Body Image and Body Schema: Interaction Design for and through Embodied Cognition

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Abstract. The interdisciplinary literature on body image/body schema (BIBS), which is within the larger realm of embodied cognition, can provide HCI practitioners and theorists new ideas of and approaches to human perception and experience. In very brief terms, body image consists of perceptions, attitudes and beliefs pertaining to one's own body, whereas body schema is a system of sensory-motor capabilities that function, usually without awareness or the necessity of perceptual monitoring. The dynamic relationality and plasticity of BIBS open up different avenues for interaction design. An overview of six main ideas deriving from BIBS literature are enumerated, followed by a discussion of projects designed for chronic pain patients that demonstrate how these ideas can be adopted in interaction design processes as a perspective or attitude rather than a mere application of traditional methods. Through bridging HCI and BIBS theories and research, we can develop a holistic framework in which we design for and through embodied cognition.

Keywords: Embodied cognition, body image, body schema, interaction design, virtual reality, chronic pain.

1 Introduction

The interdisciplinary literature on body image/body schema (BIBS), which lies within the broader realm of embodied cognition, can provide HCI practitioners and theorists new ideas of human body, perception and experience. Embodied cognition challenges the mind-body dualism and highlights how the body shapes our cognitive processing from perceiving and thinking to linguistic and emotional processing. In this context, the growing literature and research on BIBS, which draws upon diverse fields including neuroscience, psychology, and philosophy, investigates numerous aspects of embodied cognition, and directly addresses the crucial question of how mind is embodied.

The BIBS research addresses issues—such as embodiment, consciousness, awareness, attention, and agency—that play crucial roles in shaping the direction of current research on embodied cognition. In brief terms, body image consists of perceptions, attitudes and beliefs pertaining to one's own body, whereas body schema is a system of sensory-motor capabilities that function, usually without awareness or the necessity

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of perceptual monitoring [7]. For instance, BIBS can be described as the difference between having a perception (belief) regarding one's body (such as conscious monitoring of one's movement, or a belief about one's body's capacity to move), and having a capacity to move (the actual accomplishment of the movement). Since body schema primarily controls the interaction between one's body and environment, it enables us to function in an integrated way with our environment. Similar to J.J. Gibson's theory of affordance [8], BIBS research investigates how the body acts, moves or interacts through opportunities and constraints shaped by the dynamic interaction of body and environment. BIBS research also reveals that plasticity is involved in both body image and body schema, and that both are interdependent systems rather than mere exclusive categories. Such an insight into how the body functions in human experience reshapes our ways of thinking about our body, mind, interaction, technology and design. Therefore, the question emerges: what are the implications of embodied cognition, specifically of the growing body of BIBS literature for interaction design, including tangible interactions and non-verbal interfaces.

We draw upon six ideas about embodied cognition that are supported by the current BIBS literature: 1. Mind is embodied. We think with our bodies rather than solely relying on our brains, even though we are not always or often consciously aware of it [7][21]. 2. Proprioception plays an important role in embodiment and consciousness [7][21]. 3. The sense of self and perception of others are strongly informed by embodiment [1][7]. 4. Plasticity is involved in both body image and body schema, and they are interdependent systems, not exclusive categories [7][14][20]. 5. Such operations of BIBS do not become apparent to conscious awareness until there is a reflection on our bodily situations brought upon by certain 'limit-situations' such as pain [5][7]. 6. As body image and body schema are also shaped by pre-reflexive process, it is difficult to assess or evaluate BIBS-related issues based solely on reflective methods, such as interviews or surveys. The experimental situations need to be improved to address both the human subject's both reflective (how they express (verbalize) how they feel while moving) and pre-reflective / proprioceptive processes (how their body moves)[7][20].

