame shifting', Coulson (2006) is referring to the semantic reorganization that occurs "...when incoming information deviates from that predicted by the contextually evoked frame" (p. 75). The first part of a sentence may thus activate a frame in a reader's mind only to call for its immediate revision in its second part. Coulson (2006) illustrates this with the following sentence "… Everyone had so much fun diving from the tree into the swimming pool we decided to put in a little water…" (p. 55).The context described by the first part of this sentence will cue most readers to construct a [SWIMMING POOL] frame representing the prototypical elements and activities associated with such a place (by representing frames in small capitals in square brackets we follow standard notation rules in linguistics). Yet, upon reading the second part, we suddenly realize that our expectations are being played with and that we need to go back to the first part to reinterpret its meaning. This operation of a semantic reanalysis process that reorganizes a new meaning into the preexisting [SWIMMING POOL] frame is what Coulson (2006) designates as 'frame shifting' (p. 34).

In this paper we wish conceptually to explore the possibility of transferring the notion of frame shifting from cognitive linguistics to interaction design research. This move beyond the sentence towards the computer interface was prepared more than three decades ago by Minsky (1975) who developed the frame concept into an integrated part of standard HCI terminology. For Minsky frames provide the computer scientist with an analytical tool for modeling people's default knowledge about objects or events involved in routine tasks and stereotyped situations. Yet, what Minsky's frames say almost nothing about is how learning

through the encounter with unfamiliar situations and non-routine tasks typically requires a semantic transformation of such knowledge structures.

Situations like these are likely to emerge every time a user meet digital artifacts that engage unexpected structures of experience; when changes of technology-in-practice deviate from the frames and expectations that a user may invoke from contextual cues embedded in a particular physical and social environment. Like the second part of the swimming-pool example, these instances tend to produce category-inconsistent information that force users to reorganize and recombine frames in order "... to improve the relevance of their actions in and sense making of a particular situation" (Ringberg & Reihlen, 2008, p. 923).

We will use the expression 'cultural frame shifting' here to refer to this semantic process of frame reorganization, which users have to perform as a prerequisite for understanding and learning how to use new digital artifacts for work, everyday life, play or entertainment. By adding the adjective 'cultural' we want to align ourselves with the tradition of cultural anthropology and the sociology of culture where frames are used interchangeably with the related notion of cultural models (cf. Holland & Quinn, 1987; Shore, 1996; DiMaggio, 1997; Strauss & Quinn, 1997). Terms like cultural model or cultural frame emphasize more clearly that the nature and structuring of such knowledge systems depend significantly on the culture in which a person lives. In fact, anthropologists propose, "...that culture can be defined as a collection of shared understandings represented by frames or cultural models" (Kövecses, 2006, p. 70). To see what this actually means, we would now like to focus more sharply on how cultural frame shifting might be detected in interaction design.

The Conceptual Tension of Cultural Frames

The history of interaction design abounds with examples of cultural frame shifting. The most obvious, perhaps, occurred when the pioneering work of people like Douglas Engelbart, Tim Mott and many others lead to the paradigmatic change from the command line to the desktop interface (cf. Moggridge, 2007). Instead of having to tell the computer what to do by tapping in written commands in an expert programming language, the desktop interface used graphical icons representing trashcans, documents, file cabinets, and other well-known office items that made it a lot easier for everybody to interact with the invisible flow of information. This example of cultural frame shifting allows us to isolate two of the basic semantic aspects involved. As the first semantic aspect, we may notice the infringement of the cultural frame initially predicted by user expectations. This infringement may only involve one frame, or it might be a little more complex, as in this instance, where the infringement consists in the tension between two different cultural frames, namely the [COMMAND] frame and the [DESKTOP] frame.

At the time when they first appeared on the screen, the visual elements of the desktop metaphor were most likely experienced as being category-inconsistent with what was then the dominating cultural frame for using a computer (the [COMMAND] frame), though not for long. This ephemeral moment, or better, eliciting condition of cultural frame shifting was soon to be replaced by user's unequivocal and smooth conceptual assimilation of these familiar graphic elements built into the interface design. Upon seeing, for instance, a trashcan or a file folder, novices were simply able to decode the displayed information by recruiting from their culturally available knowledge of office work. This invoked [DESKTOP] frame was not meant to trigger anything like interpretative tension or doubt in the users, but quite the opposite, to secure and fulfill basic usability criteria such as speed, accuracy, transparency, and reduced training time.

Furthermore, this example enables us to see to what extent culture is responsible for structuring the content of the two colliding frames. Consider, for example, the [COMMAND] frame. This frame originally emerged out of a close alliance between military culture and first order cybernetics, which can be seen in the work of scholars such as von Neumann and Turing, which fostered the idea of a symbolic computer language based on binary digits or 'bits', as it was later abbreviated. Through special training, symbolic language acquisition, imitative processes, etc., it was then possible to transfer or internalize the necessary knowledge of this invented computer language to the individual users of technology. As more and more people adopted this language, it became consolidated as part of a collectively shared model for programming and interacting with a computer. The fact that this model is inter-subjectively shared among a social group is what makes it a cultural frame, if we accept the definition of Shore (1996, p. 44). Its value consists in rendering "...certain kinds of experiences perceptually significant and readily communicable within a community" (Shore, 1996, p. 315). One of the significant aspects of the [COMMAND] frame is that users are presupposed to: learn a binary code, master clearly defined semantic and syntactic rules to be able to program, act according to command-response sequences, and so on.

The [DESKTOP] frame, on the other hand, came out of the office culture of early modern and industrial societies. It does not primarily provide patterns for verbal and symbolic commands, but for nonverbal behavior and interaction. More specifically, a spatial setting with objects ascribed to a range of daily working routines: trashcans for throwing out, documents for writing, cabinets for filing, etc. Basing interface design on the experiential structures of this cultural frame was generally more intuitive than the complex semantics and syntax of command terminals.

Cultural Frame Shifting vs. Recognition

The second semantic aspect of cultural frame shifting has to do with how people creatively reshape preexisting cultural frames through their embodied interaction with technology. To describe it in more detail, it is useful to compare cultural frame shifting with simple recognition tasks. Whereas recognition is about organizing novel experience in relation to conventional and old cultural frames, cultural frame shifting is about the conceptual reshuffling of these frames as a way of negotiating novel experiences. Cultural frame shifting is what happens in users' minds when new experiences of technology use prompt them to reorganize already existing knowledge structures. As a general rule, then, cultural

frame shifting implies a much more subtle interplay of cultural frames with embodied interaction, which may eventually end up causing structural changes on both levels.

