Bodily Awareness in Media Perception

Taxonomy, Experimental Framework, and Experiments on Embodied Spatial Media Perception

Dissertation

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Part I

Introduction

Abstract

Current and future media is increasingly part of the acting and perceiving body of the recipient. This development demands both a deeper understanding of the connection between body and media perception than we currently have and the development of adequate interactive multimedia experimental environments to investigate the mutual dependency between body related cognition and media perception.

This dissertation develops central theoretical and practical elements necessary for investigating the interrelation between body related cognition and media related cognition within a broad range of media platforms by: (a) reviewing and structuring the current challenges and meanings of embodiment in the field of spatial content perception, (b) developing the experimental environment Inter|act3D that allows platform independent investigation of this connection within interactive media, and (c) investigating a central connection between media perception and body representations: The effect of body posture on perspective media perception within Inter|act3D.

Chapter 1

Introduction

1.1 Motivation: Embodiment of media perception

1.1.1 Media and body

Most media perception is connected to different types of covert and overt body representation activation although we rarely become aware of it. Classical media content such as movies or images continuously use combinations of visual cues to dynamically manipulate the audience's body awareness. Camera movement (pan shots) create intense illusionary self-motion, and close-ups of textures create the sensory impression of touching the surfaces (e.g., Lecuyer, Burkhardt, Henaff, & Donikian, 2006). Furthermore, observers identify with the actors' movements, simulate their perceptions and represent their spatial environment according to the actor's body and location instead of the own physical location. Thus, seeing an image of hands touching a surface immediately activates the according body simulation. Such imagery is deeply connected to cognitive processes that involve sensorimotor simulation and body representation during seemingly exclusively visual perception (Slater, 2009).

The current direction of media development amplifies this connection between body and media perception. Media rely more and more on the recipient's body by becoming tangible, multitouch, haptic, augmented, spatial, and interactive, and in some cases even extend or integrate into the body by becoming wearable or implanted. Media provide touch interfaces, gesture control, accompany our actions in real time (e.g., navigation systems, Tablets as the IPad), and integrate into the spatial bodily environment (e.g., augmented reality). Thus, they become an extension of the own body into the world (O'Neill, 2008). Accordingly, the body becomes the central interface for media perception, consumption, and interaction.

This new integration of body and medium generates a challenge for our cognitive system. More and more research delivers a broad range of support that both perception and interaction refer to the same cognitive systems responsible for body control, body representation, and bodily perception (e.g., Barsalou, 2008). Accordingly, perception and body need more coordination than in the past. This challenge did not exist in classical media such as movies or books, where recipients took a resting position. Current and future media involve an active recipient with potentially concurrent bodily states, action planning, and somatic processing. Using a touch surface or navigation system, for instance, involves coordination between current body actions (e.g., touching, driving), body feedback delivered by the media, and body references during comprehension of spatial content. Incongruent feedback from the body creates immediate negative cognitive and emotional responses (e.g., Schürmann, Hlushchuk, & Hari, 2011). Accordingly, a hanging mouse cursor or delayed visual response after a swipe action immediately creates negative reactions (e.g., Hoxmeier & DiCesare, 2000; Hazlett, 2006).

Thus, the complex involvement of the body during both media interaction and media perception is a complex challenge for both research and future media development. This dependency needs to be adequately addressed by both a detailed theoretical understanding of the cognitive connection between body representation and media perception and by developing adequate experimental environments allowing such research within the large field of interactive media platforms.

1.1.2 Investigating media and body

Currently, the body, its cognitive representation and its general connection to cognitive processing are central topics of basic cognitive science research (e.g., Adams, 2008; Aspell & Blanke, 2009; Barsalou, 2008; Borghi & Cimatti, 2010). Accordingly, investigating this connection within applied media offers opportunities for both excellent basic cognitive research and applied media research.

However, despite the importance of *body* representations for media perception, the applied intuitive understanding of this *body* concept and accordingly its assumed connection to processes during media perception lack a detailed investigation. Two central restrictions limit research: (a) inadequate or oversimplified understanding of the complex connection between cognitive body representations and media perception, and (b) limited availability of experimental environments allowing applied investigation of interactions between body activation and media perception.

Accordingly, the primary goal of this dissertation is to clarify the connection between media perception and body representations by identifying a taxonomy of cognitive body representation concepts frequently referred to in research, and to develop an embodied cognition research environment for the rapid development of browser based experiments that allow the investigation of the interaction between active body and media perception across a broad range of interactive media platforms and media content. Accordingly, the final element of this dissertation is the conduction of such experiments to investigate the connection between body and visuospatial media perception.

1.2 Spatial perception and body representation

To support the need of the taxonomy, the design of our experiments, and the functions of the experimental environment, we give a short introduction on the deep connection between space representation and body representation. Accordingly, neither the concept space nor the concept body are unitary or independent concepts. Thus, visuo-spatial content is perfectly suited for investigating the body's role in media perception.

So why may we expect interactions between active user body interaction, a process primarily seen in connection to motor preparation, and visual processing, a process primarily based on visual processing?

1.2.1 Vision activates body representations

To begin with, visual processing of the spatial environment is not as separate from body representations as it appears. There is an intimate connection between body and visual processing that implies the appearance of interactions between body action execution and visual processing.

More and more studies support that visual processing shows two dissociable components, visual object feature identification and object location processing (e.g., Hecker & Mapperson, 1997), even during mental imagery (Luzzatti, Vecchi, Agazzi, Cesa-Bianchi, & Vergani, 1998). Such findings are in line with the dual pathway theory that distinguishes processing for visual perception (ventral) and processing for guiding spatial body action execution (dorsal) (Goodale & Milner, 1992; Milner & Goodale, 2008). Accordingly, processing of a chair's location in relation to the own body and our current action is distinct from the awareness of what this chair looks like. Furthermore, during both actual and simulated action execution (e.g., in a Duke Nukem game) people represent the visual spatial environment according to their currently simulated body (Chaminade, Meltzoff, & Decety, 2005; Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006). Accordingly, the transient, egocentric body representations are not only involved in active action execution but also in simulating, remembering, comprehending and judging spatial configurations in relation to the body (Waller & Hodgson, 2006).

To summarize, viewers reactivate matching body representations (e.g., postures), motor actions and somatosensory states according to the current visual input they process. Accordingly, visual processing involves a large amount of potential references to the observer's body that has not yet been investigated in interactive media. Thus, it is reasonable to investigate the effect of simulated and actual body posture taking on the perception of visuospatial media in our experiments (Chapter 4, p.83).

1.2.2 Space overlaps with body representation

Both the taxonomy and our experiments focus visuospatial media content perception because this kind of material potentially involves the strongest body referencing. Before we start, we want to give an overview on what this connection between an observer body and spatial perception.

The body is the central element to structure space. It supports spatial perception both as normal public physical spatial element, observed from outside, but additionally delivers internal information sent by the sensory system, and thus is perceived from the inside by a great amount of mostly pre-reflective stimuli (Longo, Azañón, & Haggard, 2010). The deep connection of vision, body representation activation and body feedback leads to the central observation that body representation and space representation are two nearly indistinguishable concepts. Thus, the building of spatial representations refers to information about the body, its structure, feedback from movements, intentions, and specific somatosensory and visual feedback from moving around such as tilting the head, rolling the eyes, or touching a wall (e.g., Burgess, 2008). Accordingly, thinking about space or processing of spatial images systematically involves reactivation of the respective sensory and structural body representations involved in space perception. This means that the processing of, for instance, spatial perspective visual images probably involves the activation of the according body state typically accompanying visual processing.

1.2.2.1 Body serves as frame of reference

Besides the multiple possible ways the body and its somatic representations could be connected to spatial perception, a central function of body during spatial perception is its application as spatial frame of reference. Basically, a frame of reference is a system of axes and orientations located in space. The cognitive system refers to it for judging sizes, distances and relations. The high amount and dynamic interplay of such frames of reference during accomplishing spatial tasks is an important element of spatial perception research (Carlson, Hoffman, & Newcombe, 2010). Our own body constantly provides this information with its size, orientation, distinct parts, and dimensions, so the cognitive system can ubiquitously refer to it during spatial perception. Hence, visual spatial perception and processing is to a high degree about relating elements to the observer's body in space.

The bodily nature of these spatial reference frames is supported by the multimodal nature of the distributed cerebral system (e.g., parietal cortex) representing such frames (review Andersen, Snyder, Bradley, & Xing, 1997). Thus, despite a continuously changing physical body (e.g., growing, posture taking) that is constantly creating new multimodal somatic input streams, healthy people perceive a clear and unitary body structure, borders, and shape (Woodin & Allport, 1998). Accordingly, the separation between sensory integration, body representation and space representation is not as distinct as often assumed. We will cover this complex relation in detail in the taxonomy chapter, showing that in line with this dependency impairments of body representations lead to the according spatial processing impairment (e.g., spatial neglect).

1.2.2.2 Two major reference frames: allocentric vs. egocentric

Interestingly, the interactions between sensory integration, body representation, and space perception not only appear relative to the actual body location but also in relation to the simulated body location. Accordingly, observers frequently imagine being at other locations during speech processing and spatial perception. This motivates a frequently found separation of spatial processing into egocentric and allocentric processing that determines where the body as frame of reference is imagined during spatial processing. We address this aspect of body related space representation in detail in the taxonomy chapter.

Basically, two locations an observer identifies with during spatial perception are distinguished: viewer-centered (egocentric) frames of reference localize the axes in the viewer's physical body, whereas object-centered (allocentric) frames of reference localize them in external visual object features and coordinates (Hinton & Parsons, 1981). Verbal descriptions, for instance, often implicitly or explicitly refer to the respective frames during spatial thinking (Carlson, 1999). Thus, a cat can be resting behind the stove, a key be hanging above the lamp, and a door can be behind ourselves. Language comprehension relies fundamentally on the fluent simulation of alternative spatial self-locations to decode directional or relational verbal descriptions. Accordingly, instructions, as in our experiments, must avoid any potential triggers that could induce such self-relocation to avoid altered space representation.

Egocentric Primarily, egocentric frames explicitly refer to the body's location, its three major body axes (longitudinal, sagittal, transversal), and the body's orientation (e.g., upright, lying). Accordingly, they are necessary for defining spatial relations such as behind, in front, above, below, left, right, close, and far. A cat can only be described as behind the stove if the observer implicitly adds this kind of self referential knowledge. This knowledge about the body with limb sizes, positions, and mutual relations is often called body schema (Chaminade et al., 2005). Moreover, not only the full body but each limb or group of limbs can simultaneously and in relation to each other serve as reference (Woodin & Allport, 1998).

