Designing for Presence: Embodied Interaction in Computer-Mediated Realities

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There is only embodied interaction in computer-mediated realities. We use our bodies to sense, interact with, process, and remember environments. Effective computer-mediated realities, i.e. mixed and virtual realities, depend on the user's feeling of being part of those environments. We are explaining our approach towards a theoretical model for this sense of presence. Based on techno-psychological, philosophical, and socio-psychological models we are presenting a theory for the understanding of and design for such mediated realities. We emphasize the role of the human body as a sensing and interacting instrument and argue that presence is achieved by self-controlled navigation, object interaction, and subject interaction. Presence therefore derives from body-related possibilities of interaction with the environment. We demonstrate this through the definition of a theoretical presence model for embodied interaction in computer-mediated realities.

This article is dedicated to Martin K Purvis—one of the few *modern renaissance* scholars who is not only well educated and well read, but who continues to inspire young and curious minds, We hope that our thoughts presented here will inspire and entertain Martin as well as other readers with interests in the crossing boundaries of technology, psychology, and philosophy.

1. INTRODUCTION

Computer-mediated realities, i.e. three-dimensional worlds that can be explored interactively in real-time, currently experience a revival. These worlds range from augmented reality (AR), where physical (real) reality is enriched with spatially registered virtual objects, via augmented virtuality (AV), where virtual worlds are enriched with real objects to virtual reality (VR), where the entire experience happens within an immersive environment, leaving out any signs of physical reality (if possible and desirable). The virtuality continuum (Milgram et al., 1994) labels the range between AR and AV as mixed reality (MR) while computer-mediated realities also include VR (Regenbrecht et al., 2014).

Such computer-mediated realities (CMR) should evoke a feeling of being present for their users. To feel present means that the user feels that he/she is part of the mediated environment, accepting it as reality or world. Indeed, it seems that these computer-mediated environments aim at, benefit from, or even require a sense of presence in order to be used to their full extent. Only with a sense of presence, users will apply their full range of intuitive and heuristic reasoning and transfer knowledge from other environments in which they feel present – reality itself. In other words, computer-mediated realities can be understood as interactive, three-dimensional worlds which are considered as realities by users.

A rich and diverse field of psychological research has been conducted with the goal to understand and develop the relationship between individuals and technical environments. Within it, there exists a body of research on the sense of presence in virtual environments that has a long tradition (e.g. Barfield & Weghorst, 1993; Slater, Usoh, & Steed, 1994; Witmer & Singer, 1998; IJsselsteijn et al., 2000; Schubert, Friedmann, & Regenbrecht, 2001; Schubert, 2009; Grimshaw, 2014). Notably, a lot of it was discussed in the 1990's during the first wave of VR and AR technology development. Since then, the technology has recently seen another breakthrough with the advent of affordable and high quality display, graphics, and sensing technology.

We propose to investigate the sense of presence in CMRs by way of considering techno-psychological, philosophical and socio-psychological sources. We try to integrate knowledge from those sources to develop a framework model on CMR presence and to derive some design propositions for CMR. Presence, defined as "being in" the CMR, raises questions about "being in worlds" in general. How do body and mind relate to the surrounding environment?

Philosophically, those questions can be traced back to the Sophists and lead to a rationalism dilemma: We want to consider user (subject) and environment as one, non-divisible unit, because this is what being in an environment essentially is. On the other hand, we have to consider these two realms separately to be able to explain and communicate. Therefore, in the following we will go back and forth between these two views: an integrated, closely coupled human-environment view and a separation of the two realms where they are loosely coupled.

In both types of views, computer-mediated realities are unlike other media or technologies before. We were either present in the present (expressed with the present tense) and called this reality, or we used media, arts, and culture to be present in the past or future or imaginary, e.g. by way of storytelling or moviemaking. CMRs fold past, present, and future into one, direct experience of a feeling of being present in that computer-mediated reality—also called the sense of presence.

Briefly, our argument is the following: Human cognition is in the service of action in the world. Successful action requires being informed by knowledge about what interactions are possible in the HERE AND NOW, how interactions in the PAST went, and predictions about outcomes of actions in the FUTURE. Only possibilities in the HERE AND NOW are the immediate, direct outcome of perception; psychologists have called this the outcome of projectable information. Information about the PAST and predictions about the FUTURE are contributed by our minds; this has been called non-projectable information (Fodor and Pylishyn, 1981).