Cases of this can be found in those situations where digital technologies are 'exported' to new socio-cultural contexts, or when interactive systems 'splice' physical and digital functions hitherto unrelated. In such instances the typical user experience is that their cultural background knowledge and internalized models do not suffice to make sense of the incoming experiential inputs. This dissonance occurs because the technology in question bears no or only little resemblance to what they have experienced before.

Nonetheless, users are undoubtedly able continuously to revise their culturally available knowledge and expectations by making imaginative inferences from their embodied interaction and contextual clues. Indeed, knowledge transformation and learning of this kind are a prerequisite for appropriating innovative aspects of digital artifacts or changing forms of technology-in-practice. The intensified and ongoing proliferation of information technology into new sectors of labor, educational and cultural institutions has only made this even clearer.

The Focus of this Study

These initial observations have served merely to provide a general description of cultural frame shifting in interaction design. However, to increase understanding of this phenomenon a more detailed research strategy must be laid out and further developed.

In this paper, we intend to delve deeper into how cultural frames dynamically intertwine with users' embodied interaction, while they are in the midst of appropriating new technologies. That is, how cultural frames are derived and reconfigured during the semantic process through which users attempt to make sense out of novel technological experiences.

Secondly, we cannot account for either of the two above-mentioned aspects of cultural frame shifting, unless we expand usability ideals as cognitive transparency and performance efficiency to include aesthetic and imaginative elements of user interaction (cf. Petersen, Iversen, Krogh, & Ludvigsen, 2004; McCarthy & Wright, 2004; Dunne, 2006;). Gaver, Beaver, and Benford (2003) have suggested 'ambiguity' as a third new element of user experience in interaction design.

Throughout the rest of this paper we explore, argue and demonstrate how Fauconnier & Turner's blending theory offers a promising conceptual framework for developing this research strategy. In particular our focus will be on the following research questions:

- What are the internal configurations and governing principles of cultural frame shifting in interaction design?
- What is the effect of tension created between cultural frames and sensorimotor levels of user interaction?
- How can cultural frame shifting act as a trigger for aesthetic interaction with technology?

Blending Theory as a New Framework for Interaction Design

Blending theory is a recent framework developed by Fauconnier and Turner (1998, 2002) in order to deal with online meaning construction, which is considered to be a fundamental problem in cognitive linguistics and semiotics. More specifically, the solution to this problem requires gaining exact knowledge about how people construct meaning *as* they talk, think and act in everyday situations. To account for this Fauconnier and Turner have introduced the important notion of 'conceptual blending'.

Basically this notion rests upon the assumption that human imagination is a pivotal function of the human mind rather than confined to the whimsical activity of dreams or the creative activities such as poetry. Thus, by aligning themselves with the Kantian and Neo-Kantian tradition, Fauconnier & Turner views imagination as what makes it possible for us to integrate our mental ideas with the sensuous forms we experience in the world thereby categorizing those forms as knowable objects and events.

More important for our present purpose is the part of Fauconnier & Turner's work which concerns the uncovering of the imaginative processes involved when people manage to come up with *novel conceptualizations* needed for solving problems, learning, understanding and other creative sense-making activities. Our daily encounters with reality present us with a range of situations that ask us to create new meaning, and sometimes even require us to adjust or reinterpret our culturally entrenched modes of thought and expectations. The notion of conceptual blending offers an exciting insight into the semantic principles underlying such mental activities.

In the sense that it theorizes on how learning and new knowledge are acquired through sensuous experience of everyday situations, blending theory has much in common with pragmatist aesthetics as interpreted by Petersen et al. (2004) and McCarthy and Wright (2004) in relation to interaction design. In line with this work user imagination and active sense-making are a central concept in achieving aesthetic experiences. Furthermore, aesthetic experiences, along the line of pragmatist thinking, form the basis of forthcoming and more sophisticated experiences. Though not further developed in this paper, blending theory shows promise in providing ground for developing operational tools to more accurately and intentionally design for aesthetic experiences

Core Concepts: Mental Spaces, Cultural Frames, and Image Schemas

Fauconnier (1997) describes the basic principles of conceptual blending as follows:

> A conceptual blend operates in two input mental spaces to yield a third space, the blend. Partial structure from the input spaces is projected into the blended space, which has emergent structure of its own. (p. 149)

A 'mental space' is conceived as a 'small conceptual packet' being cognitively processed and constructed in working memory as we think, talk and act in different settings (cf. Fauconnier &

Turner, 2002, p. 40). For that purpose mental spaces draw partly on background knowledge acquired through similar past events that is stored in people's long-term memory in the form of frames and scripts, which were originally put on the AI-agenda by Roger Schank and Robert Abelson (1977). Roughly speaking, a script is just a frame that has become particularly designed with predictable temporal structure for frequently recurrent event sequences (Ungerer & Schmid, 2007, p. 214). A concrete example of Fillmore's [COMMERCIAL EVENT] frame can be seen in Schank and Abelson's now famous [RESTAURANT] script (see Fillmore, 1975).

Yet frames and scripts only account for some of the partial structures in a mental space. Mental spaces are equally organized by image schematic patterns arising from our repeated perceptual and bodily interaction with material objects and the world at large. Basically an image schema is defined as a recurrent spatial structure that gives coherence to our experience (Johnson, 1987). For instance, there is the CONTAINER schema for in-out orientations in space, the PATH schema for directions in space, and so on. But image schemas are not restricted to the phenomenological domain. One of the key insights of Lakoff and Johnson (1980, 1999) is that we constantly map image schemas onto higher-level semantic domains in thought and language, and that this is to a significant degree what makes these more abstract domains understandable and meaningful to us.

A mental space construct typically represents a set of image schemas, on the one hand, and frames and scripts, on the other. Since scripts and frames, to a large extent, are products of varying cultural factors, while image schemas are thought to be invariant embodied structures, we might then begin to understand the interplay of cultural frames and embodied interaction by exploring the way in which mental spaces are built up.

To expound this idea we can expand a little on an example borrowed from Johnson (1987, p. 20), namely the act of buying a new car. Being engaged in such an activity, we usually set up a mental space by drawing upon a [CAR BUYING] frame. This frame organizes the mental space into the conceptual categories of a *BUYER* and a *SELLER*, *MONEY*, *GOODS*, different *PROPS* such as a showroom and a desk, and so on. Depending on the number of times the buyer has actually bought a new car, the invoked frame might even be scripted into a more detailed narrative sequence of the activity itself: *a buyer going to a car lot, inspecting different car models, choosing and test driving, bargaining over the price, and buying or not buying the car.* The events of this [CAR-BUYING] script have a certain order or directionality to them, which can be explained in terms a mapping of the PATH schema onto the script. The activity is, thus, conceptualized as a series of steps unfolding between *a starting point and an end point*, indicated respectively by the buyer's physical entrance and departure. We have depicted this mental space construct in Figure 1.