According to the connection between visual and somatic feedback during space representation, the most important location for the frame of reference is centered on the eye and therefore fixed to the head and feedback from the head (Wexler, 2003). Thus, observers usually locate themselves in the head. However, other cognitive processes can also locate the self within other body based frames of reference by using the position and structural properties of hand, feet, or torso to define sub-spaces, as for example during mental hand rotation. Thus, multiple spaces around the body and its parts exist during perception of visual, tactile and proprioceptive information (Maravita, Spence, & Driver, 2003). In our Experiments we focus on the head based representations. However, to make it even more complex, in allocentric reference, an observer does not even have to identify with the physical body location.

Allocentric vs. egocentric Locating outside one's own physical body is called allocentric (lat: alius=the other) perception. Accordingly, allocentric processing is often perceived as less related or even unrelated to the physical body.

However, located outside the physical body does not necessarily mean that it was unrelated to the observer's body. Actually, it refers to body representations in multiple ways.

However, despite the frequent application of the terms allocentric and egocentric there is no well-defined general definition (e.g., Klatzky, 1998). Generally, the adjective allocentric can denominate two properties: (a) independence from the observer's current physical body, as by taking another person's perspective, and (b) independence from any physical viewpoint, by referring to landmarks or cardinal points such as north and south. This leads to an inconsistent and even contradictory continuum between definitions of allocentric and egocentric frames in literature (Grush, 2000). He identified five groups within this continuum: (a) Egocentric space, when we directly relate to our own physical body ('The lamp is above'), (b) Egocentric space with a non-ego object reference point, when we explicitly refer to an object in space, however implicitly referring to the observer's body position ('The book is to the left of the door'), (c) Object-centered reference frames, when the object itself is offering its own axes and orientation, ('The painting is on the upper side of the door'), (d) Virtual points of view, (e.g., maps with their own reference frame such as north/south) but imagined from virtual distance, and (e) 'Objective' or 'nemocentric' maps, the theoretical maps 'without viewpoint'. All of these, except the theoretical nemocentric maps, involve an imagined viewing condition, with an orientation, size, and distance and accordingly refer to the body.

We mention these groups to demonstrate that even allocentric processing involves a strong simultaneous presence of egocentric representations and thus an implicit reference to a structural body in space. Accordingly, although egocentric and allocentric processing have partially been associated with distinct neural regions (review Burgess, 2006), their neuranatomical correlates overlap to a high degree during spatial coding (Zaehle et al., 2007). This overlap is sometimes explained by a system constantly coordinating egocentric and allocentric space encoding (Sargent, Dopkins, Philbeck, & Chichka, 2010; Sargent, Dopkins, & Philbeck, 2011). Therefore, it appears that egocentric spatial coding requires a subsystem of the processing resources of the allocentric condition, making it difficult to split allocentric from egocentric frames during spatial comprehension (review Burgess, 2006). Due to the strong common activity of motor and somatosensory systems during spatial processing, the idea of body independent allocentricity seems at least questionable.

1.2.2.3 Visual dominance during localization

Working with visual material additionally requires an understanding of the mechanisms leading to such self-localization. An important observation is that under normal conditions, spatial interpretation is dominated by the information delivered by the visual system, a well-established topic in spatial attention, perception and memory (e.g., Choe, Welch, Gilford, & Juola, 1975; Posner, Nissen, & Klein, 1976). Accordingly, visual position of the hands in space and not the felt position (proprioception) of the hands biases the spatial localization of audio stimuli (Bruns & Röder, 2010).

The ventriloquism effect supports that observers automatically illusionary perceive the spatial origin of a sound from where they visually expect it (see Howard & Templeton, 1966; Spence & Driver, 2000). Accordingly, the sound is interpreted as coming from the moving lips instead of its actual origin. It appears, that the same attribution mechanism is involved in referring internal body feedback (e.g., proprioception) to spatial elements such as the own body.

This visual dominance degrades with lighting situation towards stimuli as the proprioceptive information (overview Holmes & Spence, 2004). Furthermore, specific spatial and temporal (<100ms) proximity is necessary for visual dominance (Slutsky & Recanzone, 2001). Accordingly, spatial perception starts depending stronger on stored and non-visual information if the stream of online information as visual input breaks down or becomes unreliable. Thus, interactions between vision and body are not independent from viewing conditions and especially sensitive to the quality of available visual input.

For visual media this opens up a broad range of possibilities to alter body and space representation by presenting specific visual triggers.

1.2.2.4 Peripersonal vs. extrapersonal space

The final involvement of the body in space representation we cover here is its fundamental significance for defining our perception of near and far. This is meaningful for the investigation of interactions between body and spatial perception because we may expect stronger interactions in near space than in far space, at least as long as allocentric processing is not involved.

To start with, there is space directly around the own body called *peripersonal space*. This space delivers a great amount of multisensory information whenever we touch objects and receive the resulting tactile and proprioceptive feedback. Since humans experience peripersonal space by interacting with it, it is a result of multisensory integration immediately surrounding the body and the body parts (Rizzolatti et al., 1997). Accordingly, it involves strong awareness of the body structure with its defining parts, left, right, above, behind, near, far, and separates reachable (peripersonal) from non-reachable (extrapersonal) space.

Peripersonal space and the body schema are highly overlapping if not identical concepts involving large neural overlap of both functions and a high degree of multisensory integration of visual, tactile, auditory, and somatic information (Cardinali, Brozzoli, et al., 2009). Accordingly, there are neuronal networks specialized in the multisensory representation of the peripersonal space around the head, (Avillac, Deneve, Olivier, Pouget, & Duhamel, 2005), and around the hand (review Makin, Holmes, & Ehrsson, 2008; e.g., Makin, Holmes, et al., 2007). Accordingly, processing of elements (e.g., a chair) in peripersonal space, strongly activates diverse sensory states and motor programs during seemingly purely visual processing, and the boundaries between visual processing, multisensory integration, motor planning, peripersonal space perception and body schema vanish (Cardinali, Brozzoli, & Farnè, 2009).

Extrapersonal space on the other hand, is the space of elements out of reach. It is defined relative to peripersonal space by containing everything that is not within peripersonal space. Thus, it depends primarily on visual information.

Obviously, this space separation is referring to the body's active extension into space involving the observer's action experience, such as grasping a cup, with the respective sensory responses such as receiving tactile and temperature feedback. Accordingly, action execution alters the cognitive separation between peri- and extrapersonal space, and manipulating an observer's motor repertoire alters space perception (e.g., Coventry, Valdes, Castillo, & Guijarro-Fuentes, 2008). Hence, the part of the environment that is controllable and accordingly allows us to predict sensory feedback according to our own actions defines our peripersonal space (Short & Ward, 2009).

1.2.3 Online vs. Offline body

We repeatedly mentioned the significance of bodily stimulus activation during spatial perception. This creates a challenge for understanding spatial perception since two potentially concurrent bodily levels can be involved during spatial perception. The first is the stored representation of the *offline* body referred to during spatial comprehension, for instance as frame of reference or for making spatial judgments. The second is the *online* stimuli continuously delivered by the body. The online system continuously informs the offline representational system of what the body is currently like, whereas the more static offline representation relies on long-term memory of what the body was usually like (Carruthers, 2008; Tsakiris & Fotopoulou, 2008; Waller & Hodgson, 2006).

In contrast to intuition, the consciously aware perception of the body, referred to during spatial perception, relies mostly on the activation of such stored offline body representations. During automatic action execution, however, the usually subconscious online information is preferred. This is in line with the dual pathway theory describing this distinction during actual action execution. Thus, observers only switch from the automatically processed online to the less precise, however aware offline representations when challenging online input is processed. Thus, under overloading or unreliable conditions such as after revolving on a chair or in a dark environment makes observers switch from online processing to the more robust offline representation (Riecke, von der Heyde, & Bülthoff, 2002; Waller & Hodgson, 2006).

Since spatial media perception refers to such offline representations, the simultaneous execution of actions potentially creates concurrent somatic streams and activates incompatible body representations. Accordingly, we investigate such interaction between online body and offline body representation activation in our own experiments and discuss these interactions in the taxonomy.

1.2.4 Summary

The reviewed literature shows that somatic stimulus processing, space perception, and spatial body representation are largely overlapping concepts. Accordingly, we may expect a large amount of interactions between cognitive tasks that explicitly (e.g., movement) or implicitly (e.g., spatial visual processing) refer to the body.

Above all, we expect that a great amount of interactions should be measurable between body usage and perception because of the body's concurrent involvement as frame of reference during spatial cognition, whenever delivering information about near, far, above, below, large, small, reachable, unreachable, controllable, and uncontrollable space. Accordingly, spatial perception is influenced both by the current stream of body (online) stimuli and by the current state of stored (offline) body representations. Thus, concurrent online stimulus processing or offline representations could alter both body perception and space perception.

Especially the processing of body related visual content is capable of activating and spatially orienting body representations. Together with observers' strong ability to identify with locations within an observed scenery, this creates a fairly complex pattern of possible interactions between visual content processing, body action, and space representation. The body as frame of reference can be localized anywhere within spatial scenes. The representation of visual scenes changes accordingly, meaning that physically far objects can be represented as close. Thus, the actual spatial representation of a scene depends on the observer's learned body representation, current bodily online feedback, executed actions in the environment, the place the observer identifies with, and the general power of the current visual input to activate body representations.

1.3 Overview

According to their large overlap, this dissertation investigates the meaning of body representations for the specific field of mediated visuospatial perception. Thus, the state of the cognitive systems representing the body is responsible for the way media is perceived and comprehended. Accordingly, a deeper understanding of this connection and a technical environment to conduct the necessary studies become necessary. This is reflected in the two major parts of this dissertation:

1. *Descriptive taxonomy* of the elements researchers and developers implicitly and explicitly refer to when conceptually addressing connections between perception and body.

2. *Experimental environment and experiments* for the investigation of body representations during interactive browser based media perception.

1.3.1 Why a descriptive taxonomy

The first part of this dissertation provides a classification of the elements frequently found to justify observed effects as *embodied.*

The short overview on the connection between spatial perception and body representation gives a first, small impression of the complex interplay between spatial perception and body representations. The complexity involves multisensory integration, stored body representations, bodily movement representations, and body localization. Accordingly, we find a broad, often confusing range of interpretations in literature as to what cognition should be classified as *embodied*. This supports that the understanding of spatial perception requires a deeper, more structured understanding of the processes creating an observer's body representations.

From a cognitive science point of view, the observation of interactions between space and body creates questions concerning the deeper mechanism responsible for the observed interaction. Although the complexity of these processes is beyond the possible scope of a single dissertation, we will take a first step by systematically structuring and reviewing the current state of research. Thus, we create a taxonomy of body representation related findings frequently referred to in the area of spatial perception research and identify challenges of the current logic behind classifying cognitive processes as bodily or embodiment. This taxonomy is necessary to reduce the existing discrepancy between state of research and applied assumptions about the body's involvement during spatial perception.

We suggest and discuss corresponding findings within a taxonomy (*PSMC taxonomy*) consisting of four frequently found, seemingly distinguishable body levels, namely bodily percept, body structure, body movement, and spatial body location. After identifying potential challenges by referring to these intuitive body levels, we accumulate the neural and behavioral evidence for each level and discuss its validity and reported cognitive consequences for spatial perception.