Because non-projectable information about PAST and FUTURE is so important, we share them with each other, being the social species that we are. For that purpose, we have created language and other media, and we spend a large part of our childhood learning to understand these media properly. Understanding means being able to build mental representations that allow us to act.

Indeed, we are so good at mentally simulating PAST or POSSIBLE worlds that sometimes they start to "feel" real, or that we feel present in them (e.g., in our imagined worlds, or in worlds that we are told about in books, in movies, etc.). For a long time, philosophers and psychologists have studied how humans build these mental representations from media and how they use them to enhance their interactions with the real environment

With CMR, what happens now is that media fully enter the world of projectable information, because the presentation of media content is now indexed to our body's movement. Thus, CMR now conquer the HERE AND NOW. However, that does not eliminate established media representations of other types, because they are amazingly efficient, and we already know how to use them. As a result, media representations of all kinds co-exist in CMR.

This analysis offers a framework for anyone trying to understand and create CMRs by adapting relevant philosophical foundations combined with techno-psychological and socio-psychological research. First, the CMRs' simulation of the HERE AND NOW in and by itself has to work as intended; psychological knowledge on how that works helps us to do that. Second, psychological research has investigated how understanding of the HERE AND NOW is integrated with information provided by media. Because CMRs contain both, this work is directly relevant to CMRs as well.

A sense of presence develops in three different, sometimes co-occurring types: spatial presence, social presence, and co-presence. Spatial presence, also known as the sense of "being there" breaks down to the components of the defining spatial presence, involvement, and realism (Schubert et al., 2004). Social presence or the sense of "being together" and co-presence, as the sense of (spatially) "being next to one another" are of high importance for group experiences of CMR, but are beyond the scope of this paper. Spatial presence, or simply presence, can and should be considered as a feeling (Schubert, 2009). Therefore, we have to view presence as caused by unconscious processes, as being immediate, in a philosophically loosely coupled view as having no truth value (can't be judged), and as having levels of intensity, amongst other aspects. Again, presence is the (individual) feeling of experiencing reality in the HERE AND NOW.

We are going to argue that presence develops by and through embodiment, which we break down into embodied interaction and embodied cognition. The embodied interaction aspect considers the human body as the sensing and interacting instrument in CMR while the embodied cognition aspects considers the conceptualization of reality.

The term "embodied interaction" was prominently introduced to the literature on human-computer interfaces by Paul Dourish (2011); this was often misread as being equivalent to tangible computing (Dourish, 2013). Dourish's notion of embodied interaction is one on the relationship of technical and social considerations. Hence, it is rather about "an embodied account of interaction for traditional user interface design and analysis" (Dourish, 2013, p. 2:2). We build on this notion, but focus on the relationship of technical and psychological and socio-psychological considerations. By doing this, we merge Dourish's view with Kirsh's (2013) view on embodied cognition to again decompose it into the tangible, perceptual, and instrumental aspects and the conceptualization aspects. Kirsh's embodied cognition theory proposal is grounded in four ideas: (1) that interaction with tools influences perception and thinking, (2) that thinking is embodied, (3) that doing contributes more to knowing than seeing, and (4) that sometimes we literally think with things (Kirsh, 2013, p. 3:1). If we combine both authors' views, we end up with an unsatisfactory ambiguity in terminology. In a philosophically loosely coupled way, we propose to separate embodiment into embodied interaction and embodied cognition (although we are aware of the rationalist dilemma within this).

In the remainder of this paper, we use Heidegger's concept of being in this world as a philosophical scaffolding to explain interaction and presence in CMR. Of particular interest are the aspects of *Zuhandendem* and *Vorhandenem* and the transition from *Sein* to *Dasein*. Both aspects can be seen as a strong account for the essence of embodiment and presence for CMR.

We then discuss three models of perception and how they relate to presence, leading to the conclusions that human cognition is embodied, that humans act on projectable information, and that past and future (non-projectable) experiences are meshed into affordances shaped by the format of the medium, here CMR. This discussion is followed by considerations on how CMRs are mentally constructed and presents an argument why CMRs are neither equivalent nor arbitrary interpretations of worlds. We shed a different light on mental models as co-existing and partial (analog) representations to be considered for designing CMRs. Finally, we present a set of propositions summarizing our model in a more tangible way for designing for presence.

For the composition of our model, we start of by considering ways of understanding perception which are predominantly used in theory and application of interaction design and human-computer interaction research.