Imagining different enactments of this situation also enables us to notice the crucial role that experiential information from the immediate context play in the concrete shaping of a mental space. If a woman, for instance, rushes to a car dealer and jumps straight at buying a new car without even testing it, asking about its performance or the price, her deviance from the expected action sequence could then possibly lead to one of the following judgments, each of which represents a new mental space. Either she is very rich and doesn't care about money; or she's on the run and in desperate need of an escape car; or a more mundane mental space construct would be that she has not internalized the inherent 'shopping-logic' and shared beliefs of critical consumer culture. Not only is it the structure of the event that is culturally significant, but also the execution of the various elements, such as inspection and price negotiations. This rich array of different interpretations does not only illustrate how culture and embodied experience act as two co-constitutive factors in online meaning construction but it also reveals what online meaning construction is essentially about: the dynamic setting up and reinterpretation of mental spaces for purposes of local understanding and action (cf. Fauconnier, 2007, p. 351).

Conceptual Blending of Mental Spaces

One of Fauconnier & Turner's major achievements is to have unraveled the numerous ways in which the human mind, under the pressure from real-world affordances and incoming contextual information, is capable of blending structures from two mental spaces into a third blended space, thereby creating new meaning for local understanding and action. We have schematized this process in Figure 2, depicting the partial structures with black dots.

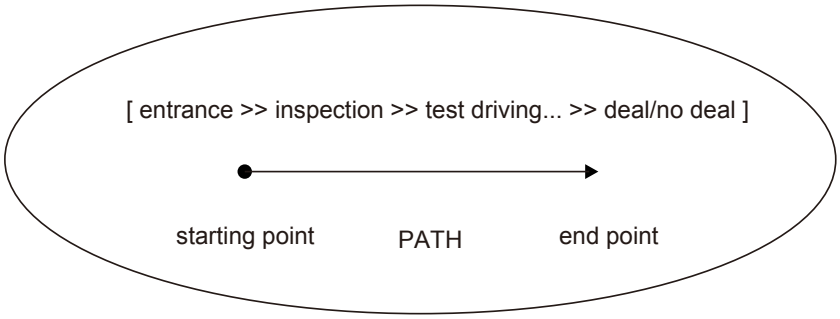

Figure 1. Image schema and script structure organizing a mental space construct.

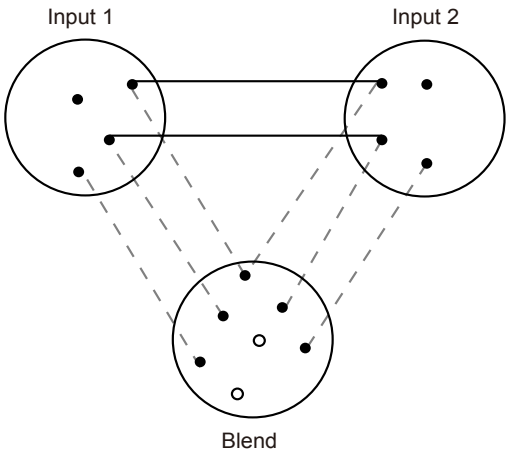

Figure 2. Conceptual blending as a network of mental spaces.

Note, here, that the blend develops emergent new structure that does not exist separately in either of the two input spaces. As we shall see shortly, this may actually involve modifying existing cultural frames. This happens through three interrelated cognitive operations as described in Fauconnier (1997, pp. 150-151):

> COMPOSITION: Taken together, the projections from the inputs make new relations available that did not exist in the separate inputs.
>
> COMPLETION: Knowledge of background frames, cognitive and cultural models, allows the composite structure projected into the blend from the inputs to be viewed as part of a larger self-contained structure in the blend. The pattern in the blend triggered by the inherited structures is "completed" into the larger, emergent structure.
>
> ELABORATION: The structure in the blend can be elaborated. This is "running the blend". It consists in cognitive work performed within the blend, according to its own emergent logic.

Interestingly, Fauconnier and Turner (2002, pp. 22-23) have employed the desktop interface in order to illustrate how these operations function when technology design acts as a prompt for conceptual blending (see also, Imaz & Benyon, 2007, pp. 50-54).

Input spaces. Interacting with the desktop interface cue people conceptually to blend two inputs: A mental space for ordinary office work (input 1) and a mental space for computer commands (input 2).

Composition. On the basis of so-called *cross-space mappings* between counterpart elements from the two inputs (the solid lines in Figure 2) composition makes new relations available in the blend. A trashcan is attributed the delete command, a printer icon the print command, and so forth (the dotted diagonal lines).

Completion. Through completion background knowledge of the culturally entrenched frame of office work can be recruited into the blend thereby helping the user to understand the course of his interactions. Lifting, moving and dropping a document into a new folder thus draw heavily on our mental conception of traditional workspace, not on the technical device itself.

Elaboration. The experience of the desktop interface also reveals how elaboration leads to emergent new structure in the conceptual blend. Double-clicking to open folders or dragging icons across the screen does not rely on reference to anything in the inputs taken separately, but must be seen as inferences made possible by the desktop blend's own emergent logic.

As all of these blending processes are located in the individual mind of the user there is clearly a mentalistic bias underlying blending theory. Yet, in an attempt to safeguard the formal and physical element of artifacts, Hutchins (2005) has argued for adding the notion of 'material anchors' to Fauconnier & Turner's original framework. Hutchins defines a material anchor as "…an input space from which material structure is projected into a blend" (p. 1555). In so doing, he avoids the tendency of treating the input spaces as purely mental constructs (p. 1559), and instead calls attention to the centrality in blending processes played by the physical form of input spaces and the bodily interaction with the physical world (p. 1560).

The usefulness of the notion of material anchor will become evident in our subsequent case analysis. Here it will enable us to show how the form of a specific architectural genre such as a public aquarium may contribute with input structure to a conceptual blend. Our hypothesis is that this blend is a likely outcome of inviting visitors to use an interactive exhibition hydroscope inside the aquarium. By using Fauconnier & Turner's blending theory as a framework for describing and mapping some of the key operations involved in the setting up of the conceptual blend, we further demonstrate that our design case could be seen as an example of cultural frame shifting in interaction design. However, let's start out by describing the technological design of the hydroscope.