We discuss some of our, The Transforming Pain Research Group's[1], projects here in order to demonstrate how these six BIBS-related ideas can be adopted in interaction design processes as a perspective or attitude rather than as a practical application of existing methods. Two of our current projects the *Virtual Meditative Walk* and *Mobius Floe* are unique, immersive virtual environments with distinctly different approaches to chronic and acute pain management. The *Virtual Meditative Walk,* for example*,* includes visual biofeedback and verbally coaches users to learn how to meditate. In addition, the primary navigation interface, a treadmill, was incorporated to address kinesiophia, a fear of or reluctance to move. The system is designed to directly address chronic pain patients' specific embodied conditions, bodily awareness and potentially a sense of agency that they may develop over their persistent pain. We combine mindfulness-based stress reduction (MBSR) with the technologies of VR

[1] The Transforming Pain Research Group (Pain Studies Lab) is affiliated with the School of Interactive Arts and Technology at Simon Fraser University.

and biofeedback as tools that enable patients to develop a greater awareness of their interoceptive or inner processes and share their physical conditions in more expressive ways. In contrast, *Mobius Floe* does the opposite by focusing the patient away from their bodily awareness through continuously engaging distractions, which help reduce the intensity of perceived pain [9]. This type of VR treatment - pain distraction - was developed specifically for acute or chronic pain patients who are experiencing a sudden worsening of their bodily pain, at least for the short periods of time. These and other examples offer a compelling case for how BIBS-related ideas influence and guide researchers' approaches to health-related projects. Insights from BIBS literature can be translated into a set of tangible tools and principles for creating practical HCI and interaction design projects within a holistic perspective.

BIBS research, which enables the investigation of the various aspects and conditions of embodied cognition, can contribute to HCI practitioners and theorists by offering new ideas about embodiment and interaction. If the body, and its interaction with the environment shape how we perceive our own body, self, and others, as well as the artifacts and the environments we interact with, then we need to integrate the insights deriving from BIBS literature into our design theories and practices in order to generate human-computer interactions that may be ultimately more effective, expressive and engaging. However, we also think that such connections between the fields of BIBS and interaction design necessarily imply a shift in the perspective or the attitude towards body, subjectivity, and interaction beyond applications of those ideas that are still shaped by traditional hierarchical or dichotomist understanding of the relations of mind and body. This is no small feat, as our understandings of mind as separate from body are persistent, implicit and deeply inculcated. Additionally, a holistic perspective of BIBS research can address the HCI theories and practices that focus on embodied interaction, and design for diverse communities including groups of people with varied embodied conditions or cultural sensitivities since it motivates adaptive user interfaces that lie beyond assistive technologies. Finally and conversely, we believe that HCI theories and practices can in turn enrich the research methodologies that are employed in BIBS-related theory and research. For instance, affective computing offers BIBS research new contexts for experimentation with our bodily states and interactions because it newly accounts for bodily capacities. By the integration of HCI and BIBS theories and practices, we can develop a holistic framework around specific contexts and needs, and new vocabularies and trajectories for further research. This offers a new, enlarged, lens to think with and create through, and enables concrete examples of design for and through embodied cognition.

2 Body Image/Body Schema: Unfolding Embodied Cognition

The phenomena of the human body and experience are part of complex and long-lasting interdisciplinary inquiry in diverse fields of study including cognitive science, psychology and philosophy. During the 20th century, many thinkers and researchers made the body a central issue in their works (e.g. Maurice Merleau-Ponty). Consequently, even though the dualism of body and mind (disembodied mind) haunt all

claims to the contrary, we can say that the contemporary cognitive sciences offer strong examples and arguments, that prove that the mind is embodied [4][7][11][13][21]. The core argument of embodied cognition is that the thoughts and beliefs we have about the world, self and others, are grounded in our perceptual-action experience with things and the environment. It means that our bodily states, actions and interactions will shape how we perceive and think; which implies a necessity for more dynamic and interactive body-mind relations.