2. PHILOSOPHICAL SCAFFOLDING: M. HEIDEGGER

The work of German philosopher Martin Heidegger can be divided into two phases: (1) his earlier work considered the concept of being and being in this world (*In-der-Welt-Sein*) and (2) his later work dealt with the relationship between men and technique (and technologies). Both aspects are of high relevance to presence in computer-mediated realities and therefore will be examined here[1]. His philosophy developed complex concepts that he typically referred to with newly coined or abstracted German terms.

Heidegger asks what the definition of being (*Sein*) is and what it differentiates from *what is*, or the "entity" (*das Seiende*), some specific thing that is. The entity (*Seiende)* can be found in all material objects, in abstract measures, in imaginations, in subjects (people), or even in the absolute (the divine). Building on this distinction, he introduced the term *Dasein*, the human form of being (*Sein)*. The essence of *Dasein* lies in its very existence (Heidegger, 1957, p.42). *Dasein* is achieved by understanding, exploring, or in Heidegger's terms, grasping (*begreifen,* which is the German term for grasping, both in its literal and abstract sense). Through grasping (*begreifen*), we move from mere being-in-the-world (*In-der-Welt-Sein*) to *Dasein*. When merely being in the world (*In-der-Welt-Sein)* we can't distinguish between the self and the world, even self-doubt happens within the world. Grasping (b*egreifen)* is strongly linked to interaction and the situation we are (inter-)acting in.

Heidegger also introduced the term thrownness (*Geworfenheit)*, loosely translated as "to be thrown". We are thrown into this world (whether we like it or not) and are made to act! Humans are in a constant state of thrownness, in a constant state of acting.

The world in turn, is not simply there; the world reveals itself by *Zuhandenem*—tools or objects with a purpose or being ready-to-hand. To illustrate this thought Heidegger used the example of a hammer: The hammer is out there in the world to be used as a hammer. This makes it part of the (current, individual) environment, it is ready to hand (*zuhanden)*. During the process of hammering, the hammer as something ready to hand disappears, it simply serves its purpose and is present-at-hand (*vorhanden)* (simply there, but with this "invisible"). Only if the hammer fails its function (e.g. brakes) it will become apparent again, and with this ready to hand (*zuhanden)*. Therefore, in Heidegger's world it is reasonable to explain and

[1] We are aware of the complicated side of Heidegger. During the rise of fascism in Germany, he evidently took the side of fascist movement and supported discrimination of Jewish colleagues. We believe that much of his work can be interpreted despite these condemnable behaviours.

name things and matters in terms of their readiness-to-hand (*Zuhandenheit,* being *zuhanden*) and not simply in terms of their apparent (surface) properties.

To understand presence in CMR, we can use Heidegger's concepts in the following ways: Virtual worlds are embedded in the real world to different degrees, ranging from augmented reality to immersive virtual reality. For a user, there must be (enough) clues or hints to realize or accept the presented CMR as a world. It is not sufficient to just provide a being-in-the-virtual-world (*in-der-virtuellen-welt-sein*), rather, the CMR has to provide a set of clues and objects to interact with, of *Zuhandenem*. Only then, the user can turn the ready-to-hand (*zuhanden)* objects in the world into present-at-hand (*vorhanden)* objects by interacting with the world and with this coming into a state of *Dasein*. The being-in-the-world becomes *Dasein*, becomes presence. The (technical) CMR apparatus provides a situation of thrownness *(Geworfenheit)*, which makes the user act in.

The Heideggerian concepts adapted so far stemmed from his earlier period of work. Later he explored humans' interactions with the technological world they created. His notion of the *Ge-stell* can serve as guidelines for understanding technological systems. We will use it here to consider the technical apparatus of a CMR system, i.e. the technology surrounding the user as well as the (3D) content and possible interactions. *Ge-stell* can be loosely translated into the frame, the scaffolding, the stage, or the background that is used to set the CMR scene. It serves to reveal (*entbergen*) the hidden (*verborgene)*. It includes all forms of interaction like production or presentation. For CMR design that means, that we should keep the user away from consciously working in and for the *Ge-stell*. He/she should rather interpret (*entbergen*). In a simplified way, we could even say that the focus is on content, not technology.

Sein and *Dasein* have to be seen in relation to the self—the interplay of self and environment leads to presence.

Presence develops in the *Ge-stell* through action. Presence can only develop if the environment is recognized and accepted as a world (reality) by the user (self). CMR technology is a necessary, but not sufficient prerequisite for presence.