Case Description and Analysis

To illustrate and ground our argument in concrete experiments the following section describes a prototype installation for exploring self-constructed fish in the setting of a public aquarium. The prototype installation is part of a larger project set up to explore and challenge interactive exhibition spaces. We provide a full description of the prototype installation constituted by a station for construction and moveable interactive devices for exploration. However, we will for the sake of clarity in argument focus on the explorative part of the prototype, the hydroscope.

The prototype installation was subject to two periods of trial use where the time between the periods of trial use was used for design iterations based on the experiences of the first period. The description of the prototype installation is based on the current version and design changes, revisions between the two versions are put in perspective of our overarching argument. As earlier mentioned in this paper use experiences were documented in video recording of uninstructed use and ad hoc semi-structured interviews were used to gather information of experiences (Dindler et al. 2007).

Constructing and Exploring the Life of Fish

The Kattegatcentret, Grenå, Denmark is a public aquarium with fish and marine life from all over the world. Among the

big attractions are large-scale aquaria with a variety of tropical sharks. The centre is predominantly based on visual means and a special atmosphere is created around the different types of fish. For instance, the sharks can be seen from a glass tunnel running through the bottom of the tank where you get the feeling of being immersed in the marine environment.

The rationale for our design case was to explore a different range of means by which visitors could relate to fish and marine life. In particular, our design work evolved through the use of playful construction and exploration. Our objective was to provide visitors with a new perspective on the centre. Rather than explicitly communicate information about marine life we looked to create a space where visitors could imagine how marine life could be like. In a very literal sense we constructed a setup where visitors could experiment by constructing their own fish from individual parts and exploring its qualities. Having constructed an imagined fish from different parts, visitors are able to release the fish into a digital ocean where it will live alongside fish created by other visitors.

Constructing Fish with a RFID Kit

To support the construction of the fish, we developed an RFID based construction kit with physical pieces with embedded RFID tag (Figure 3a). The physical pieces can be assembled to an imaginary fish on top of an RFID tag-reader, and when the user is satisfied with the constructed fish, it can be released into the virtual sea. The tag-readers are built into a special table with a dome display viewing into the virtual sea universe. The dome view is provided through a display on top of the table (Figure 3b). The construction set is developed on the basis of five different fish species, deconstructed into the following types of pieces: body, head, tail, swim bladder front fin and back fin. Each piece is linked (by the RFID tag) to information and a digital fish part that appears on the dome display. On the dome display the partly finished fish is shown together with information about its physical strengths and weaknesses. This is supplemented with a graphical assessment of its abilities to survive.

Exploring Fish in Hydroscopes

To view the fish in the digital ocean, visitors have to use the hydroscopes that inhabit the exhibition spaces. The hydroscopes enable visitors to look 'down through the floor surface' into the digital ocean. During the design process several solutions for creating the digital ocean were envisioned. Initially, the digital ocean was conceived as a large projected floor surface, where the entire ocean was visible. This would provide visitors with an overview of the ocean and allow them relatively quickly to find different fish.

The design of the hydroscope, promotes a somewhat different agenda. The hydroscopes do not provide overview and they do not make it easy for visitors to find fish or navigate the ocean. Rather, the hydroscopes were designed as a way for visitors to explore the hidden universe of the digital ocean. Instead of revealing the ocean and the constructed fish, they encourage visitors to actively explore the ocean and to imagine what is hidden beyond the range of the hydroscopes. The ocean is only visible through the hydroscope and visitors have to move around this Peephole to explore the ocean (Figure 4a & 4c). Dependent on the properties of the constructed fish, they will find their way to the most appropriate waters in the digital ocean. As navigating the hydroscope requires users to move it through the physical space, the connection is made between the physical layout of the locale and the digital space of the ocean. Alongside the rim of the central compass of the hydroscope interface (Figure 4b) simple

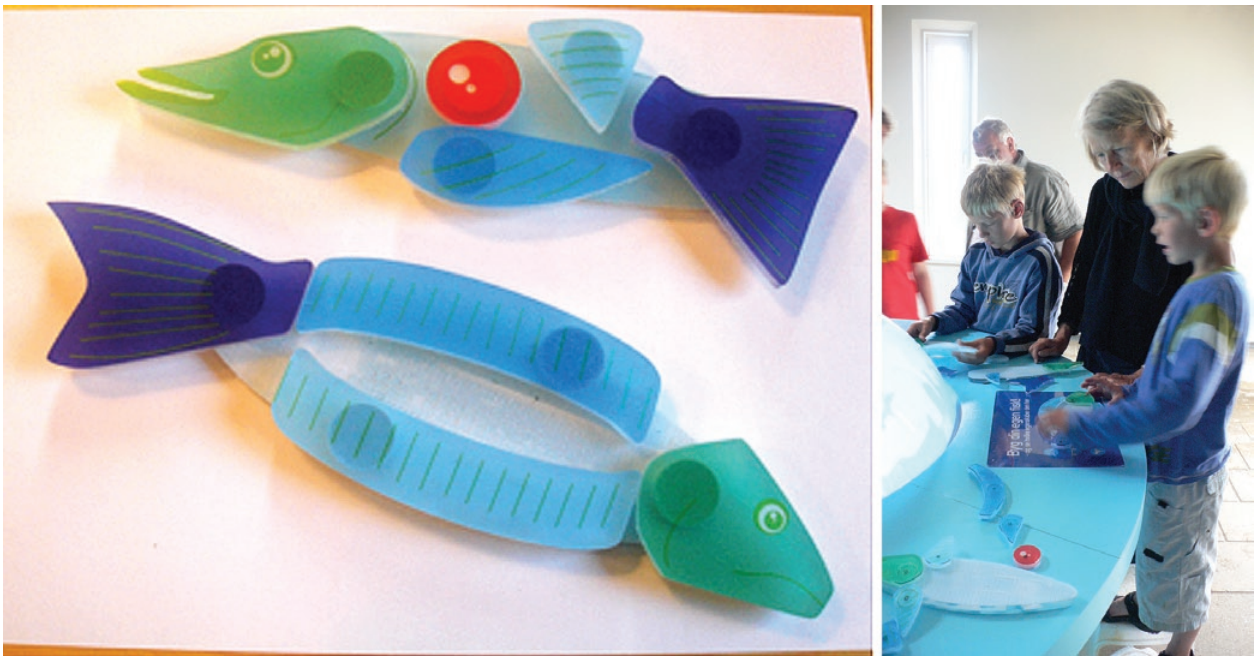

Figure 3. (a) Fish construction set with RFID tagged pieces, (b) Construction table with dome display.