Since the subjective impression that something refers to the body (e.g., limbs, movements) contains no explicit information as to how and on which level this categorization influences human perception, our taxonomy provides a more detailed and integrated understanding of the connection between body and space related perception. Especially the observable discrepancies between assumed involvement of body representation systems during perception and their actual involvement during perception indicate the importance of offering this detailed overview on this connection, a precondition for designing adequate operationalizations and experiments.

1.3.2 Why an experimental environment and experiments

The second part of this dissertation describes the development and structure of our specialized experimental environment *Inter|act3D* and reports our experiments investigating the connection between bodily posture taking and perspective visual perception.

We developed a specialized environment because the currently fast development of interactive media requires an experimental environment that reaches a broad range of presentation platforms and media content. Most existing experimental environments that allow embodied cognition research focus on the investigation of a specific cognitive process within lab conditions, limited to a specific, usually synthetic media environment. This means they are specialized in the investigation of a single, specific cognitive process by developing specialized tools. Although there are good reasons for such an approach, for instance, to isolate a specific cognitive process, for applied media research it is equally important to investigate the appearance of such effects within real media environments.

Accordingly, we developed an environment (Inter|act3D) that allows rapid development of embodied media perception studies with potentially remote participants on a broad range of media platforms. It is a complete browser based experimental environment to transfer lab-studies into frequently found interactive media environments according to the requirements of embodied perception research.

Central elements for executing such studies are reliable user separation, secure data recording, organized and scheduled media presentation, and generally the execution of embodied media perception research directly in the browser. Accordingly, it provides all functions necessary for accessing most applied local and remote media platforms (e.g., tablets, touch-tables, head mounted displays, smart-boards, laptops).

To deliver support for the quality of the possible research, we conducted five studies within this environment that investigate the interactions between posture taking and perspective perception, a combination frequently found in interactive media. The results demonstrate that perspective spatial image perception actually interacts both with simulated and actual posture taking. We call this interaction the posture-image compatibility (PIC) effect.

In the Pretest and Experiment 1 we test visual material, posture instructions, and the general ability of the browser based experimental environment *Inter|act3D* for platform independent, browser-based embodied media perception studies. The results indicate the general limits of visual material design set by a trade-off between visual cue reduction and increase of image ambiguity. Experiment 2 demonstrates for the first time a significant interaction between media induced action (posture) and perception of presented spatial image material, the PIC effect. Experiment 3 examines and replicates the PIC effect under more demanding, web typical conditions, such as additional distraction and concurrent activities. Experiment 4 verifies that the observed PIC effect is independent from specific image ambiguity. Finally, Experiment 5 demonstrates that the PIC effect generalizes independent from external spatial and visual input.

The results clearly support that with our experimental environment it is possible to measure a major influence of common media interaction (head posture taking) on the perception of one of the most common media types (visuospatial perspective images).

This finding is on the one hand highly relevant for the design of interactive media, because more and more media rely on the simultaneous execution of posture taking during spatial content perception (navigation system, touchscreens), and on the other hand for basic cognitive research by supporting the specific connection between cognitive head posture on perspective visual comprehension. Taken together, the overview by the embodiment taxonomy, the experimental freedom given by the experimental environment Inter|act3D, and the significant results from the experiments deliver important theoretical and technical support for applied media oriented embodied cognition research and researchers.

1.3.3 Summary

To summarize, the purpose of this dissertation is the development of tools necessary for detailed investigation of the connection between visual spatial media perception and bodily media interaction. Because of the deep interdependence between both concepts we developed a taxonomy, an experimental framework, and conducted empirical examination of a prototypical interaction between posture and media perception to expand the awareness for meaning of body representations for media perception. Accordingly, we deliver the technical and theoretical tools necessary for adequately investigating this connection within applied local and remote media environments.

Part II

Taxonomy

Abstract

The connection between visuospatial perception and body activity is currently under detailed investigation. However, most results are named by marginally defined terms as 'embodied'. Thus, despite the myriad of reported interactions between body and perception delivered by neurology, neuroscience, or cognitive psychology, heterogeneous and fragmentary terminology makes it difficult to integrate these findings into one coherent cognitive concept describing their connection.

In the following chapter, we (a) describe the current linguistic and conceptual challenges while referring to the body, (b) identify and discuss concepts frequently motivating the categorization of results as embodied within a PSMC taxonomy, namely the references to bodily percepts (PBA), spatial body (SBA), body movement (MBA), and body in space (CBA). These elements are usually operationalized as if they were independent from each other. To clarify the problem of such an assumed separation, we (c) accumulate neural and behavioral evidence supporting the levels' distinct properties, cognitive effects, and mutual dependencies within the taxonomy to identify certain discrepancies between assumed and actual level properties, cognitive consequences and dependencies. Generating awareness for this complex interplay is a first step in the endeavor to understand the versatile interactions between content perception and body representation systems.

Chapter 2

Taxonomy and discussion of body representation concepts found in embodied perception research

2.1 Introduction: Body and spatial perception

2.1.1 Motivation

Humans have an intuitive understanding of their body, its elements and processes. Accordingly, embodied cognition research that investigates the interrelation between content perception and body often refers to similar body related concepts as movements, body posture, or somatic percepts. However, despite a clear subjective sense of body awareness, on only a tiny amount of the actually involved body representations come to conscious awareness. Accordingly, we find neuronal activity during content processing without consciously noticing the covered motor activity (e.g., Fischer & Zwaan, 2008). This creates a discrepancy between actual and assumed body involvement. Accordingly, the conceptual understanding of the body's cognitive involvement lacks detailed understanding and is often derived from its aware elements instead of its actually involved systems.

With regard to visuospatial comprehension, this paper discusses the validity and nature of four bodily concepts frequently found in embodiment studies by accumulating neural and behavioral evidence according to these concepts.

2.1.2 Embodiment - Thinking by body representations

We start with the impressive human ability to control, represent and actively simulate the body with its states, elements and properties. "Feel your toes" or "imagine falling backwards" can easily be imagined by most humans. Such body awareness "relies on perceptual functions (e.g., tactile, proprioceptive, gravitational, visual) and on motor programs for bodily action, [...] a sense of the self as the object of sensory stimulation and as the agent of motor intentions and execution [...] and knowledge of its borders" (Brugger, Knoblich, Thornton, Grosjean, & Shiffrar, 2006, p.171). The ease of imagining the body indicates that cognitive processes can make supportitive use of this ability.

Accordingly, several cognitive tasks, such as playing chess, can be intentionally facilitated by imagining one's own spatial body interacting with the elements to plan moves and strategies (e.g., Kirsh, 2009). It helps understanding spatial alternatives by perceiving the self in other places, simulating the execution of alternative moves, knowing the potential extension into space, getting perceptual feedback, feeling the taken posture, and receiving feedback from the muscles needed for pushing the figures from one position to another. The actual amount of simulation depends on the person's experiences.

Thus, a trained piano player automatically simulates the respective finger movement while listening to a familiar piece of music (e.g., Haueisen & Knösche, 2001).

Thus, simulation supports and influences cognitive processing and, by that, comprehension. Due to this deep involvement of the body in comprehending actions of oneself and others, the question arises where to separate body related from non-body related cognitive tasks.

2.1.3 Challenges of embodiment

2.1.3.1 Challenge: All cognition seems embodied

A major challenge for thinking about the connection between body and perception is that at some level all cognition could be interpreted as embodied. Accordingly, perceptual and action-related sensorimotor processes are tightly linked to abstract cognition (Barsalou, 1999, 2008; Barsalou, Kyle Simmons, Barbey, & Wilson, 2003; Glenberg & Kaschak, 2002; e.g., Glenberg, Havas, Becker, & Rinck, 2005). Furthermore, cerebral motor activity (motor resonance) subserves visual cognition, action understanding, and language comprehension (review Fischer & Zwaan, 2008). And even spatial comprehension of environments, spatial perspectives, and self-object relations refer to the multisensory body (review Legrand, Brozzoli, Rossetti, & Farnè, 2007). Thus, drawing a line between embodied and disembodied cognition is more difficult than its frequent use would imply.

From a developmental point of view, this deep mutual integration is plausible because higher brain functions and the ability to control and perceive the body are developing dynamically in parallel over time (Smith, 2005). Accordingly, the body constantly creates a stream of sensory (e.g., vestibular, proprioceptive, tactile, visual) and biochemical input (glucose, dopamine, adrenalin, oxygen level) that influence and shape cognitive processing. Thus, strong versions of embodied cognition claim that the specific body and its motor repertoire is not only related to higher cognition but directly responsible for abilities such as social perception (e.g., Gallese, Rochat, Cossu, & Sinigaglia, 2009).

The deep mutual integration raises the question of whether and how the cognitive system establishes structures to separate from this great amount of constant bodily influence, generated, for instance, by breathing, keeping balance, moving the eyes, or gesturing. Thus, we have to ask how and when the cognitive system can attend, ignore, adapt to, and represent specific bodily input despite the overlap with most other cognitive processes (e.g., Krakauer & Mazzoni, 2011).

The development of mechanisms to consciously address, classify, attend, or ignore body related elements appears to be an important technique for the cognitive system to establish at least a conceptual separation between the actually overlapping concepts body and cognition. Consequently, the according linguistic representations of this highly complex relation do not match the actual interrelation.

2.1.3.2 Challenge: Linguistic clarity

Giving a verbal description of the connection between body and cognition is difficult because of the large amount of overlapping, aware and unaware body related elements. Multiple terms exist to label the aware body, as, for instance, Body Schema (e.g., Holmes & Spence, 2006), Body Image (e.g., Cash, 2004), Bodily awareness (e.g., Hari et al., 1998) with all conceivable sub-elements as perceptive awareness (e.g., Tamarit, Dietrich, Dimond, & Russ, 2001), tactile awareness (e.g., Schwartz, Assal, Valenza, Seghier, & Vuilleumier, 2005), or limb awareness (e.g., Hunter, Katz, & Davis, 2003), Embodiment (e.g., Rohrer, 2007), Embodied simulation (e.g., Gallese, 2005), Motor simulation (e.g., Negri et al., 2007), Motor imagery (e.g., Johnson-Frey, 2004; e.g., Munzert, Lorey, & Zentgraf, 2009), Kinesthetic imagery (e.g., Fourkas, Bonavolonta, Avenanti, & Aglioti, 2008; e.g., Guillot et al., 2009), Grounded cognition (Barsalou, 2008), Motor resonance (e.g., Zwaan & Taylor, 2006), or Corporeal awareness (e.g., Blanke & Mohr, 2005; e.g., Blanke, Landis, Spinelli, & Seeck, 2004).