3. THE FLOW, THE DAM, AND THE KAYAK: THREE WAYS TO UNDERSTAND PERCEPTION

Psychological theorizing has proposed at least three classic ways of how to understand what happens during perception. These three classics will inform our discussion because they obviously apply to the perception of virtual environments, but they will also help us to better understand what virtual environments actually do. In short, the three ways are the Gibsonian view (the environment affords itself to us), the Fodorian view (we recognize objects and their properties), and the embodied way (perception is embodied action). Let us explain each of these classic views in turn.

3.1 The Gibsonian View: There is only flow

J.J. Gibson (1979) developed a model of perception, which assumes that we pick up (apparent) properties from our environment, defined by an optical flow array. The perceiver selects (picks) those properties from a rich information environment that are of immediate relevance. Those properties form an ad-hoc individual environment, which is not based on mental representations but rather on directly perceivable properties.

The environment is both, the object of perception as well as the perceptual information. The perceiver and the environment form one, tightly coupled unit. Information from the environment is to be considered of relevance if they require action, becoming so-called ecological objects. Gibson introduced the term affordances to describe those action-relevant properties of objects. The environment consists of affordances, and only those are relevant.

An ontological consequence of such a thought is the necessary interplay between environment and perception to describe the nature of existence of organisms, here humans. The perceiver influences the environment - the environment influences the user. Distinguishing between subject and object is almost impossible (the rationalism dilemma). Hence, the only measure for perception is effective action in the environment. According to Gibson, all other constructs, like mental models, are redundant.

The claimed redundancy of models sparks two essential questions: (1) How can effective acting be defined and measured? Applying Gibson’s framework to CMRs, Zahorik & Jenison (1998) defined effective action as any acting which finds its equivalence in the real world. I.e. if we can interact with a CMR in the same way as in the real world then we would call this effective. Obviously, CMRs don't have to follow the same laws as the real world (e.g. gravity), so this might invalidate this argument. Nevertheless, Zahorik & Jenison argue that to date all development (cultural, social, psychological) happened in the real world, so was learned only there. (2) Aren't there objective indicators, like time needed to complete a task to suffice the requirement of measurability?

3.2 The Cognitivist Dam: There is flow, and then there is knowledge

Fodor & Pylishin (1981) criticized Gibson's model in many ways. Of particular relevance to us is their argument that we need to differentiate ecological (affordances) from non-ecological objects.

> "..., if any property can count as an invariant, and if any psychological process can count as the pickup of an invariant, then the identification of perception with the pickup of invariants excludes nothing." (p. 141)

> "Our argument will be that (a) the prototypical perceptual relations (seeing, hearing, tasting, etc.) are extensional [...] (b) whereas, on the contrary, most other prototypical cognitive relations (believing, expecting, thinking about, seeing as, etc.) are intentional; and (c) the main work that the mental representation construct does in cognitive theory is to provide a basis for explaining the intentionality of cognitive relations." (p. 188)

To solve this problem, they offer the concept of projectable and non-projectable properties of perception. Projectable properties are those which can be directly picked up from the environment, like Gibson's optical flow array. Non-projectable properties, on the other hand, require additional information from the user's knowledge. They are not obvious, apparent or directly perceivable.

Take as an example a bottle of soda. The bottle is designed and manufactured to afford the actions of being picked up with one hand, being tilted, and pouring the liquid – if you wish, directly into your mouth, with just the right aperture to fit it. All that information is projectable but comes into being in conjunction with a body able to pick up, tilt, and drink. On the other hand, the drinkability and digestibility of the liquid of a certain consistency is most likely not hard-coded into our genetic makeup but learned as a fact, and thus not projectable.

3.3 Navigating the flow: Embodied action

There are major differences in the views of Gibson and Fodor & Pylishin. Nevertheless, we can extract some valuable, pragmatic thoughts here:

1. Perception in CMR is based on an action-perception loop. There is no action-independent perception.
2. There are projectable and non-projectable properties in the CMR.

Varela, Thomson, and Rosch (1991) attempted to mediate between the different object-subject viewpoints, which are reflected in their extremes by rationalism/positivism and idealism/solipsism, with their proposed Embodied Mind approach. They developed a cognitive science theory inspired by Buddhist philosophy and embodied perception. Their approach can be summarized as an:

> "... emphasis on mutual specification ... [that] enables us to negotiate a middle path between the Scylla of cognition as the recovery of a pregiven outer world (realism) and the Charybdis of cognition as the projection of a pregiven inner world (idealism). ... Our intention is to bypass entirely this logical geography of inner versus outer by studying cognition not as recovery or projection but as embodied action." (p.209)

These two views, also referred to as the hen-egg problem, address the question of objectivity. On one side, the hen position, there is an objective world which can be represented or imagined by the perceiver. On the other side, the egg position, the world is entirely constructed by the perceiver. In both cases we talk about representations, either constructed externally or internally.