Figure 4. (a) Movable mixed reality Hydroscope at the Kattegat Centre, (b) Screen dump from the Hydroscope, (c) Children collectively pushing the Hydroscope.

arrows provide hints of underwater characteristics such as the bed of river, low and deep waters. We deliberately chose not to mark the physical floor according to the mapping of the seabed visible through the Hydroscopes as the slow gradual discovery of different waterbeds is seen as an attractive pointer for spurring curiosity.

Theorizing on User Experience

The architectural design of specific building types is generally believed to reflect cultural frames, which presupposes certain behavioural and experiential patterns (cf. Shore, 1996, p. 53). Among such building types are clearly museums or centres made for exhibition. In these places cultural beliefs about ways of choreographing the learning experience will be reflected in the spatial and interior design. Culture thereby manifests itself in material structure. Then, upon visiting the place, this material structure may serve as an external stimulus prompting the user to derive and reconstruct the institutionalized belief system as a frame in a mental space. Just like the graphic representation of the words *swimming pool* cue language users to construct a mental space organized by the [SWIMMING POOL] frame.

As an aquarium, the Kattegatcentret evokes a mental space organized by a standard [AQUARIUM] frame. However paradoxically it may sound, bringing an interactive hydroscope into this marine centre is somewhat inconsistent with this cultural frame, and forces users to perform cultural frame shifting in order to interpret the use of the hydroscope. In the following we theorize on this user experience and we use blending theory to unpack its internal configurations and governing principles. We start out by using Hutchins's (2005) concept of material anchors in order to describe how the material structures of physical space and objects constraint users experience in our design case.

The Structures of Material Anchors

The architectural space and interior design of the Kattegatcentret might be seen as a material anchor that embodies a dominant cultural model of how to exhibit things to a public audience. Like most other exhibition spaces, the Kattegatcentret is primarily organized into a *vertical* surface for visual information and a *horizontal* ground surface for bodily movement and action. That is, the relationship between visual perception and movement is asymmetrical with vision acting as the most privileged sense for acquiring new knowledge. At the same time, these material structures are reflected in the props for presentation that we expect to find in a traditional exhibition space. Whether experiencing paintings on the walls in galleries, historical items in showcases or living creatures in aquariums the picture remains the same: Something is held up rectangularly *in front* of our eyes, while the

rest of the body is tacitly directed to stand passively in a fixed upright posture. In fact, traditional exhibition design generally represents this 'Cartesian' view of the body where a cognizing "Ego is floating above a machine of flesh" (Spuybroek, 2002, p. 93).

However, the in-front-of pattern of the aquarium anchor is opposed by the structures of the hydroscopes. The hydroscopes clearly deviate from the rectilinear organization of traditional exhibition design as they transfer visual information under the horizontal surface for movement. Navigating with the hydroscopes thereby presupposes not a Cartesian, but an active body whose movements and kinesthetic experiences play a crucial role in the interactive learning process. This is an emergent cultural model for learning that is becoming more and more influential in museum institutions and learning environments. It may also be seen as a literal translation into the explorative design of the 'aesthetic ideology' of the Kattegatcentret, which officially announces on its website that its main objective is to let visitors "explore a world beneath the sea" (*our italics*).

Image Schematic Tension

Material structures are thought to exist in objective reality independent of the user's mind. To account for how they are mentally conceived and experienced it is necessary to employ some of the other concepts we have introduced. If we elaborate on our observations by applying Fauconnier & Turner's blending theory we might view the embedding of the hydroscope into the surrounding aquarium context as giving rise to two mental spaces.

As already mentioned, the material structure of the aquarium is most likely at first to activate a mental space organized by the culturally shared [AQUARIUM] frame. However, we theorize that the interactive use of the hydroscopes is experienced to be inconsistent with this first mental space and, therefore, requires a reinterpretation of the situation. Our evaluations from video material revealed that users were not immediately able to orientate and locate their fish in the mixed reality environment. Instead they began curiously to explore different ways of relating the visual information seen in the hydroscope with their movements on the floor. Following from the framework we have laid out we can see this unfolding experience as a sign of interpretative labor in the user corresponding to the set up of a second mental space. This mental space is a cognitive reaction to the presentation of a problem and its purpose is to optimize the choice of the next action.

If we analyze the two mental spaces at an image schematic level (reflecting how material structure is bodily experienced), then we see that the inconsistency between the hydroscope and aquarium experience result from two very different senses of containment. We might even speak of an image schematic tension. A graphic representation of this tension can be found in Figure 5 where we have magnified the image schematic structures of the two mental spaces for the sake of clarity. By putting squares around the two mental spaces we follow Hutchins's (2005) proposal for representation of material anchors.

In the case of the mental space 1 for the surrounding aquarium context, what gives coherence to user experience is a CONTAINER schema (A), which organizes the whole scene conceptually according to specific in-out orientations and entailment structures. Thus, the aquariums restrict certain forces (water, fish, sharks, etc.) within a container. Because of this restraint of forces, the contained 'objects' get a relatively fixity of location. This fixing of location means that the contained object becomes accessible to the view and closer scrutiny of the visitor.

The hydroscope, on the other hand, cue users to construct a mental space 2 based on a more ambiguous schematic CONTAINMENT configuration (B) of the experiential domain. As the visitors move around with the hydroscope in the virtual sea, they get 'swallowed up' in a foreign and amorphous environment without any clear-cut boundaries of containment or directions for navigation. Because of the relatively unrestrained forces and limited contextual clues, the roles of being contained are thereby blurred or perhaps even reversed. Here, the user experiences the diffuse feeling of, whether it is (s)he or the animals that is contained (indicated by the dashed line between fish and visitor). You might even say that the users get close to orient themselves as from a fish-eye point of view. You cannot really imagine a better way of letting the visitors explore "a world beneath the sea" than by letting them share the same behavioral conditions as the creatures living in this world.