The situation is becoming even more challenging because embodied cognition research is often conducted as an add-on to classical disciplines such as embodied social cognition (critical e.g., Goldman & de Vignemont, 2009), embodied visual cognition (e.g., David, 2008), embodied spatial cognition (e.g., Mallot & Basten, 2009), or embodied language comprehension (e.g., Fischer & Zwaan, 2008). These additive strategies produce multiple implicit, often redundant and overlapping meanings of *embodied* without explicit clarification. Often the driving intention behind using the label is to emphasize the body's involvement within domains that traditionally favor amodal explanations for their findings (D. Anderson & Michael, 2006; M. L. Anderson, 2008).

Obviously, this broad embodiment terminology is insufficient for research. However, the common ground of categorizing something as embodied seems to refer to a common intuitive impression that something is related to the body. Accordingly, the addressed body elements refer to common concepts, such as bodily percepts (e.g., touch), physical body structure (e.g., limb, full body), neuroanatomical topography (e.g., motor cortex), or movement (e.g., kinesthetic).

To summarize, the applied verbal concepts lack the precision necessary for understanding the connection between body and perception, largely, because a great amount of body activity remains completely unaware. Simultaneously, people refer to a common set of bodily elements derived from bodily awareness. Taken together, this creates a challenging interplay between aware and unaware body involvement.

2.1.3.3 Challenge: Aware vs. unaware body

The most particular aspect of the connection between body and cognition is that most sensory and motor activity, for instance during language processing, remains unaware, although humans constantly think relative to their body, talk about it, and perform covert motor simulations (e.g., Fischer & Zwaan, 2008).

It appears that the complex connection between body awareness and multisensory integration is responsible for this discrepancy. Only a tiny amount of the multiple bodily processes involved in cognitive processing create awareness. The cognitive system developed highly complex multi-level mechanisms to distinguish between normal and extraordinary stimuli to limit their access to conscious awareness, for instance by visual top down selection during search tasks (e.g., Mavritsaki, Allen, & Humphreys, 2010) or by neuronal repetition suppression (e.g., Grill-Spector, Henson, & Martin, 2006). Thus, predictable stimuli, such as self-produced tactile stimuli, are perceived less intense than externally caused ones and therefore, in cases of high predictability, even stay unnoticed (e.g., Blakemore, Frith, & Wolpert, 1999). Accordingly, most of the body stays unaware most of the time, as long as the current sensory input matches the previous experiences. Thus, we do not have to attend our legs while we are walking. Only under unexpected sensory conditions does the body regain our explicit awareness. Accordingly, special neuronal substrates in the parietal lobe, an area responsible for multisensory integration, and interconnected brain structures such as the frontal area appear to be centers of body awareness (review Driver & Vuilleumier, 2001; review Rees & Lavie, 2001).

Reasons for body simulation There are several reasons why a cognitive system applies covert simulation of bodily aspects: (a) future prediction (expect feedback, plan motions, understand goals) during action preparation (e.g., Sebanz, Bekkering, & Knoblich, 2006), (b) understanding others' and planning own alternative actions, and (c) structuring and constraining the spatial environment in relation to the body (e.g., Shelton & McNamara, 2001).

Firstly, body simulation activates the respective sensory anticipation to distinguishing unpredictable (atypical) from predictable (typical) input by comparing the actual stimuli with the predicted stimuli (e.g., de Fockert, Rees, Frith, & Lavie, 2001). This is necessary to filter the relevant stimuli from the great amount of self generated stimuli (e.g., proprioception). Accordingly, prediction facilitates processing of stimuli and execution of respective actions. Neuroimaging supports that a great amount of thinking consists of simulating motor interactions with the environment and predicting the respective sensory outcome (Hesslow, 2011). Thus, a major function of the cerebellum is the creation of action related forward predictions of probable sensory outcome to support action execution (Knolle, Schröger, Baess, & Kotz, 2011). Accordingly, the systems for thinking of moving, planning of movements, and respective sensory prediction overlap (Blakemore & Decety, 2001).

The second reason for covert body simulation is to imagine one's own and others' bodies in alternative conditions and actions to infer consequences without actual movement (e.g., Kirsh, 2009). Thus, the others' goals and intentions can be derived from body simulation (Iacoboni et al., 2005). The observer's repertoire of body related experiences (constraints, intentions, outcome, feedback) allows him or her to infer other person's current or potential actions within the own cognitive body representation, an important social ability that involves sensomotoric simulation (Barsalou, Niedenthal, Barbey, & Ruppert, 2003; Wilson, 2002).

The third reason for covert body simulation is that the simulated body can serve as spatial frames of reference. Thus, spatial comprehension of spatial distances, egocentric relations, and relative sizes can be derived according to one's own body position and size. Accordingly, mental rotation can be facilitated by adding bodily limbs to 3D cubes (Amorim, Isableu, & Jarraya, 2006). Adding bodily cues supports mental rotation by adding references to the familiar spatial structures and properties of the body. Especially referring to the spatial body is a central, although often implicit, aspect of body awareness.

To summarize, three major groups of cognitive processing make use of body simulation: planning future actions, comprehending others' actions and intentions, and spatial referencing. Accordingly, a great discrepancy between observable physical body activity and covert body activity is created. This supports the general challenge of referring to *embodiment* in relation to an directly observable, moving body.

2.1.4 Challenging classification systems

To overcome the challenging conceptualization of the body and to describe its relation to cognitive processing, several classifications have been suggested. The major classifications refer to (a) functional neurophysiological activity, often in relation to according neurological body perception disorders, or (b) terms as body image or body schema.

2.1.4.1 Classification by cerebral physiology and neurology

The availability of neurological measures such as fMRI, EEG, TMS, or electro-stimulation allows assigning specific cognitive processing to cerebral activity. Accordingly, cognitive tasks are assigned to specific neural correlates (e.g., Perani et al., 2001). Especially topographically structured areas (e.g., primary motor and sensory cortex) suggest such assignments. Accordingly, the most frequently and oldest found assignments between body perception and neural activity refer to the primary sensor areas located in gyrus postcentralis and the motor in the gyrus praecentralis (Penfield & Rasmussen, 1950). Actually, the relation between activation in healthy subjects or localized lesions of neurological patients (e.g., after stroke or surgical treatment) deliver support for connections between these areas and several aspects of body perception.

However, such assignments easily lead to problematic over-interpretation of the actual function of these areas (e.g., Schott, 1993). An area that exclusively initiates specific muscle contractions or sensory perception is interpreted as an area representing a complete concept such as movement or perception without discussing that additional knowledge about spatial proximity, motion repertoire, attention, spatial position and orientation, name, sense of possession or body- and self-relatedness, originate from other levels and areas. Accordingly, activity of the hand control initiating part of the primary cortex is not the same as involvement of the hand, and should not be interpreted as such.

This suggests a more distinct discussion of the assumed body concepts and the actual function of the observed neuronal activity.

2.1.4.2 Classification by body image vs. body schema

Observed changes of cerebral activity and subjective body perception after altered cerebral physiology (e.g., by injury) inspired the frequently found classification of body perception into *Body Schema* and *Body Image* most cognitive disciplines such as psychology, neuroscience, medicine, neuropsychology, and philosophy refer to. The most common and oldest meaning addresses the structural and spatial aspects of body perception as *body schema* and the semantic, emotional perception as *Body Image* (Corradi-Dell'Acqua et al., 2008; Head & Holmes, 1911). Double dissociation in deafferent patients support this separation (Gantchev, Mori, Massion, Paillard, & S-nbm, 1999).

However, multi-disciplinarity and the long history of application are responsible for a growing overlap and even interchangeability of both terms (Holmes & Spence, 2006; e.g., Poeck & Orgass, 1971). In the case of medical sciences the term Body Image reaches from structural spatial body comprehension to a very broad understanding mostly related to abstract body judgments during obesity or anorexia (e.g., Schwartz & Brownell, 2004; Thompson, 2004; Tiggemann, 2004). This makes it difficult identifying related works by referring to the respective terms.

Due to the widespread meanings of Body Schema and Body Image, Sirigu et al (1991) redefined the terms and added an additional element, again based on groups of neurological symptoms. They split body perception into the three levels: *body schema*, *body-structural description* and *body image*.

Schwoebel & Coslett (2005) demonstrated in a large-scale investigation of 70 single-hemisphere stroke patients a triple dissociation of the three model elements. Body schema impairments were identified by the influence of hand imagery on actions and their laterality, body structural description impairments by the ability to localize body parts or stimuli on body parts, and body image impairments by the inability to match function or clothes and body parts. Accordingly, the *body schema* represents the relative positions between body elements and is generated by specific combinations of sensory (e.g., proprioceptive, vestibular, tactile, visual, efference copy) and motor stimuli and interacts with action generation systems. Its updating takes place at an unconscious level (Cardinali, Brozzoli, et al., 2009, p. 256). The *body structural description* is generated by visual input and defines the topology of body surface, boundaries, and proximity. Finally, the *body image/semantics* contains lexical-semantic representations of the body such as the limbs' names, functions, and relations to other elements such as clothes (see Schwoebel & Coslett, 2005).

2.1.4.3 Classification by manipulation methods

Holmes & Spence (2006) criticize the frequently observed re-usage and reinvention of abstract unitary body concepts and suggest classifications by experimental methods used to manipulate bodily experiences as an experimentally more tractable classification method. This involves comparing the effect of behavioral, neuropsychological, and neuropsychological approaches onto a specific matter of subjective body perception. Accordingly, they suggest in their overview three ways to manipulate subjective body perception: (a) by visual modifications (e.g., prisms, mirrors, television, and shadows), (b) by artificial body-parts (rubber limbs, clothes), and (c) by tool use. This idea is very interesting. However, it again implicitly refers to implicit classifications of body awareness by addressing the element of body awareness altered by these manipulation methods.

2.1.5 Summary

Classifying the body's contribution to cognitive processing faces several challenges. The great amount of covert simulation both during cognition and body usage creates a great discrepancy between aware and unaware body involvement. This reflects in the large amount of conceptual separations that lack clear verbal and conceptual definition because it remains unclear what is actually used to classify an observed effect as 'embodied'.

Thus, despite several attempts to classify embodiment, it appears that the existing terms do not significantly support research. Both neuroanatomical assignments, classifications according to altered body perception (e.g., into body schema vs. body image), and manipulation methods refer to an intuitive, however vague understanding of the body elements actually addressed.

2.2 PSMC taxonomy

Existing classifications of body awareness usually refer to an implicit classification of elements intuitively perceived as body related. Accordingly, we will not suggest another, better classification. We identify and discuss four groups of bodily concepts frequently found in research, namely bodily percepts (e.g., touch), spatial-structural body (e.g., hand), bodily movements (e.g., jump), and the body in space. We suggest that reference to these four elements, although frequently made, usually lacks definition and accordingly involves an insufficient understanding of their actual cognitive effects and mutual interrelationships. To overcome this problem we review the embodied cognition literature, the typically assigned neurological systems, related neurological symptoms of patients, related cognitive effects, and manipulation methods of body perception in the following PSMC taxonomy.