The combination of both representations, however, introduces the concept of embodied action. Cognition cannot be decoupled from the biological, psychological, or cultural background of the perceiver and experiences resulting from sensory and motor interaction. Varela et al. developed a model of enaction: Perception is always perception-driven acting and acting is based on cognitive structures made of sensorimotor patterns. The cognitive model is based on the sensorimotor experiences of the self.

This model of Varela et al. has contributed to the field of embodied cognition, which has emerged in the last two decades. For instance, cognitive scientist Arthur M. Glenberg (1997) proposed a theory of memory building upon embodied cognition concepts. His approach focused on both perception of real actual environments, language, and their interaction.

Like Varela and Gibson, Glenberg considered perception as an integral sensorimotor process; he sees the body as the central element of this perception loop. On one hand, the body is the main reference frame for all actions; on the other hand, it is also the instrument for sensorimotor perception: acting and perceiving. Experiences made this way are stored as embodied experiences in memory.

While Glenberg also recognizes projectable and non-projectable properties he claims that objects can only be perceived if there are possible actions. Importantly, and in line with the general notion of embodied cognition, Glenberg argued that non-projectable properties are always stored as embodied experiences, i.e. they are not independent from the situation in which they have been (sensomotorically) generated.

A continuous meshing of projectable and non-projectable properties leads to implicit or indirect memory. „When we are walking the path home, we do not need to consciously recall which way to turn at each intersection;“ (Glenberg, 1997; p. 10). We conceptualize a meshed set of patterns of action.

Using dangerous, everyday situations as examples, Glenberg demonstrates that normally the projectable properties dominate. They „...may not require any sort of representation of the environment and they may not require memory.“ (p. 4). He calls this concept clamping. Non-projectable properties are clamped to develop different, situation-specific conceptualizations resulting in different possible meanings for a given situation: „...the world is conceptualized (in part) as patterns of possible bodily interactions, that is, how we can move our hands and fingers, our legs and bodies, our eyes and ears, to deal with the world that presents itself?“ (p. 3). He emphasizes the assignment of meaning by possible actions.

The process of meshing projectable and non-projectable information is exemplified by understanding language that refers to a situation. E.g., imagine trying to understand instructions of how to find your way to the bus stop. In order to find your way successfully, you have to generate mental representations of possible actions, mesh them with your current state, and then execute and update them based on your locomotion.

However, sometimes it is necessary to suppress certain perceptions. This is in particular necessary if there are contradicting or incoherent sensations and perceptions. Suppression implies mental load. If you try to understand instructions that do not refer to your current situation but some future state, you need to partly or completely suppress representations based on current projectable information. This is what you do when you read novels or watch TV.

Conceptualizations are constantly changing and form trajectories. „Here is the proposal for updating memory: memory is updated automatically (that is, without intention) whenever there is a change in conceptualization (mesh).“ (p. 7). Later we refer back to those trajectories as feelings of memory to mesh new conceptualizations. Those trajectories are embodied, i.e. they "describe" the memorized situation in relation to own actions and therefore are easily applicable to the current situation.

> „...memory is embodied by encoding meshed (i.e. integrated by virtue of their analogical shapes) sets of patterns of action. How the patterns combine is constrained by how our bodies work. A meshed set of patterns correspond to a conceptualization.“ (p. 3).

3.4 Summary

To sum up: Cognitive scientists have grappled for decades with the ontological status of the information that humans use to adapt their behavior. Is it out there, and we take it in, implying a difference between us and the environment, or is there never anything in us, but we simply interact? A viable (and informative!) solution seems to be to acknowledge that:

1. Human cognition is always in the service of action, and action always requires a body.
2. Humans act on the basis of information picked up directly from affordances in the environment. Such affordances are defined jointly by the environment and the body. We can call this type of information projectable information.
3. However, action is also shaped by information that is either remembered from past experiences, or information that is generated in simulations about possible future environments. This type of information can be called non-projectable. Humans mesh such information with information from affordances picked up from flow. The meshing is eased by the format in which these mental representations (memories and simulations) are run, namely in an embodied, modal, format – the same format that the direct perception of the environment based on affordances uses as well.