For instance, the studies on phantom limb reveal the effects of visual input on phantom sensations and inter-sensory effects (such as the relationship between visual and touch perception): V.S. Ramachandran's research show that the phantom hand was felt to move when the patient sees a normal hand being moved in the mirror (which is also known as mirror-touch synaesthesia in the phantom limb) [15]. Such findings strongly ask for a more dynamic and interactive model of brain rather than hierarchical models. On the other hand, there is extensive neurophysiological evidence of a close link between action observation and action execution. Studies on mirror neurons show that the same neurons get fired, when we both act and visually observe the same action being performed by another, since it gets translated into proprioceptive sense of that action. Simultaneously shared modalities of observation (of others) and action capability (of one's self), which occur within brain areas related to language production, emphasize their significance for intersubjective communication and understanding [16]. Furthermore, David Kirsh's study with dancers showed that using one's own body to explore a dance movement is a better way to understand dance movement than watching someone else exploring it [10]. This means that observing someone doing a certain act has a stronger impact than merely mentally thinking or imagining that act for understanding or learning it, but if someone actually performs that act, even in an imperfect ways or without completing it, it has a stronger impact than merely observing someone else doing it. As Kirsh discusses, "to fully make sense of what we are seeing we need to run our motor system simultaneously with watching to get a sense of what it would be like if were to perform the action ourselves" (6). Thus, studies of embodied and situated cognition (e.g. Suchman), which reveals its impact within design-related fields as well, support an understanding of body as embedded within physical and social environments that constitute self and perception of others and surrounding objects, and motivates action, thought, emotion and communication [7][21].

In this regard, the research on body image and body schema constitutes one of the most significant themes within the realm of embodied cognition, as it reveals the variety of ways we have of relating to and becoming aware of our bodies. In the literature, there is almost an agreement that body image and body schema address different aspects of body but are interrelated. Even though there is some variance about the nature and dynamics of these notions across various disciplines, BIBS's contribution to our understanding of embodied cognition has received widespread confirmation as an area of study of valid arguments. In basic terms, body image addresses phenomenal aspects of embodiment, which refers to a first-person awareness of one's own body and its contribution to the content of one's conscious experience [7]. For instance, patients with anorexia nervosa have a disrupted body image that cause them to

perceive their own body in a way different than it actually is. Thus, we can say that body image consists of a system of perceptions and beliefs about one's body. Therefore, it can be shaped by perceptual, conceptual, emotional, cultural and interpersonal factors. On the other hand, body schema refers to prenoetic aspects of our perception, which refer to the structuring of consciousness rather than the apparent structure of consciousness [7]. This means that the notion of body schema addresses the question of how one's body shapes or constrains one's perceptual field. Body schema refers to the system of sensory-motor capabilities and tacit performances that function without our awareness or the necessity of our perceptual monitoring. Not surprisingly, the reciprocal interactions between body image and body schema are related to other fundamental notions such as agency, consciousness, attention, ownership, control and intersubjectivity [1][7].

However, as Shaun Gallagher argues, it would be wrong to describe body image and body schema along the lines of manifest versus latent, or conscious versus unconscious realms. It is better to frame the distinction as having a perception (belief) of something and having a capacity to accomplish it (to do something; or conscious monitoring of movements and the actual accomplishment of movement)[7]. Body schema functions in a more holistic way, as it is integrated with its surrounding environments or objects (such as tools and devices in a hand). This shows that body schema can extend beyond the boundaries of body image. Here, it is very crucial to understand that body image and body schema are related to one another. There is a relationality and plasticity involved in both body image and body schema: a transformation in one can derive from or yield a change in the other [7][20]. For instance, some patients compensate the impairment of body schema by employing body image in unique ways. Visual awareness of one's own body (or even visual perception of other's functioning body as in the case of V.S. Ramachandran's work with a mirror to mitigate phantom pain) can override one's body-schematic functions simultaneously. And long-term body image can function prenoetically, that is, without our awareness after learning, and so become part of our body schema. On the other hand, the body image may change based on the operations of the body schema since the body schema controls the interaction of body with the surrounding environment, and negotiates the environmental affordance in Gibson's terms. Therefore, it is important emphasize both the interrelatedness and the plasticity of body image and body schema, and that they are dynamic and relational rather than being fully given or immoveable.