The model The PSMC taxonomy suggests four conceptual elements of body awareness derived from everyday language, namely feel (PBA), body in space (SBA), movements (MBA), and body in space (CBA) (Figure 2.1, p.25).

Perceptive body awareness (PBA) refers to aware perception of percepts interpreted as bodily percepts as touch or pain. Spatial body awareness (SBA) involves the awareness of a distinct body structure in space, with its limbs, dimensions, position, and distances. Movement body awareness (MBA) refers to aware movement, its planning, execution, constraints, effects, and targets. Finally, Cartesian body awareness (CBA) covers awareness of the body within the spacial environment, including the imagination of alternative spatial self-localizations.

According to this idea, thinking about and investigating the opening of a bottle is usually structured by those concepts of body awareness into feeling the sensory feedback from touching the bottle (PBA), imagining respective postures of limbs (e.g., hand, finger) while opening it (SBA), preparing the respective movement (MBA), and knowing where you are in space while opening the bottle (CBA).

Figure 2.1 additionally shows the levels' mutual connections that potentially create concurrent access to body references. Such concurrences can lead to cognitive impairments, for instance by concurrent presentation of body referent triggers, concurrent body representation dependencies, or concurrent cognitive side effects (e.g., on spatial perception).

The chapter structure follows the four major body aspects, their functions, properties, dependencies, activation, cerebral systems, and effect on other cognitive processes.

2.3 Perceptual body awareness (PBA)

Perceptual body awareness (PBA) is the concept derived from the awareness of the body's sensory states as touch, muscle tension, or pain. A great amount of studies refer to such percepts (e.g., Blakemore, Bristow, Bird, Frith, & Ward, 2005; Bufalari, Aprile, Avenanti, Di Russo, & Aglioti, 2007; Capelari, Uribe, & Brasil-Neto, 2009). In the following section we review cognitive science research to identify the cognitive basis of perceptual body elements and to identify the cognitive impact of activating or changing perceptual body representations.

2.3.1 Elements of PBA

The basic understanding of percepts refers to five classical senses directly related to specific

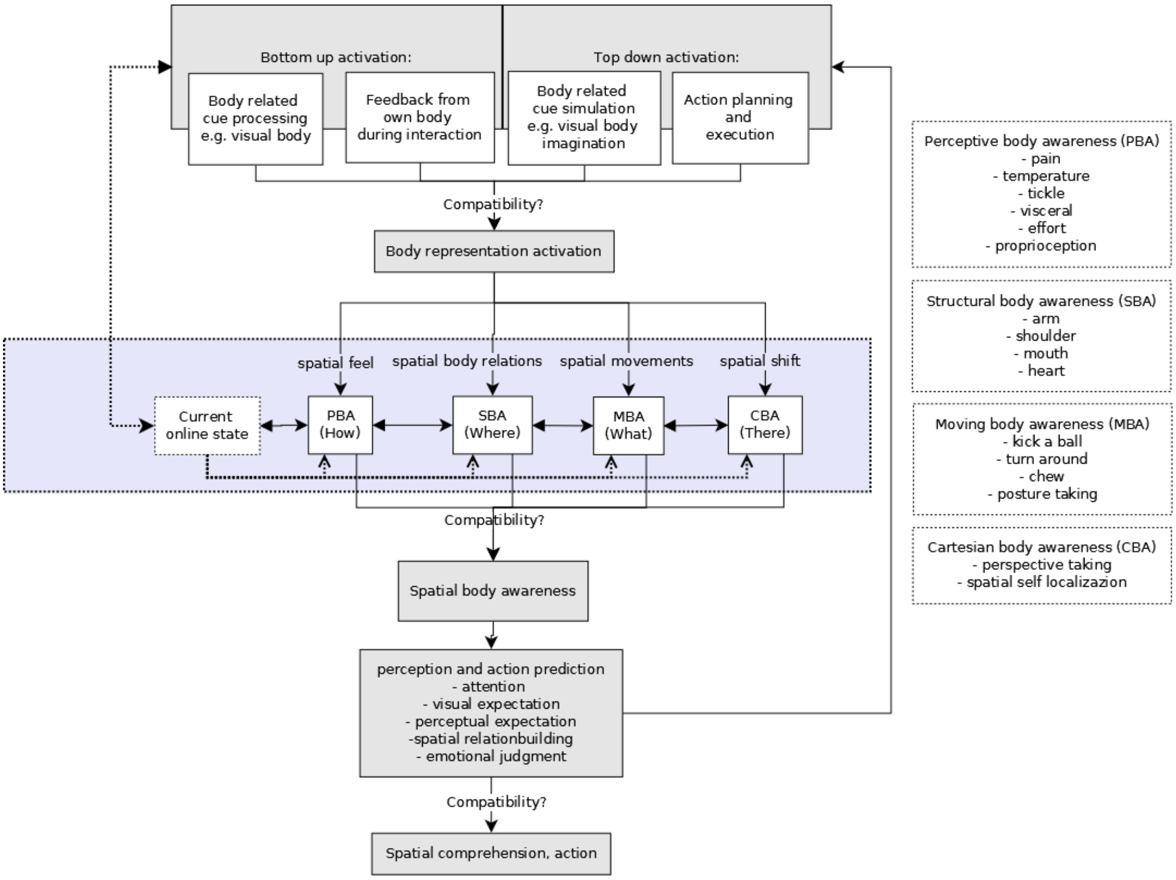


Figure 2.1. PSMC taxonomy - Potentially concurrent activation of levels according to the aware body representation concepts PBA, SBA, MBA, and CBA. The right side contains examples of each level's respective properties. The major diagram flow indicates the steps that potentially generate cognitive incompatibilities.

bodily sensory organs: (a) visual, eye, (b) auditory, ear, (c) olfactory, nose, (d) gustatory, mouth, and (e) tactile/touch, skin (e.g., Sorabji, 1971). Accordingly, thinking about perception is not only connected to the percept (e.g., tactile impression), but also to the respective limb (e.g., finger tip). Besides those five senses, modern physiology distinguishes additional senses not related to single body elements but appearing all over the body: (f) proprioceptive, (g) vestibular / balance / acceleration, (h) pain, (i) temperature, and (j) kinesthetic. Those percepts are deeply responsible for the perception of the body and accordingly for perceiving and representing the body. Furthermore, these percepts are involved in perceiving the environment by representing the effect of the environment upon the own body.

2.3.2 Neuronal cases and neuronal basis of PBA

We mentioned that thinking of perception (e.g., simulating the warmth of a coffee) and actual sensory processing involve overlapping cognitive activation. However, it might be conceivable that imagination and awareness for stimuli, as for example touch, were two completely distinct cognitive processes. To confirm their deep connection by the somatic processing systems, we give a quick overview of the respective neuroscientific and neurological findings.

Imagination equals processing A major challenge of references to PBA, is the question if the cerebral activity during processing percepts such as touch or pain is comparable to the activity during awareness of percepts, induced by cues or imagination. To begin with, the neural areas activated during physical perception of stimuli strongly overlap with those activated during imagining the percept. This has been demonstrated for visual imagination (Ganis, Thompson, & Kosslyn, 2004; Thompson, 2004), acoustic imagination (Halpern & Zatorre, 1999; Schürmann, Raij, Fujiki, & Hari, 2002), motor imagination (Parsons et al., 1995; Willems, Toni, Hagoort, & Casasanto, 2009), tactile imagination (Yoo, Freeman, McCarthy III, & Jolesz, 2003) and is probable for most other sensory states (e.g., Belardinelli et al., 2009). Moreover, the regions respective activity (fMRi) during imagery corresponds with the subjective vividness, as demonstrated for visual, gustatory, tactile, kinesthetic, and proprioceptive imagery (Palmiero et al., 2009).

Even the covert simulation during comprehension of cues involves the respective area activation. Accordingly, disturbing processing of areas in primary somatosensory cortex (rTMS) necessary for touch perception, specifically impairs the identification of an observed finger event such as touch (Bolognini et al., 2011). Moreover, congenital lack of pain perception can significantly reduce the ability to derive the pain of others from observing a specific situation (Danziger, Prkachin, & Willer, 2006). Even more abstract, seemingly disembodied processing, such as conceptual thinking and language processing, involves percept simulation (e.g., Gibbs & Berg, 2002).

Especially for spatial perception, the vestibular organ is of particular interest. It has great significance for navigation and spatial memory; thus loss of vestibular perception significantly hinders spatial memory (Brandt et al., 2005). Accordingly, injury of the vestibular processing system leads to cognitive impairment such as loss of concentration, spatial processing, or short-term memory (review Hanes & McCollum, 2006). Hence, an intact and activated vestibular processing system is playing a crucial role for informing us about executed motion paths, current position, and environment rotation.

To summarize, percept specific cerebral activity is both related to the process of mental simulation of the percept and to the degree of subjective experience of this percept. Especially comprehension of spatial content refers to multiple percepts directly involved as perceptual simulation during spatial cognition. Accordingly, perceptual compatibility between actual and simulated percept processing can influence comprehension of content.

2.3.2.1 Challenge perceptual separation

The involvement of perceptual simulation during seemingly abstract cognition (e.g., space or language processing) indicates that the processing of percepts might not be as distinct from each other as their conceptual separation could suggest. The seemingly clear distinction between percepts, such as touch or vision, actually reflects a complex interplay between receptor feedback, multimodal cross-activation, emotion activation, and reference to higher spatial and temporal levels of representation.

Vision and multimodal simulation There is a discrepancy between the conceptual distinctiveness between visual perception and bodily perception such as touch. Thus, learning of visual cues (e.g., geometrical shape) during exposure to an additional acoustic cue (e.g., white noise) creates covert acoustic activation of the related cue whenever an according shape is processed (Brunel, Labeye, Lesourd, & Versace, 2009). Accordingly, shape processing influences following processing of acoustic signals.

Since one's own body constantly delivers stimulus combinations during perception, primarily proprioceptive, tactile, pain, and vestibular stimuli, visual processing must as well be seen as coded in relation to this continuous perceptual input. Studies with adults that experience synesthesia, a phenomenon where unimodal stimuli trigger awareness for another modality, support that such interrelation of stimuli from different modalities is a general mechanism of perception development (Spector & Maurer, 2009).

Visual observation directly triggers matching perceptual experiences. Thus, the somatosensory cortex is active (fMRI) both while being touched and while observing someone being touched (Keysers et al., 2004). Moreover, activity during feeling pain and observing others' pain overlap (review Jackson et al., 2006). Accordingly, people feel pain in an observed rubber hand (Capelari, Uribe, & Brasil-Neto, 2009). Furthermore, observing olfactory disgust overlaps with the own disgust processing system activity (Wicker et al., 2003). In extreme cases of vision-touch synesthesia observed touch is even felt physically by the observer (Blakemore, Bristow, Bird, Frith, & Ward, 2005).