4. INTERPRETATION OF VIRTUAL WORLDS AND A MODEL FOR PRESENCE

As indicated earlier, computer-mediated realities form a subset of possible alternative realities humans might construct. Even if we reduce this set of worlds to digitally constructed ones we might struggle to formulate what can and what should be included in our considerations. From a technological point of view, we might define CMR as: (1) computer generated, (2) three-dimensional, (3) interactive with real-time feedback, and (4) immersive (aiming for a user's sense of presence in that reality). From a content provision point of view, environments can be offered which reflect as close as possible real-world (physical world) situations, as for instance needed for VR or AR supported design reviews of to-be-manufactured goods. Alternatively, artistic environments might be created with properties beyond what we know from the real world (within limits).

Now, let us apply the insights from cognitive science on how humans perceive and interact with CMRs. Traditional media, such as books, but even spoken language, provide us with non-projectable information that, once processed and mentally represented, can be meshed with projectable information from the environment. This is how we learn that the red end of the compass needle points north (where we have to walk to get home), or that milk is bad for us if we are lactose intolerant, and how we hopefully act adaptively based on this knowledge. The information that we acquire this way can be about the past or about possible futures. Interestingly, any non-projectable information conveyed in a medium has of course to hitchhike on actual perception of the real environment and thus projectable information: the letters on this page are made of actual atoms on paper or a screen.

The distinction of projectable and non-projectable information gives us an understanding of what CMR does in terms of perception: The truly amazing achievement of CMR technology is that it goes beyond providing non-projectable information that we still need to mesh. Instead, it is a medium that provides projectable information. It shares this feat only with a few other media forms that usually are not nearly as efficient, such as (participatory) theatre, role play, or, in few rare moments, movies.

To appreciate the difference, consider how you would perceive and apprehend a photo: First of all, the projectable information provided is that the photo is displayed on some kind of surface, and that surface can interact with your real body. In addition, you can construct a spatial mental representation of the environment depicted in the photo, which is an acquired skill – but this is not based on projectable properties directly—it requires interpretation and additional cognitive processing. Only after doing this, you can suppress your real environment and mentally place yourself in the depicted environment. Of course, all these processes are happening rapidly and efficiently in adults, and are mentally impenetrable. A CMR allows the perceiver to skip these steps.

Nevertheless, CMRs do not only convey projectable information. Because it can simulate projectable information, it can also simulate any other medium (with hopefully enough resolution!).

Varela et al.'s and Glenberg's notions have been the basis of our own approach to develop a model for presence in CMR. Human actors in a CMR receive projectable information from the real environment (e.g., the weight of the head-mounted display on their head and the floor they walk on), projectable information from the CMR that changes in accordance with movements and other actions (e.g., speech), and non-projectable information from the CMR (e.g., labels). They may even receive additional non-projectable information from outside the CMR, for instance if a VR session is accompanied by instructions what to do in the virtual environment. Accordingly, spatial presence, when defined as a subjective experience, develops when control of the own body is seen as a possible action in the CMR. Presence can be increased if more meaningful possibilities of interactions are offered and appropriate conceptualizations can be made (Regenbrecht and Schubert, 2002a).

Also, the possible actions with objects in the environment lead to a better understanding of the CMR. If those actions are perceived as body-related, then this will lead to presence within the environment. Body-related stimuli increase presence.

The need to suppress incoherent stimuli leads to the opposite effect: presence will be decreased or will break.

4.1 Mental Models and Metaphors for CMR Design

If we understand embodiment as embodied interaction and embodied cognition, which cognitive models could be applied to inform CMR design? How do users of CMR represent the surrounding environment? Is it rather a symbolic-abstract representation, also called propositional, or is it a rather analogue or in laymen's terms representational model?

The nature of CMR, their spatial extents and their appearance suggest themselves to analogue models. Based on theories developed by Johnson-Laird (1983), Schnotz (1994) developed an approach of mental models as representations of actual situations. Mental models are used to build constructions about the matter, structure, and function of "worlds".

Mental models are based on three principles:

> "1. The principle of computability: Mental models, and the machinery for constructing and interpreting them, are computable. [...]
>
> 2. The principle of finitism: A mental model must be finite in size and cannot directly represent an infinite domain. [...]
>
> 3. The principle of constructivism: A mental model is constructed from tokens arranged in a particular structure to represent a state of affairs.“ (Johnson-Laird, 1983, p. 398)

Those principles show that mental models (a) are interpreted constructions, (b) those constructions are simplified to a degree that they are "computable" (also "principle of economy of models"), and (c) that it is impossible to transfer (objective) realities to internal representations.