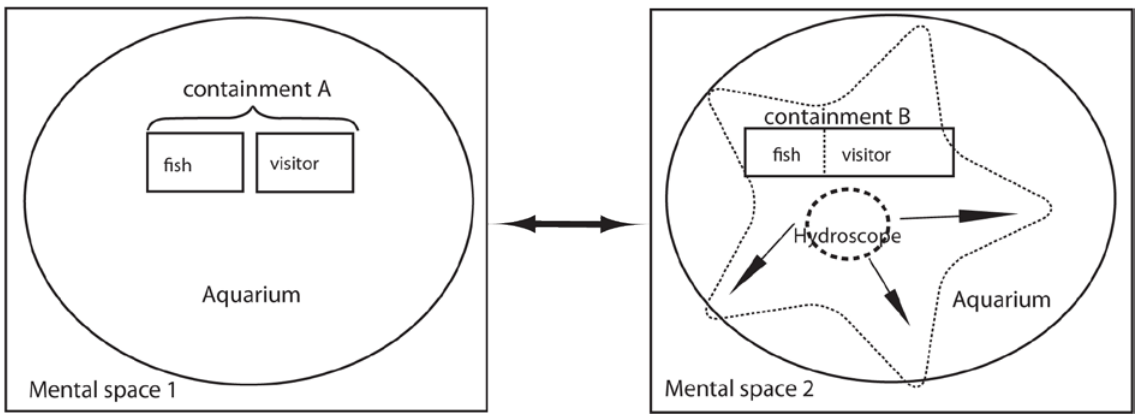

Figure 5. Image schematic tension in user experience.

Mapping Cultural Frame Shifting as a Conceptual Blend

On the basis of blending theory we argue that 'conceptual tension', created by the image schematic conflict, does not necessarily result in user frustration, but acts as a trigger for cultural frame shifting. Our video material shows, for instance, children and adults playing and collaborating to share discoveries around the hydroscopes. We take these empirical data as supportive of the idea that users were able successfully to reorganize new experiential structures and meaning into their culturally entrenched [AQUARIUM] frame. Such a semantic reinterpretation would in fact be a highly imaginative endeavor whereby the conceptual tension would have to be developed into a conceptual blend. We can describe this blending process further as being based on the principles of a so-called *double-scope network* in the terms of Fauconnier and Turner (2002, p. 134). In such a network, two input mental spaces yield a third blended space comprised of organizational structures from both inputs. It is in this blended space that the cultural frame shifting is supposed to take place (conceptually speaking). Let's conclude our case analysis by describing the dynamic principles that govern this frame shifting process as it is depicted in Figure 6.

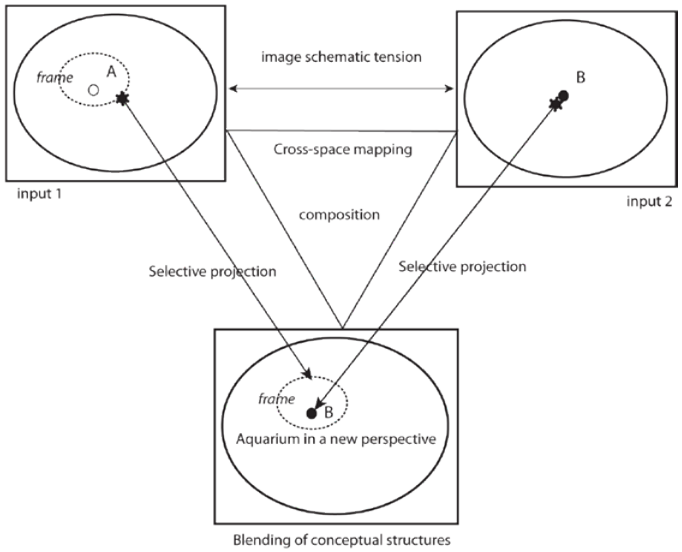

Figure 6. Enacting cultural frame shifting with the interactive hydroscope.

The mental space evoked by the physical environment and structured by the [AQURIUM] frame (the dashed oval) and CONTAINER schema A is input 1. The mental space emerging from hydroscope navigation in the virtual sea and structured by CONTAINER schema B is input 2. Since we assume that only experts and marine biologist are skilled users of hydroscopes, there is no richly developed cultural frame available for this input.

Though it might seem as if the hydroscope mental space supersedes the aquarium mental space as experience unfolds this is not really the case. After all the navigation is enacted inside a physical environment the reality of which cannot simply be ignored or temporarily suspended. The floor is not literally floating; the virtual sea is only visible through the peephole, etc. Meaning that there is a cognitive link to physical reality that is 'kept alive', while the visitor is moving with the hydroscope 'into' the virtual sea. This ambiguous perceptual bond seamlessly connecting the physical and the digital is exactly what the notion of 'mixed reality' is meant to capture. Or, to translate it into blending terms, mixed reality experiences like this depend on simultaneous cross space mappings between counterpart elements in the two input spaces: the virtual sea is mapped onto the floor, the hydroscope is seen as fulfilling the role of an aquarium, and so on (the horizontal lines in Figure 6).

On the basis of these mappings *composition* makes relations available in a third blended space that does not exist in the separate inputs (represented by diagonal lines). Ultimately, this blended space is what makes it possible for the visitors to infer from the visual information in the hydroscope that fish and other hybrid creatures are swimming around beneath their feet.

However, to achieve this blend we argue that users would have to perform some additional and more complex blending operations. As we have demonstrated the information displayed in the hydroscopes is not understandable in terms of the CONTAINER schema of the contextually evoked [AQUARIUM] frame. This violation of user expectation is a first sign of cultural frame shifting and is depicted in Figure 6 as a conceptual tension between the two input spaces (the double pointed arrow). As noted by Fauconnier and Turner (2002) such tensions clearly possess some aesthetic qualities: "Far from blocking the construction of the network, such clashes offer challenges to the imagination; indeed, the resulting blends can be highly creative" (p. 131).

The challenge to the imagination consists in this case in solving the tension by making an online reorganization of the [AQUARIUAM] frame. This implies that this frame, which is entrenched in long-term memory, must somehow be recruited and made malleable for novel conceptual integration. Evidence from cognitive linguistics indicates that the human mind actually has the ability to 'empty' or deactivate elements of a preexisting frame for this purpose. Remember that the second part of the swimming pool joke required readers to leave out the water element of the [SWIMMING POOL] frame in order to make sense out of the situation described by the first part. In the same vein we can now assume that users are also able to leave out image schema (A) of the [AQUARIUM] frame in order to make sense out of the hydroscope situation. Additionally, image schema (B), which accounts for the meaningfulness of the hydroscope experience, must likewise be made available for frame integration.

In Fauconnier and Turner (2002) the imaginative operation, which is presumed to be responsible for picking out different organizing input structures for further integration, is appropriately termed 'selective projection'. By means of this *completion* mechanism, the central structural and inferential principles for elaborating the blend are instantiated.