Furthermore, judgments of pain intensity change according to the degree of currently perceived pain (Eich, 1985). Moreover, deafferent patients, who have lost cutaneous touch and proprioception below the neck after a spinal injury, have problems with deriving an object's weight from observing somebody's posture during lifting the object (Bosbach, Cole, Prinz, & Knoblich, 2005; Bosbach, Knoblich, Reed, Cole, & Prinz, 2006).

Thus, visual perception, although subjectively categorized as distinct from bodily precepts is not processed in isolation. Awareness for vibration, proprioception, balance, or acceleration, despite their origin in specific sensory organs is perceived in relation (binded) to each other and to visual and spatial processing. Accordingly, bodily sensory input serves as context during visual encoding and processing.

Emotions as sensory simulation Another multi-perceptual cognitive element overlapping with somatosensory activity during perception is the relation between perception and emotions (Bechara & Naqvi, 2004; Craig, 2002). Specific sensory input is either perceived as well-being (e.g., caress) or as bad (e.g., pain). Brain imaging supports a multilevel relationship between interception from the body and phenomenological, aware, and self-reported emotional experiences (review and model, Wiens, 2005).

Accordingly, perceptual feedback from bodily postures and facial expressions is tightly connected to specific emotional states (review Niedenthal & Maringer, 2009). A quantitative study with 108 patients each suffering from focal brain regions revealed that the understanding of emotions expressed by faces requires intact right somatosensory and directly related areas (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000). Even the understanding of emotions in acoustic signals requires fully functional somatosensory processing (Banissy et al., 2010). Accordingly, perceptive feedback from more or less fluent motions supports retrieval of matching positive or negative memories (e.g., Casasanto & Dijkstra, 2010). Thus, any investigation of perceptual activity must additionally consider the emotional aspects within the presented conditions.

High-level representations during perception Finally, another important aspect of aware percepts is that they involve additional temporal, spatial, and structural knowledge that the physical stimulus itself never contained. Accordingly, tactile stimuli involve different types of spatial and temporal knowledge about themselves and their neighbors. Merabet et al. (2004) demonstrated this by a cerebral and functional double dissociation between *tactile roughness judgment* and *tactile distance judgment* by both applying low-frequency transcranial magnet stimulation (rTMS) on healthy participants and by showing the specific tactile impairments after respective cerebral damage. Accordingly, patients with occipital damage, the area responsible for distance judgments, and participants with disrupted occipital activity lose the ability for tactile distance judgments while keeping the ability to execute tactile roughness judgments, whereas disruption of somatosensory cortex created the opposite pattern. Thus, tactile perception can involve additional temporal and spatial processing and accordingly involve covert occipital cortex activity whenever spatial discrimination is involved in tactile perception.

Furthermore, percept awareness additionally triggers and influences structural, spatial, and movement related body representations (SBA, MBA, CBA) that themselves influence cognition. Accordingly, tactile or proprioceptive stimulation directly alters the aware structural representation of one's own body (e.g., de Vignemont, Ehrsson, & Haggard, 2005). Moreover, listening to parts of a well-trained piano piece (=percept) covertly exhibits the respective motor activity in primary motor cortex (Haueisen & Knösche, 2001), and visually observing others' actions automatically activates the respective muscle activity in the primary motor cortex (e.g., Fadiga, Craighero, & Olivier, 2005). Accordingly, there is premotor activity during a great amount of mental perceptual simulation and stimulation.

2.3.2.2 Summary

We presented neurological support for perceptual simulation during content perception to show potential discrepancies between actual and assumed perceptual participation. Both physical perception (e.g., touch), observation of content showing others' perception, and imagination of perception create very similar neuronal activity of sensory processing. Accordingly, the observer is only aware of a small amount of actual sensory simulation. The observer's respective awareness for the percept appears to depend on the degree of activity of the respective cerebral areas. Accordingly, awareness involves a specific amount of such activity. Thus, mutual obstruction or facilitation of perceptual processing could happen even without awareness for this simulation. Since sensory simulation is covertly involved in a broad amount of content processing (e.g., touch, pain simulation), we may expect interactions with both actual and simulated body perception.

However, a challenge for investigating the influence of simulated perception of a percept is that percepts are not encoded in isolation. Accordingly, simulation of percepts involves a complex interplay of simultaneously activated modalities and abstract representations. Accordingly, percepts are coded in relation to each other (e.g., touch+proprioception+vision), and can activate additional information about their relation to the body structure, such as the position on the body surface, and additional spatial (e.g., touch distance) and temporal information (e.g., touch duration). Furthermore, the boundaries between sensory processing, emotions, and motor preparation are ambiguous. Thus, despite quite distinct nervous processing systems (specific receptors, distinct channels, distinct primary processing areas) the integration of somatic perception into cognitive processing is rather complex. Accordingly, the idea of addressing a single perceptual level by a specific experimental manipulation methods has to be rethought.

2.3.3 Cognition and PBA

Because of the anticipatory nature of cognitive processing, content processing also involves continuous anticipation of the typically perceived bodily stimulus combinations (e.g., Hommel, Musseler, Aschersleben, & Prinz, 2001). Thus, the observation of potentially pain generating situations or objects activates an observer's pain perception (Jackson, Rainville, & Decety, 2006). Accordingly, touch observation generates tactile sensory perception in the observer (Bolognini, Rossetti, Maravita, & Miniussi, 2011). Even perception of surfaces (e.g., rough, cold) and of specific environment configurations (e.g., steepness) raises the according tactile, temperature, or pain perception.

Thus, spatial estimations of the steepness of a hill or distances interact with current perceptual body feedback. Being tired, in poor physical condition, in declining health, or encumbered with a heavy backpack makes hills appear steeper and distances appear longer than for people in better condition (Proffitt, 2006). Moreover, the observers proprioceptive feedback from the own hand (rotated, hidden) accordingly influences the performance during mental objects rotation (Shenton, Schwoebel, & Coslett, 2004).

Accordingly, the continuously simulated and actually perceived body feedback during visually perceiving the world is building a constant cognitive context that potentially interacts with cognitive processing.

2.3.4 Summary and conclusion

We presented neurological support that not only the body itself but also visuospatual processing and simulation of many elements covertly activates body related perceptual simulation. Accordingly, visual processing continuously triggers bodily touch, proprioception, temperature, vestibular feedback, and pain to support cognitive processing. Even abstract judgments of an object's heat, weight, a task's effort, fluency, and haptic refer to perceptual awareness. Moreover, abstract visual elements such as colors become warm and cold, objects appear tangible, and surfaces look rough and soft. Its influence often remains unconscious, as the warmth of a handshake or one's own body's muscle tension. Thus, perceptual awareness adds sensory information about 'how things feel to the body'. Accordingly, it slightly alters spatial judgments and preferences and creates a connection between environment and body. Furthermore, this perceptual awareness is an integral part of higher body representations as for the ability to gain movement awareness (e.g., simulation of movement feedback) or body part representations (e.g., posture feedback). Accordingly, percept related investigations need detailed hypotheses about the potential involvement of such higher body representations, as we will see in the following sections.

2.4 Spatial body awareness (SBA)

Spatial body awareness (SBA) is the concept that refers to the body's spatial and structural parts and their relation. A great amount of studies refers to structural elements, for instance, by referring to hands, feet, bodies, or postures (e.g., Corradi-Dell'Acqua et al., 2008). In the following section we review cognitive science research to identify the cognitive bases of structural body elements and to identify the cognitive impact of activating or changing structural body representations.

2.4.1 Elements of SBA

The basic understanding of the structural body refers to limbs and body elements such as fingers, hands, head, or torso. These elements have a defined spatial extension, spatial orientation, sub-elements (e.g., fingers of hand), and a relation to other parts and the full body. Accordingly, SBA additionally contains information about mutual relations such as distances between limbs, and their relative sizes, positions, and orientation. The respective representations of the mutual relation are created by the constant stream of bodily online feedback (e.g., proprioception). Accordingly, online stimuli from the body continuously update and alter the spatial body representation, a central mechanisms of SBA.

2.4.2 Neurological cases and neuronal basis of SBA

To confirm the deep connection of cognition and structural body representations, we give a quick overview on the respective neuroscientific and neurological findings. We present support for (a) a structural body representation system, especially triggered by visual processing, (b) relations between this system and spatial cognition, (c) the meaning of multisensory integration for creating it, and (d) the effects of conflicting sensory integration on space and body perception.

2.4.2.1 Visual body perception - Vision, perspective

From a cognitive point of view, visual processing involves frequent referencing to the structural body representation. The neuronal activity during the observation of bodies is an important indicator for this. Functional magnetic resonance imaging (fMRI) studies support that specific brain regions in the occipital-temporal cortex such as the extrastriate body area (EBA) are particularly active during visual processing of human bodies, and body parts (review Peelen & Downing, 2007). A triple dissociation of EBA activity during processing of faces, bodies and inanimate objects supports that visual processing clearly distinguishes between these visual stimulus patterns (Pitcher, Charles, Devlin, Walsh, & Duchaine, 2008, 2009). This is important because it supports that cognitive processing starts distinguishing these elements on a quite early visual stage of processing. Hence, specific EBA activity indicates an observer's reference to body elements during visual processing.

However, body parts can be perceived from multiple different angles. How does an observer solve the problem to refer different visual input to a specific limb (e.g., right hand)? Generally, two strategies could be applied during processing of perspective bodies: (a) directly mapping the observed body onto the own body representation system (=SBA), or (b) taking the position and orientation of an observed person (=CBA) so it matches the observer's body orientation and size. Comparing the brain activity while seeing images of body parts (hand, foot) either from egocentric or allocentric view supports that there is both (a) selective and (b) overlapping activity in EBA (Saxe, Jamal, & Powell, 2006). Hence, besides perspective dependent processing there is perspective *independent* activation that indicates references to a common body element in both processing mechanisms.

Notably, the body representation accessed during visual processing of others' bodies appears to be the same as the representations accessed during perception of one's own physical body. Thus, patients suffering from reduced structural body awareness (neglect body parts) can regain awareness by observing the respective body elements on video (Fotopoulou, Rudd, Holmes, & Kopelman, 2009).

Referring to the body representation not only activates the representation itself but also activates the observed attention distribution relative to this body. Accordingly, observing a person ignoring a green bar in fixed relation to the body leads to avoidance of the according element around the observer's body (Frischen, Loach, & Tipper, 2009). Furthermore, seeing objects close to the own body reflection in a mirror interacts with the speed to identify vibrations on the corresponding body area (finger) (Maravita, Clarke, Husain, & Driver, 2002).

To sum, visual presentation of bodies is a strong trigger of body awareness. The visual processing of bodies is connected to specific cerebral activity in the occipital-temporal cortex (as EBA). Furthermore, the visual processing of bodies overlaps with activation of the observer's own body representation system. Moreover, the observation of bodies influences the distribution of spatial attention relative to the observer's body. Accordingly, visual processing of bodies significantly reduces the separation between self and other.