Mental models are constructed before the background of individual experiences. "...our view of the world is causally dependent both on the way the world is and on the way we are." (p. 402).

Possible concepts which can be represented in mental models are categorized into: time, space, possibility, permissibility, causation, and intention. Using those concepts, mental models organize structures for possibilities on semantic operators. Perceptual processes normally build a three-dimensional (kinematic) model which relates volumina of objects into an object-centric coordinate system, hence the suitability of mental models as models to explain the perception of and interaction with CMRs.

Purely propositional models, based on for instance words or symbols, are rejected by Johnson-Laird. He refers to the behavior of little children or to the difficulty in distinguishing between object and belief. Important is the representation: "What Meister Eckart believed about God could not be expressed in words ..." (p. 432).

Johnson-Laird gives us a cognitive theory which allows to develop categories of spatial structures and with this the relation of the self to the surrounding environment.

4.2 Plausibility of CMR

In the style of Eco (1990/1995) we are distinguishing between categorizations of worlds as possible/impossible and as imaginable/unimaginable. Normally, and if seen from the viewpoint of the designer of a CMR, imaginable and possible worlds are the norm. We want to create augmentations for the real world which (almost) seamlessly blend in with reality or we want to create virtual worlds, even if they are immersive and therefore (partially) decoupled from real stimuli, with properties known from real world experiences. If those worlds are plausible, i.e. possible and imaginable, we call them effective.

There are worlds which are imaginable but normally impossible, like speaking animals in fairy tales. In CMR, these worlds require some sort of willingness of the user to accept, at least for a certain while, the lack of plausibility in those situations.

Possible and impossible, imaginable worlds can be communicated by writing about them, for instance, those worlds are of lesser interest for CMRs.

Imaginable (possible and impossible) CMRs can be interpreted differently, depending on one’s perspective. On one hand there is the intention of the designer of the world who makes an offer for the recipient to interpret the world. Eco talked about a model reader (because he wrote mainly about texts), hence a fictive person or group of persons, which functions as a proxy during the design process. In interaction design those persons are sometimes referred to as personas. For CMR we might call this fictive person, our imagined user, proxy actor. This proxy actor, on the other hand, explicitly or implicitly forms a picture of the creator of the CMR; what does this world expect from me?; What is the intention? This includes not only the (imagined) person of the designer but also includes algorithms, the "machine" as such, or the "artificial intelligence" of the CMR - the proxy author.

Norman (1989) discussed in a practical way what creators (authors) and recipients (actors) might have in their minds when developing and using CMRs.

The author's design goal is to offer a CMR which expresses a certain form (appearance), a (narrative) plot and possibilities for interaction. Using the concept of mental models the following constructs develop:

- $MM_{author1}$ (real world): mental model of the author about the environment the proxy actor lives and acts in. This is characterized by "nature and nurture" factors.
- $MM_{author2}$ (CMR): mental model of author about ten to-be-created CMR. This model often changes many times during the development process.
- $MM_{author3}$ (actor): mental model of the author about the proxy actor; can be a real person group, or a fictive user (e.g. persona)
- $MM_{author4}$ (MM_{actor} (CMR)): the mental model of the author about the actor's mental model of the CMR. This model addresses the question how the actor might construct a model about the developed CMR.
- $MM_{author5}$ (MM_{actor} (author)): the mental model of the author about the mental model of the actor about him/herself.

Whether and how often and how deeply authors think about this is unknown, also whether further considerations or recursions happen in the form of MM_{author} (MM_{actor} (MM_{author} (...))).

The author tries to provide the proxy actor with a set of stimuli to satisfy his mental model about the to-be created CMR and the user's mental models about it. An equivalent interpretation, i.e. a 100% match of those mental models is impossible.

From the user's (actor's) point of view there is a corresponding set of mental models:

- MM_{actor1} (real world): the mental model of the user about his/her real environment, including nature/nurture background.
- MM_{actor2} (CMR): the mental model of the user about the CMR at hand. This model changes during interaction, it would therefore be helpful to (at least) break this mental model into three phases: before, during, and after use/experience.

All other possible mental model relationships can be developed in a similar way as for the author's view.