However, the complex interactions between body image and body schema do not become apparent to consciousness until there is a disruption which requires a reflection on our bodily situations brought by certain 'limit situations' with which our bodies react and cope with, such as discomfort and pain [5][7][11]. For instance, patients with chronic pain may perceive and experience body and its surrounding environment differently, since their disrupted body image or impaired body schema requires more attention and effort for actions that can be done by normal subjects without conscious efforts or inattentive guarding of painful areas [5][7]. Furthermore, making an interior experience sharable through externalization or objectification, such as descriptive expressions, is a real struggle for pain patients [17]. Pain experience is very difficult to communicate. This is parallel to the fact that the objectivist or

phenomenological methodologies, which rely on one's conscious experiences or reflections, fail to acknowledge the significant mechanisms underlying those experiences. Pre-reflective and proprioceptive processes shape the body image and, especially, body schema; therefore, the assessment and the evaluation of those BIBS-related issues have some difficulties need to be addressed. Furthermore, the body image and body schema are not fixed but open to transformation through new encounters with the body, environment and others, through new experience and cognition of the body, through imagination and learning [20]. This transformative quality reminds us about the significance of developing technologies or adopting existing technologies in order to address those plasticity and immediacy of the body image and body schema. Therefore, design for diverse communities, such as chronic pain patients, is not only widening the scope and inclusiveness of design practice, but also practicing of design to explore the complex phenomena of human body and experience in general; this approach in design in turn can address diverse physical conditions and cultural sensitivities.

This is a very compelling idea for the field of design; as the literature on embodied cognition including BIBS, provide empirical evidence and theoretical support for encouraging interaction design for and through embodied cognition. To cite David Kirsh's paper on the convergence of embodied cognition and interaction design, "If it is true that we can and do literally think with physical objects, even if only for brief moments, then new possibilities open up for the design of tangible, reality-based, and natural computing." (3)[10]. Parallel to this conclusion, we also highlight the significance of interaction design *for* embodied cognition, which may guide further research within the field of BIBS by addressing the complexity, immediacy and plasticity of that embodied cognition.

3 Interaction Design for and through Embodied Cognition

While we discuss about the ideas deriving from BIBS literature may enlarge HCI research, we also acknowledge that the HCI community has already accepted some of those ideas in one form or another. For instance, theories such as situated cognition (Suchman) [19], the extended mind (Clark & Chalmers) [4], and enacted perception (Noë) [13], which have considerable impact on HCI-related fields, emphasize an understanding of distributed and interactive mind rather than a disembodied one. They argue for an understanding of cognition that is continuous with the process in the environment, and with the actions we perform with others or other objects. Therefore our actions and interactions are part of our cognition; the cognition is situated, distributed and interactive. Similarly, Paul Dourish voiced and emphasized the need for an incorporation of embodiment into interaction design by making systems we build more tangible and meaningful in terms of human experience [6]. His works and his notion of 'embodied interaction' have illuminated t a different way of approaching interaction design, which is experientially, cognitively and socially grounded. In this regard, we also acknowledge Xerox PARC's longstanding contributions to the incorporation of those concerns and ideas into computing and HCI-related fields.

The recent research and practice within the subfields such as tangible interaction, haptic robotics, affective computing or wearable technologies have employed various embodied cognition-related ideas and contribute to the knowledge about our embodied capacities. However, we propose further research agendas for not only employing those ideas, or any other empirical and theoretical support from embodied cognition literature, but also for taking those ideas as departure point or end itself rather mere means to certain ends. This comes back to our emphasis on the interrelatedness of design through and for embodied cognition, with a holistic perspective, such as within the realm of body image/body schema in our case.