2.4.2.2 Overlap of peripersonal space and body element representation

It appears that the ability to map visually observed elements onto the observer's own body representation is a central mechanism to create the structural body representation. Accordingly, the idea that somatic processing ends at the physical body surface might be incomplete. Mapping allows that the observer's own body dynamically ranges beyond the visual body surface by integrating spatial elements into the observer's own body.

Indeed, we frequently find simultaneous impairments of body representation and spatial perception, especially within peripersonal (=near) space after prefrontal and parietal destruction (Cardinali, Brozzoli, et al., 2009). The overlap between body representation and peripersonal space representation seems a logical result of the way body representations are built by integrating visual and somatic stimuli. Near space delivers most combinations of visual and somatic stimuli. Accordingly, we find a deeper interactions between the physical body and near space elements. This tight space-body connection has been intensively investigated for the representation of the hand and the space around the hand (peri-hand space) (review Makin et al., 2008).

The results support that specific neuronal receptive fields encode peripersonal space by reacting specifically on simultaneous tactile and visual stimuli, whereas elements in extrapersonal space react dominantly on visual stimuli

(Makin, Holmes, & Zohary, 2007; Schicke, 2007). Thus, body feedback is an integral part of near space and body comprehension. Accordingly, the strongest cross-modal interactions (e.g., between visual and tactile stimulus perception) are found for stimuli in peripersonal space around hands and feet (Schicke, Bauer, & Röder, 2009).

However, the observed tactile-visual interaction not only appears on a distinct limb, it also appears across limbs, for example, when the visual stimulus is presented near the foot while the tactile stimulus is presented near the hand. This indicates an involvement of a unitary full body representation during spatial stimulus processing around specific body elements.

Body parts and the full body Since the observation of limb related spatial attention influences attention on other limbs, it appears that body parts are not coded in isolation but by a common representation.

Actually, there is support that two systems are involved in the visual processing of bodies: a fronto-parietal system encoding the full body configuration and an extrastriate body area, for processing local body part relations (Urgesi, Calvo-Merino, Haggard, & Aglioti, 2007). Accordingly, repetitive transcranial magnetic stimulation above distinct areas known for their specific involvement in visual body processing (body shape, motion, spatial transformation, and mirror neurons) induces the respective perceptual impairments during visual comparison of body postures. The respective effect pattern supports that familiar upright images are compared by referring to a whole body representation, whereas inverted images by single body elements relations. Accordingly, stimulation above the left ventral premotor cortex and right superior parietal lobe leads to impairments during familiar posture comparisons that favor a full posture comparison strategy, whereas stimulation above the extrastriate body area impairs judgments of inverted postures, a task that favors comparisons on a limb specific level.

Typically, structural body awareness during cue processing involves both types of knowledge, the spatial relation between single body elements and their relation to the full body (Urgesi et al., 2007). Thus, awareness for single body elements, as a hand, additionally involves awareness for its relation to the full body. Accordingly, several effects vanish when the observed limb is presented in a bio-mechanically implausible way in relation to the full body (Tessari, Ottoboni, Symes, & Cubelli, 2010).

To sum, both limb specific and full body activation interact during visual perception and must not be seen as independent. Accordingly, the manipulation of the awareness for a single limb can alter awareness for another as well. The actual activation of the full body or of limb specific representations is task dependent. However, how does the cognitive system build these structural body representations?

2.4.2.3 Multisensory creation of SBA and its elements

In order to understanding SBA, we need to understand the mechanisms creating it. Above all, multisensory integration and the unique sensory input patterns during body usage build these representations of the spatial body and its elements (review Makin et al., 2008). Bayesian perceptual learning binds the frequently co-occurring percepts from different modalities to each other and creates the respective bodily correlates (Armel & Ramachandran, 2003; Holmes & Spence, 2006). Accordingly, the cerebral ability to represent, perceive, and control the body, despite its continuously changing shape, posture, and spatial extension depends on the availability and integration of multisensory connections (Moseley & Gallace, 2011).

Above all the integration refers to feedback from tendons and skin around joints, as reflected in the respective topographical dimensions of the somatosensory cortex. The multiple joints all over the body create a large amount of sensory input and afferent processing in specialized brain structures each projecting into further brain structures such as the frontal lobe, the limbic system, and the insula, and build higher body representations (review Mountcastle, 2005).

This deep involvement of complex non-visual stimuli patterns might explain why the determination of exact ending- and starting points of seemingly clear elements such as hand, arm, or head is quite difficult. The visual borders are only a single aspect involved in defining the respective body elements. Accordingly, most of the time groups of limbs move together and send simultaneous combinations of visual and proprioceptive stimuli that create overlapping representations. Thus, finger representations overlap with the hand representation, and hand representations with the arm.

Generally, it appears that the comparison between experienced stimuli and the represented stimuli patterns plays a fundamental role in the creation of the different structural body elements and of the related spatial perception (Casadio et al., 2010). Thus, the quality of both body and space perception depends on the quality of multimodal integration. Accordingly, sensory integration disturbances alter both space and body perception, as supported by several neurological disorders.

2.4.2.4 Disturbed body and spatial perception: Agnosiae and Neglect

Two groups of neurological patients deliver support for the connection between multisensory integration, aware body, and spatial perception: patients suffering from body related agnosiae and hemispatial neglect. In all cases the patients remain unaware of spatial stimuli in relation to the own body, despite intact sensor processing. The properties of these impairments deliver important insight into the functional and anatomical connection between space and body representation.

Agnosia: *Agnosiae* comprise impairments of awareness for specific cognitive elements such as, for instance, faces, fingers, sounds, colors, or parts of the environment after specifically localized cerebral destruction despite intact sensor systems (review Bauer, 1993; review Vignolo, 2009). Accordingly, visual shape recognition can be lost despite intact visual acuity and color seeing (Milner et al., 1991). The often clear localization of the lesions responsible for the impairment supports that the awareness for an environmental element is directly connected to the activity in specialized processing and representation units.

Thus, the simultaneous appearance of body related and spatial impairments is an important indicator of a common cognitive interrelatedness. One of the oldest scientifically reported body related agnosiae is the autotopagnosis or atopognosis, a loss of the ability to spatially identify the position of a touch or derive an object's shape from touch (Head & Holmes, 1911). Furthermore, patients fail to point at specific body parts even though they are still able to control them (Buxbaum & Coslett, 2001). It seems that these patients lost conscious access to the own body representation. Accordingly, finger agnosia patients cannot identify the finger they were touched on, although they are able to detect the fact that they were touched (Anema et al., 2008). Repeated transcranial magnetic stimulation (rTMS) of the left angular gyrus, the area mostly affected by finger agnosa patients, generates equivalent symptoms in healthy subjects (e.g., Rusconi, Walsh, & Butterworth, 2005).

A patient's inability to refer to the body can impair the ability to attend to spatial elements in relation to the body. Accordingly, anosognosia patients can be blind for cues presented on one body side (hemisided blindness), lose control for a single body side (hemiparese), and lose awareness for a single body side (hemiplegia) (Karnath, Baier, & Nagele, 2005). Thus, limited access to the full structural body representation has strong impact on spatial attention.

The existence of body related agnosiae and the related spatial impairments support the overlap between spatial body representations and spatial stimulus processing.

Neglect: Another special agnosia is the *neglect*, a broad impairment of awareness, which in principle can appear in any possible sensory modality such as olfactory, tactile, or visual, and by that affect motor planning, movement execution, or spatial perception. Such impairments of awareness are not homogeneous but can appear on different levels and in different degrees (Marcel, Tegnr, & Nimmo-Smith, 2004). Accordingly, we focus on one specific neglect.

The central body related neglect is the *hemispatial neglect* where patients defectively ignore and respond to stimuli in relation to the body's side, current posture, and its vertical axis (review Adair & Barrett, 2008). From a neurological point of view, the actually neglected side during spatial processing is normally opposite (contralesional, typically left) from the side of the cortical damage and can appear both in relation to the own physical body or in relation to the logical orientation of an observed objects (Karnath & Rorden, 2011).

Furthermore, spatial neglect can be limited to body related sub-spaces (see introduction), thus it can appear in peripersonal (near) body space, while perception of far space stays intact (Halligan & Marshall, 1991; Mennemeier, Wertman, & Heilman, 1992). This spatial separation can also be created with healthy subjects after specific transcranial magnetic stimulation (Bjoertomt, Cowey, & Walsh, 2002).

Interestingly, not only parts of space but also parts of objects in space can be neglected (e.g., Rao & Ballard, 1996). Thus, object perception itself refers to the body representation. Accordingly, spatial neglect is frequently explained as a disturbance in guiding attention relative to the body instead of an impairment of the body representation itself (review Corbetta & Shulman, 2011). Since object perception refers to the body as frame of reference, object based neglect also refers to the egocentric body (Karnath, Mandler, & Clavagnier, 2011).

Both actual and imagined processing can suffer from neglect, and patients that neglect the environment relative to their body also neglect the environment during description and imagination of formerly familiar spatial environments (Bisiach & Luzzatti, 2000). Accordingly, spatial neglect provides evidence that intact structural body representations are necessary for spatial processing, comprehension, and imagination (Coslett, 1998; Karnath, 1994). Thus, changing the body representation or access to the body representation additionally alters space perception.

2.4.2.5 Manipulating structural body awareness: Phantom limbs & supernumerary limbs

Until now we have addressed the importance of accessing the structural body representation during visual-spatial processing. The question arises as to how static and reliable this structural body representation is.

Phantom limbs are the most cited and oldest support for an aware structural body representation in the brain (e.g., Head & Holmes, 1911). It comprises the phenomenon that people have conscious sensations, postures, and spatial extension in physically lost limbs (review Melzack, 1992). The existence of such a phenomenon supports that the awareness of body parts refers to specific cerebral activation patterns independent from the physical existence of those body parts. Most amputees experience phantom limb phenomena and several even suffer from uncomfortable painful postures in these non existing limbs.

The strong connection between vision and structural body representation and its multisensory nature motivates multiple techniques to manipulate the structural body awareness of lost body parts by simultaneous visual input and somatic (proprioceptive, tactile,...) stimulation. Actually, observing the hand on the typical former visual location of the lost hand leads to the subjective impression to be able to move the lost hand itself (Ramachandran & Hirstein, 1998). As we will see, this specific connection between visual input system and limb perception can also be used to manipulate body representations of healthy subjects (e.g., supernumerary limbs, rubber limb illusion).

An illusion similar to phantom limb illusions is called *illusory supernumerary* and can be observed in paraplegic patients after specific vestibular stimulation that makes patients perceive an illusionary third arm or extra legs (Andre, Martinet, Paysant, Beis, & Le Chapelain, 2001; Le Chapelain, Beis, Paysant, & Andre, 2001). Even in healthy participants disrupting proprioceptive input from the limbs by pressure-cuff ischaemia leads to a illusionary limb supernumerary (Gross & Melzack, 1978). It appears that the dissociation between felt and seen limb location lead to the subjective impression of an additional limb (overview Holmes & Spence, 2006). Hence, seeing one's own finger directly with the one eye and through a finger doubling prism with the other, creates, even in healthy subjects, subjective supernumerary limb perception.