Even if an equivalent interpretation by the author and actor of the CMR is impossible, that does not mean that there is an arbitrary number of interpretations, and neither is there a unique interpretation. There are interpretations which are inadequate. In Eco's words relating to texts: "...any act of interpretation is a dialectic between openness and form, initiative on the part of the interpreter and contextual pressure" (p.

21). Hence, the interpretation of a CMR happens within the limits of equivalent and arbitrary interpretation, but excluding the extremes.

We now have a scope for representations and interpretations of CMR. Let's now "throw" a user into our CMR environment. Will that user develop a feeling of presence, i.e. the sense of being part of that CMR?

5. PROPOSITIONS

We are presenting a set of propositions to be considered when designing and analyzing computer-mediated realities.

The sense of presence, in particular spatial presence, can best be explained with mental models and not with propositional approaches. Propositional elements might be present within mental models though.

Presence results from the user's effort to imagine and to construct a world including her/his relations to this world. This requires (a) a willingness to perceive an alternative (computer-mediated) world and (b) the willingness to put in this effort.

Presence only develops if, and only if the CMR is perceived as such. There have to be stimuli which allow for an appropriate interpretation. The design of the CMR determines the possible room of interpretations, which is not arbitrary. This does not mean, that there aren't any interpretations which fall outside of the intentions of the designer.

Presence develops in a biological, psychological, and cultural context of a user. It can't be considered outside the background and experience of the user. Those experiences are mainly based on real/physical world interactions and perceptions. These days this includes the interaction with computing artifacts.

Interactions can be of different types: imagined, planned, planned and executed or simply executed.

The to-be-perceived environment consists of projectable and non-projectable properties. Projectable properties are perceived sensorial in a direct manner and do not require cognitive effort. Non-projectable properties are amended with experiences from memory, resulting in changing conceptualizations of the situation at hand. CMR have the potential to fold past and future into present and with this into projectable properties.

Objects within the CMR are either relevant for orientation or for action. Orientation-relevant objects are perceived in the "being a" aspect of an object, don't require (or only little) mental resources and therefore have projectable properties. Action-relevant objects are perceived as objects of possible actions - they can have projectable and non-projectable properties.

One and the same object can be interpreted by the users as orientation- or action-relevant depending on the situation at hand. The current goal of action determines the mode of interpretation.

There should be more projectable than non-projectable properties in a CMR to maximize the likelihood of presence.

The more non-projectable properties one finds in a CMR the more interaction is required to conceptualize the environment. Von Foerster's (1992) 4D cube experiment might serve as an example here: When only watching other users interacting with the a stereoscopic hypercube (a mathematical 4D→3D→2x2D projection) the environment appeared to have almost only non-projectable properties. Only when users interact with the system for a certain while the environment could be conceptualized (grasped).

Presence develops through interaction with the CMR. There are three forms of interaction (cf. Regenbrecht, 2000):

1. self-controlled movement through the environment
2. interaction with objects
3. interaction with subjects (communication and cooperation)

Presence develops through an action-perception loop or sensory-motoric perception. While action and perception form one concept they have to be separated for (rationalistic) model building here.

The act of acting in CMR is body-related, it is embodied! Objects of the CMR are interpreted in relation to the own body. That means that (a) all Cartesian variables (like distance, size, or position in space) are put into relation to the body (with all their projectable and non-projectable properties) and (b) all possible actions are related to the body as an interaction instrument.

Action-relevant objects in a virtual environment do increase the sense of presence if they are presented in a body-conform way. Orientation-relevant objects increase the sense of presence if they are presented as part of the experience context (also embodied) of the user in their "being a" aspect and therefore immediately projectable.

The suppression of incoherent stimuli between the different domains of a CMR, i.e. real, augmented, and virtual, demands mental resources. If a user can't free up those resources transparently the sense of presence will decrease or break. This leads to two ramifications: (1) the easier the (intended) conceptualization can be achieved the less has to be suppressed and (2) the fewer incoherent stimuli from other domains are perceived the easier the conceptualization.

The meaning of the CMR as a whole (not necessarily of its single elements) is determined by the possible, body-related actions of the user. Those actions derive from possible patterns of actions (intention of the designer of the CMR) and the patterns of actions of the user. Conceptualizations lead to possible actions in the CMR.

The more relevant a CMR is for a user the higher the sense of presence (including non-spatial presence). Spatial presence develops through body-related possibilities for interaction within the CMR.

There is only embodied interaction in computer-mediated realities.

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