4 Designing for Chronic Pain Patients and BIBS

We discuss our projects here in order to demonstrate how these ideas, deriving from BIBS literature, can be adopted in interaction design processes as a perspective or attitude - as a framing or lens through which we approach body, mind, interaction, technology and design in a holistic way- rather than mere practical application nailed to more traditional methods. Therefore, it would be more appropriate to discuss our research projects as a trajectory through which we develop a responsibility to build bridges between areas that support such a holistic design perspective and practice. Our projects start with the idea that mind is embodied; and draws upon the significance of bringing the variety of sense information and experience into consciousness, and of addressing the immediacy and plasticity of our body image/body schema. As BIBS literature reveals, we sense the physical states of our body based on a variety of sense information, including proprioception, kinesthesia haptics, nociception (pain-related), temperature, and visceral sense. In our projects, we attempt to address this variety and richness of sensory information and experience through our design practice for pain patients. In this regard, we can say that our focus on BIBS within our design practice grew directly from our works and involvement within the framework of designing for chronic pain patients. As we state earlier, some 'limit-situations' of body, such as persistent pain, may reveal unique sense experiences through which we may explore the complexity of the phenomena of human body and experience. Designing for chronic pain patients, who have diverse embodied states, help us to set a research trajectory along the continuum that addresses the various aspects of BIBS as outlined in this paper. As BIBS ideas encourage and help us to build a holistic research trajectory, designing for chronic pain patients requires a similar perspective or attitude based on a transdisciplinary and multi-faceted research agenda, and biopsychosocial methodological framework (which simultaneously takes biological, psychological and social factors into consideration).

For instance, within our VR-based research projects, we acknowledge the significance of 'pain self-modulation' where the attention is directed inward rather than pain distraction based on attention being directed outward. It is a different paradigm in which we seek the ways in which we can develop 'intraface' by enabling a greater awareness of responsiveness and greater sense of agency based on revealing the plasticity of our body image/body schema. Evidence suggests that degree of mismatch strongly correlates to severe levels of chronic pain, and if they could be trained to better match body image with their body schema, the pain may be mitigated [14].

Fig. 1. A scene from Virtual Meditative Walk

For instance, our current projects such as *Virtual Meditative Walk* (Figure 1) and *Sensorium*, which corporate unique virtual environments with biofeedback and meditation, address chronic pain patients' specific embodied conditions and bodily awareness. We take into consideration their proprioceptive and interoceptive senses, which strongly shape human movement, interaction and experience, and bring embodied states -and how they are affected or transformed- into conscious awareness by mapping the changes in one's embodied states (through biofeedback mechanisms such as galvanic skin response and heart rate variability) onto changes in visual and sonic qualities of VR environment. We employ VR technologies for pain mitigation and management by controlling changes in 3D visual & sonic elements based on mindfulness-based stress reduction (MBSR) and biofeedback data in real-time to support their learning of mindfulness meditation techniques. As immersants learn how to meditate while walking, real-time biofeedback technology continuously measures breathing, skin conductance and/or heart rate. For instance, sonic VR project, *Sonic Cradle* enables users to compose a soundscape in real time using their breathing, which is one of the key elements of mindfulness meditation and self-pain-management. By revealing the changes in their bodily states in a peaceful and relaxing way, this approach encourages a calm mental clarity and loss of intention where breath-rate becomes an interface to composing a soundscape. [22]

Once brought into consciousness and learned in VR, body image and body schema can be transformed in relation to one another. For instance, the recent study conducted by William Stephoe, Anthony Steed and Mel Slater [18], which explores immersive embodiment of an 'extended' humanoid avatar featuring a tail and its impact on one's sense of ownership and agency over their body, reveals the importance of visuomotor synchrony in forming convincing perceptions of body ownership and agency, and of

the plasticity of the brain's representation of the body for gestural human-computer interfaces. The study's findings show that some participants start to act as if they have a tail, by moving it through hip movements or protecting it as they move. A short-period experience of 'having a tail' in VR was enough for the participants to gain the sense of ownership over the tail, and their body schema was extended and modified through such an experience. From our perspective, such a study strongly confirm the significance of the plasticity of BIBS, and the potentials of VR environment for exploring such impacts, including therapeutic implications within diverse settings. For instance, in our most recent research, we work with teenagers, before, during and after surgery for treating scoliosis, in order to help them to transform their distorted body image and restore its balance with body schema. In this regard, the research studies on phantom limbs and neuron mirrors support the idea that watching another body performing a specific movement, even though they are not available for the person, are actually helping to fire neurons associated with those acts, and enable a psychophysical state associated with those acts. For example, seeing one's or other's body acting or moving perfectly –without any distortion – might support the physical and psychological healing through the compensation or transformation of body image and body schema (based on their plasticity and interrelatedness).