We believe our case example demonstrates that as users were running around playing with the hydroscopes they actually managed to elaborate the blend. More specifically, their creative feat consisted in conceptually integrating the [AQUARIUM] frame with the underlying image schematic topology of the hydroscope. This is a 'new perspective' on the marine centre

representing an emergent meaning that did not exist prior to the experience. On the contrary, it is through this embodied interaction with technology that people reorganize another structure into their cultural frame for aquarium design. However, this does not mean that the experience and physical shape of the hydroscopes predetermine meaning construction. What we hope to have demonstrated is instead how such an occurrence of cultural frame shifting is based on an intertwining process of cultural factors and embodied interaction.

Discussion and Future Perspectives

The primary purpose of this paper has been to argue for and draw attention to the potential strengths of blending theory both in terms of analysis and in terms of providing guidelines for design activity. Our claims and analysis are based on limited user studies and will need more examples and cases for a complete and rigorous framework. While positioning blending theory and highlighting its general applicability in interaction design we also leave several paths unexplored. Among these are the relations between the concept of appropriation and blending theory – to put it simple: how does the possibility of many potential blends in a use situation contribute to understanding the work of appropriation? Furthermore, some of the ideas presented in this paper point to "Cultural Frame Shifting" being the resource for aesthetic experiences. This, however, needs further investigations. We argue that by basing our concept of cultural frame shifting on blending theory it is possible to come up with an understanding of the learning aspects of aesthetic experience. There are shortcomings in the current use of pragmatist aesthetics (Shusterman, 1992) in interaction design, as tensions are not well articulated as a resource in aesthetic experience. This is characteristic of McCarthy and Wright (2004) who seem to subscribe fully to what one of their main sources of inspiration, John Dewey (1958), has once said about aesthetic experience: "that which distinguishes an experience as esthetic is conversion of resistance and tensions, of excitations that in themselves are temptations to diversion, into a movement toward an inclusive and fulfilling close" (p. 56).

Apart from the unity and completeness of aesthetic experience, our concept of cultural frame shifting is meant also to encompass the ambiguity and open-endedness of aesthetic experience. In the prototype installation of our case example the tension is precisely a central prerequisite for an aesthetic learning process.

We have seen how such qualities might be caused by a subtle interplay of cultural factors and embodied schemas. If we compare our study to the taxonomy of ambiguities in design set out by Gaver et al. (2003), the conceptual integration network we have mapped would correspond to what they call 'ambiguity of context', which "requires an integration of seemingly incompatible meanings" (Gaver, et al., 2003). However, it is not enough simply to come up with rough taxonomies. To increase understanding, one must also be able to show what are the internal configurations and governing principles of the taxonomy. Indeed, this could be an interesting aim of the future: to use the concept of cultural frame shifting to develop Gaver et al.'s taxonomy more in depth. Having done so, interaction design research could then move on to connect the 'aesthetic of ambiguity' with the 'aesthetic of unity' found in activity theory and pragmatic approaches. The overarching goal of this enterprise would be to account for the way in which culture and experience always goes hand in hand in technology use.

Conclusion

It is of course incredibly difficult to know what goes on inside the user's mind. However, we do not think that this challenge should be met with a resort to behaviorism. As blending theory takes its point of departure from cognitive linguistics and cognitive semiotics its assumptions about the mind are firmly grounded on verifiable evidence, namely language and meaning construction. To be of more value to design practice, new empirical methods for testing blending theory in use situations would though be desirable. Yet, in its current state blending theory is capable of providing some interesting answers to the research questions we initially set out to explore.

First, the network model of conceptual blending enables design researchers to describe some of the central principles and internal semantic operations that govern cultural frame shifting in interaction design. A key finding in this respect is the blending process by means of which cultural frame structure become malleable for novel integration with different embodied schemas and incoming informing. This may be of much value for further research into the dynamic relation between technology-in-practice and cultural change.

Secondly, there is a general belief in HCI that the notion of 'mental models' hasn't been able to elucidate the "very interesting cognitive actions going on in the pause between the presentation of a problem and the choice of the next action" (Caroll & Olson, 1997, p. 54). Our case analysis has clearly demonstrated the nature of these cognitive actions as they ensure from tensions between cultural factors, reasoning and embodied experience. As a result of replacing 'mental models' with the dynamic notion of 'mental spaces' we have actually proposed a tool for giving a structural description of this tension.

Thirdly, with the use of blending theory we have expanded interaction design research in order to include imaginative elements of user experience. More specifically, we have demonstrated how cultural frame shifting by fulfilling the principles of a double-scope network might act as a trigger for imaginative and perhaps even aesthetic learning processes. This might be seen as a further theoretical development of work initiated in Petersen et al. (2004) and Markussen (in press).

Acknowledgements

We are indebted to the editors of International Journal of Design, two anonymous reviewers and Peer F. Bundgaard from Centre for Semiotics at Aarhus University for their valuable and constructive comments to earlier drafts of this paper. We also thank the Danish IT-Corridor for providing the grant enabling the realization of the design prototype, Christian Dindler, Kaj Grønbæk, Liselott Stenfeldt, Sofie Beck and Kaspar Rosengren Nielsen for their work on the prototypes.