For instance, in another project, we bring soundwalking (exercise in acting listening) and biofeedback together in order to develop a unique non-invasive system for reducing pain anticipation and other effects of kinesiophobia (the fear of movement) by both encouraging and eliciting muscle activity. We examine if listening to a first-person walk through a sound environment elicits covert muscle contractions, as assessed with an electromyogram (EMG). As previous studies have shown, such covert muscle activity is triggered when participants viewed others performing certain physical activities [2] or when they visualized themselves performing a physical activity [3]. We look at whether our system, which presents the sounds of muscle movement through sounds of walking, might also elicit such covert muscle contractions and this could have therapeutic benefits in its own right [12].

Furthermore, our approach for designing for patients who have chronic pain or other chronic conditions that involve pain is not limited to VR. We also work on mobile applications and devices to extend what is learned in VR, as well as with a haptic robot and wearable sensor technologies that allow for different approaches to related problems. Based on affective computing, sensor technologies and biofeedback mechanisms, we help patients to change their affective states in order to support and encourage patients to better manage their pain experience. For instance, the projects *Analgesic Glove*, and *Haptic Creature*[23] (in collaboration with Dr. Karon MacLean and SPIN Lab at the University of British Columbia), draws upon the idea of changing the perception of self and other through the interaction with an object (a glove-like device and an animal-like creature), which have responsiveness based on sensory technologies often in combination with biofeedback. Through interaction with the objects - whether by becoming aware of proprioceptive processes that are not consciously monitored otherwise or by extending the objects or incorporating affective experience into our own body image/body schema - we can transform one's body image and body schema. As highlighted in this paper, the research on neuroplasticity underscores the significance of potentials enabled by our bodily explorations and interactions with the objects/environments to transform our embodied states, perceptions and other cognitive faculties.

The goal of this work is to offer sensorily richer and expressive communication of embodied states to the patients and health practitioners, as it affects both pre-reflexive and reflexive processes underlying those states and transformations. Furthermore, this work also aims at developing noninvasive methods to help chronic pain patients to visualize their pain, express the intensity and variability of their pain experience, and learn to use more relaxing and non-drug based treatments, such as meditation, through their interaction with immersive environments and sensory technologies. This work also addresses the issue of presentation or communication of sensory experience and data, which can go beyond the methods that are either too self-reflective (such as surveys) or too objective (such as medical examination). This confirms once again that we need to develop a holistic understanding and practice of design for bridging all these areas relevant to embodied cognition, interaction design and pain experience. The overview of our research trajectories revealed that designing for and through embodied cognition accompany one another, as we do not only design for chronic pain patients based on BIBS-related research, but those practices help us to explore the phenomena of human body and experience in unique ways that can guide further BIBS-related research.

5 Conclusion

In this paper, we outlined six fundamental ideas, derived from BIBS literature that show how the mind is embodied. We discuss our own research trajectory, within the framework of designing for chronic pain patients, which necessitates and supports a shift in our perspective of approaching interaction design. Based on our experiences, we argue that incorporating those ideas into design practices requires a shift in the perspective or understanding of the human body, perception and its experiences, all of which affect interaction design in unique ways. The dynamic, interactive and distributed understanding of cognition, where the interrelatedness and plasticity of BIBS play a crucial role, guides our approach to interaction design. The integration of BIBS literature is concerned not only with developing more expressive, inclusive or efficient designs, but about approaching design in novel ways, where we can explore the phenomena and mechanism of the human body and experience in rich multidimensional ways.This comes back to our emphasis on the interrelatedness of design for and through embodied cognition with a specific awareness of ongoing discussions and needs of both fields; embodied cognition and interaction design.

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