References

1. Bærentsen, K., & Trettvik, J. (2002). An activity theory approach to affordance. In *Proceedings of the 2nd Nordic Conference on Human-computer Interaction* (pp. 51-60). New York: ACM.
2. Caroll, J. M., & Olson, J. R. (1997). Mental models. In M. Helander, T. K. Landauer, & P. V. Prabhu (Eds.), *Handbook of human-computer interaction* (pp.45-65). Amsterdam: Elsevier.
3. Coulson, S. (2006). *Semantic leaps: Frame shifting and conceptual blending in meaning construction*. New York: Cambridge University Press.
4. Cienki, A. (2007). Frames, idealized cognitive models, and domains. In D. Geeraerts & H. Cuyckens (Eds.), *The Oxford handbook of cognitive linguistics*. New York: Oxford University Press.
5. Crary, J. (1990). *Techniques of the observer: On vision and modernity in the nineteenth century*. Cambridge, MA: MIT Press.
6. Dewey, J. (1958). *Art as experience*. New York: Capricorn.
7. DiMaggio, P. (1997). Culture and cognition. *Annual Review of Sociology, 23*(1), 263-287.
8. Dindler, C., Krogh, P., Beck, S., Stenfeldt, L., Nielsen, K., & Grønbæk, K. (2007). Peephole experiences – Field experiments with mixed reality hydroscopes in a marine center. In *Proceedings of the 2007 Conference on Designing for User eXperiences* (No. 20). New York: ACM.
9. Dourish, P. (2001). *Where the action is: The foundation of embodied interaction*. Cambridge, MA: MIT Press.
10. Dunne, A. (2006). *Hertzian tales: Electronic products, aesthetic experience, and critical design* (Rev. ed.). Cambridge, MA: MIT Press.
11. Fauconnier, G. (1997). *Mappings in thought and language.* Cambridge, UK: Cambridge University Press.
12. Fauconnier, G., & Turner, M. (1998). Conceptual integration networks. *Cognitive Science, 22*(2), 133-187.
13. Fauconnier, G., & Turner, M. (2002). *The way we think: Conceptual blending and the mind's hidden complexities*. New York: Basic Books.
14. Fillmore, C. (1975). An alternative to checklist theories of meaning. In C. Cogen, H. Thomson, G. Thurgood., & K. Whistler (Eds.), *Proceedings of the Berkeley Linguistic Society* (pp. 123-31). Berkeley: Berkeley Linguistics Society.
15. Ford, G., & Gelderblom, H. (2003). The effects of culture on performance achieved through the use of human computer interaction. In *Proceedings of the 2003 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists on Enablement through Technology* (pp. 218-230). New York: ACM.
16. Gaver, W. W., Beaver, J., & Benford, S. (2003). Ambiguity as a resource for design. In V. Bellotti & T. Erickson (Eds.), *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, (pp. 233-240). New York: ACM.
17. Gibson, J. J. (1979). *The ecological approach to visual perception.* Boston: Houghton Mifflin.
18. Giddens, A. (1985). *The constitution of society: Outline of the theory of structuration.* Cambridge: Polity Press.
19. Holland, D., & Quinn, N. (1987). *Cultural models in language and thought.* Cambridge: Cambridge University Press.
20. Hornecker, E. (2005). A design theme for tangible interaction: Embodied facilitation. In H. Gellersen, K. Schmidt, M. Beaudouin-Lafon, & W. E. Mackay (Eds.), *Proceedings of the 9th European Conference on Computer Supported Cooperative Work* (pp. 23-43). Dordrecht: Springer.
21. Hornecker, E., & Buur, J. (2006). Getting a grip on tangible interaction: A framework on physical space and social interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 437-446). New York: ACM.
22. Hurtienne, J., & Israel, J. H. (2007). Image schemas and their metaphorical extensions: Intuitive patterns for tangible interaction. In *Proceedings of the 1st International Conference on Tangible and Embedded Interaction* (pp. 127-134). New York: ACM.
23. Hutchins, E. (2005). Material anchors for conceptual blends. *Journal of Pragmatics, 37*(10), 1555-1577.
24. Jay, M. (1993). *Downcast eyes: The denigration of vision in twentieth-century French thought*. Berkeley, CA: University of California Press.
25. Johnson, M. (1987). *The body in the mind*. Chicago: The University of Chicago Press.
26. Klemmer, S., Hartmann, B., & Takayama, L. (2006). How bodies matter: Five themes for interaction design. In *Proceedings of the 6th Conference on Designing Interactive Systems* (pp. 140-149). New York: ACM.
27. Kövecses, Z. (2006). *Language, mind, and culture.* Oxford: Oxford University Press.
28. Krippendorff, K. (1995). On the essential contexts of artefacts. In V. Margolin & R. Buchanan (Eds.), *The idea of design* (pp. 156-184). Cambridge, MA: MIT Press.
29. Lakoff, G., & Johnson, M. (1980). *Metaphors we live by.* Chicago: The University of Chicago Press.
30. Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh.* New York: Basic Books.
31. Larsen, A., Twenebowa, T. R., & Edwards, J. (2007). The feel dimension of technology interaction: Exploring tangibles through movement and touch. In *Proceedings of the 1st International Conference on Tangible and Embedded Interaction* (pp. 271-278). New York: ACM.
32. Markussen, T. (in press). A cognitive semiotic approach to the aesthetic interplay between form and meaning in responsive environments. In S. Vihma & T-M. Karjalainen. (Eds.), *Design semiotics in use.* Helsinki: University of Art and Design Helsinki.
33. McCarthy, J., & Wright, P. (2004). *Technology as experience.* Cambridge, MA: MIT Press.

34. Minsky, M. (1975). A framework for representing knowledge. In P. Winston (Ed.), *The psychology of computer vision* (pp. 211-277). New York: McGraw-Hill.
35. Moggridge, B. (2007). *Designing for interactions*. Cambridge, MA: MIT Press.
36. Norman, D. (1988). *The psychology of everyday things*. New York: Basic Books.
37. Petersen, M. G., Iversen, O., Krogh, P., & Ludvigsen, M. (2004). Aesthetic interaction: A pragmatist's aesthetics of interactive systems. In *Proceedings of the 5th Conference on Designing Interactive Systems* (pp. 269-276). New York: ACM..
38. Ringberg, T., & Reihlen, M. (2008). Towards a socio-cognitive approach to knowledge transfer. *Journal of Management Studies 45*(5), 912-935.
39. Schank, R., & Abelson, R. (1977). *Scripts, plans, goals, and understanding: An inquiry into human knowledge structures*. Hillsdale, NJ: Lawrence Erlbaum.
40. Shore, B. (1996). *Culture in mind: Cognition, culture, and the problem of meaning*. New York: Oxford University Press.
41. Shusterman, R. (1992). *Pragmatist aesthetics: Living beauty, rethinking art*. Cambridge, MA: Blackwell.
42. Spuybroek, L. (2002). wetGRID: The soft machine of vision. In N. Leach (Ed.), *Designing for a digital world* (pp. 93-101). London: Wiley Academy.
43. Strauss, C., & Quinn, N. (1997). *A cognitive theory of cultural meaning*. New York: Cambridge University Press.
44. Ungerer, F., & Schmid, H-J. (2006). *An introduction to cognitive linguistics* (2nd ed.). New York: Longman.
45. Vyas, D., Chisalita, C. M. , & van der Veer, G. C. (2006). Affordance in interaction. In *Proceedings of the 13th European Conference on Cognitive Ergonomics* (pp. 92-99). New York: ACM.
46. Winograd, T. (1997) From computing machinery to interaction design. In P. Denning & R. Metcalfe (Eds.) *Beyond calculation: The next fifty years of computing* (pp. 149-162). Amsterdam: Springer.