Thus, the aware perception of one's own body is an element easily altered and influenced by specific combinations of sensory input. Especially its connection to visual processing makes it an excellent target of visual stimulus material based manipulation.

2.4.2.6 Summary and conclusion

What are the most central conclusions from this chapter? There is a cognitive and cerebral equivalent to the intuitive idea of the body in space. However, this structural body awareness is created by an interplay of multiple structural representations and a result of complex multisensory integration.

Visual processing distinguishes bodily and inanimate elements on an early stage of visual processing. The observation of body elements directly activates the respective representation of the observer's own body. This involves both the activation of full body and limb specific representations. Thus, visual processing of body elements is directly connected to the observer's body and influences the observer's body perception.

Accordingly, and potentially against intuition, the observer's own body overlaps with objects in space. Furthermore, the representations of the structural body and peripersonal space are overlapping, if not identical. Continuous interaction with the environment and the accordingly generated combinations of external (vision, touch) and internal (proprioception) stimuli deliver a great amount of the input necessary for building the structural body.

Accordingly, both body and peripersonal space rely on the same integration of multiple somatic online body feedback in combination with synchronous visual stimuli. Thus, deviations between visual and somatic feedback can be used to change perception of space and the observer's own body. Especially neurological cases such as agnosiae and neglect support that spatial stimulus processing and awareness implicitly relate to structural representations of one's own body and that impaired access leads to impaired perception of spatial stimuli. Even with healthy subjects the manipulation of neuronal processing, proprioceptive feedback, and disturbed visual feedback alters the perception of the subject's body structure and accordingly of space, as for instance demonstrated with supernumeral limb illusions. Accordingly, visual input can reactivate lost limbs and create illusionary additional limbs, with specific locations and sizes.

These phenomena and, as the oldest example, phantom limb illusions support that the awareness for the structural body depends on the activity in respective cerebral areas and that this awareness does not necessarily require a physically connected limb. The generally strong influence of visual perception on this structural body awareness makes it an important manipulator of both space and body perception.

2.4.3 SBA and cognition

The SBA directly influences two major elements of spatial cognition: representation of spatial elements in relation to the current body and spatial attention in relation to the body.

2.4.3.1 Space representation and spatial elements provided by SBA

Body in space - implicit spatial reference Even without any active effort, the body is involved in spatial cognition. Thus, distances on the retina, distance between an observer's eyes, or feedback from eye movement (occulomotoric proprioception) become part of visual and spatial comprehension. Thus, the feedback from the focal muscle apparatus modulates visual processing to support identification of objects in the respective distance (Murray, Boyaci, & Kersten, 2006). This allows judging the actual spatial size of objects, despite their identical shape and size on the observer's retina. Based on the muscular feedback, the cognitive system activates the matching offline body representation to represent the spatial environment in relation to the current body state (Makin, Holmes, et al., 2007). Accordingly, the body, its current state, and its spatial extension influence visual spatial cognition by implicit connections.

Body as frame The most important implicit reference to the body representation is its function as ubiquitous three-dimensional coordinate system (see body as frame of reference, p.7). The body delivers important spatial information to structure the visual environment, as by its origin, orientation, direction, and scale (Hinton & Parsons, 1981). Thus, the SBA enables an observer to think about the body in space (e.g., hand size, positions), relate objects and body parts to the body, and to perform planned actions with those parts (Chaminade et al., 2005). Accordingly, changing the body representation affects a viewer's comprehension of space, a connection we already observed both in neurological patients and healthy participants.

Thus, body postures and the current physical position in space influences spatial perception. For example, humans normally perceive numbers to the left side as smaller as to the right side (mental-number-line theory) and accordingly mental and physical line bisection biases with posture taking (e.g., Longo & Lourenco, 2007). Even slightly leaning to the left reduces judgments of a building's size (Eiffel tower), whereas leaning to the right increases judgments (Eerland, Guadalupe, & Zwaan, 2011). Thus, the implicit reference to the body changes with the body posture. Accordingly, space representation changes with body posture.

Body axes and orientations The body is used by the cognitive system as frame of reference by referring to its specific structural properties. Thus, spatial concepts such as up, down, behind, in front, above, and below become meaningful. All spatial object relations can then be coded by relating objects in the environment to this egocentric bodily reference frame (e.g., Mou & McNamara, 2002). The body's axes and orientation deliver a natural separation of space into three subspaces called longitudinal, sagittal, and transversal. Egocentric coordinate systems during spatial processing have their origin in the location of the viewer's body and are oriented relative to these body axes (Klatzky, 1998b; Tversky, Morrison, Franklin, & Bryant, 1999).

The *longitudinal* axis allows representation of the orientations *above* and *below*. It is involved in representations of postures such as standing upright, bowing down, or lifting the arm. Therefore, the gravitational orientation of the body in the environment, delivered by integration of vestibular and visual sensor systems, supports the SBA with the knowledge about it vertical orientation.

The *sagittal* axis allows representation of *front* and *behind* and divides the representation of the body into *front* and *back*. The simplest way to distinguish in front of from behind is by the different visual and attention consequences. We look at and attend the front and turn away from the back. So *behind* means currently not visible and not attended.

The *transversal* axis allows representation of *left* and *right* and is given by the left-right symmetry of the body. Accordingly, left and right eyes see slightly different perspectives and the left hand can reach elements the right hand can not. This creates systematic left-right asymmetries during attention and memory retrieval that the cognitive system can refer to during space encoding (e.g., McGeorge, Beschin, Colnaghi, Rusconi, & Della Sala, 2007).

Thus, cognitive processing concurrently referring to the body and its bodily axes potentially creates conflicts. Accordingly, judgment speed and accuracy of the spatial direction a sound is coming from is systematically biased towards the direction of a touch on the left or right finger (Bruns & Röder, 2010). The bigger the spatial discrepancy between touch direction and sound direction the bigger the spatial judgment discrepancy.

To summarize, spatial cognition implicitly refers to the current structure, orientation, axes, and spatial extension of the observer's body and its elements in space. Any cognitive reference to spatial directions as above, below, behind, or left will implicitly refer to the body. Accordingly, concurrent referencing to the body (e.g., by simultaneous touch and target localization) influences the accuracy of spatial and bodily judgments.

2.4.3.2 Distance awareness

Limb distance A precondition for using the body as spatial frame of reference is the development of a metric system that allows estimation of positions, distances, and sizes in relation to the body. Without such a system, neither touch events, limbs, or targets could be localized or perceived as close, far, small, or large. Thus, on top of the somatosensory systems, the structural body representation system adds such spatial information, for instance, to compare distances between fingers on two hands (Rusconi, Gonzaga, Adriani, Braun, & Haggard, 2009).

Accordingly, several body perception illusions support that the perceived distance between stimuli on the body surface is not derived from the actual physical stimulus and receptor position but from its integration into the structural high-level representations (SBA). Thus, the subjectively experienced distance between touch stimuli on the body depends on factors different from their physical distance, for instance from the receptor density in the respective body area (e.g., Weber illusion) and the temporal distance between two tactile stimuli (Tau phenomenon). Accordingly, alternatingly stimulating two points of the body surface (e.g., on wrist, elbow) creates the illusion of being touched on different, continuously changing points between these two touch points (Cutaneous rabbit illusion) (e.g., Green, 1982).

Furthermore, due to the overlap between peripersonal space and body representations precepts can even be perceived outside the physical body. Thus, the cutaneous rabbit illusion can create illusionary touch events outside the physical body, for instance, when one touch event appears on the end of a stick the participant is holding (Miyazaki, Hirashima, & Nozaki, 2010). This supports that additional activation of higher, multisensory representations of the body are involved in scaling and localizing the tactile input by mapping it onto the currently available spatial body representation (Taylor-Clarke, Jacobsen, & Haggard, 2004).

However, the receptor input is interpreted in relation to a congruent spatial body representation. Thus, In the *Pinocchio effect* blindfolded subjects grasp their nose with one hand while having the grasping arm's biceps vibrating (Lackner, 1988). Both the arm and the grasped nose are illusionary extended (see Schwoebel & Coslett, 2005). The distance judgments on the illusionary elongated finger change accordingly (Vignemont et al., 2005). This supports that the current multisensory input is integrated according to a bodily self-representation that is often incongruent with the physical body (Rusconi et al., 2009).

Thus, using the body as frame of reference involves referring to the currently aware state of the body and not the actual physical body. Since physical and aware body can become quite discrepant, distance judgments change according to the aware body, despite an unchanged physical body. Accordingly, it is important to evaluate the state of an observer's simulated body during perception and not only the physical body to estimate potential biases during spatial perception.

Spatial distances: near vs. far space Not only distances on the body surface but distances between body and spatial environment are important elements of spatial cognition. Thus, the SBA is the central reference frame for distinguishing near (peripersonal) space from far (extrapersonal) space. This concept manifests in terms of proximity, within vs. out of reach space, peripersonal space vs. extrapersonal space, or simply near vs. far space.

Especially in near space the boundaries between multisensory integration, body schema, and space vanish (Cardinali, Brozzoli, et al., 2009). Knowing if something is near means that it is graspable and therefore consists of both visual representations and a great amount of multisensory (proprioceptive) representations of the bodies elements (Makin, Holmes, et al., 2007). We repeat this observation because this separation, and its multimodal nature has major consequences for cognition. The concepts *near* and *far* change according to the structural body representation. Thus, the observer's arm length augments the size of near (peripersonal) space. Accordingly, specific asymmetries only appearing in peripersonal space (e.g., asymmetric line bisection) extend into space proportional to the participant's arm length (Longo & Lourenco, 2007b). Furthermore, attaching weight to the wrist makes participants bi-sect lines as if they were further away because the perceptual body feedback deforms both body representation and size of peripersonal space (Lourenco & Longo, 2009).

Moreover, near items (e.g., close to the hand) receive more visual analysis and attention than far items (Abrams, Davoli, Du, Knapp III, & Paull, 2008; Reed, Grubb, & Steele, 2006). Interestingly, this effect appears both for actual proximity and for imagined proximity, as by only imagining having own hand close to an object. Accordingly, both imagined and physical proximity heightens visual analyses and by that slows down letter search in an area perceived as close to the hand (Davoli & Abrams, 2009). Accordingly, estimation of object distances is not only significantly better in actual peripersonal space but also in imagined peripersonal space (Gabbard, Cordova, & Lee, 2009).

This supports the high involvement of the structural body representation during using the concepts *near* and *far*. The current actual and simulated state of the structural body awareness directly influences the perception of spatial locations, sizes, and distances

2.4.3.3 SBA guided spatial attention

Activation of specific parts of the structural body, as for instance by using the own arm as a spatial frame of reference, not only influences distance perception, it also changes an observer's distribution of spatial attention.

Body activation shifts attention Different types of cues, independent from their specific modality, can activate structural body awareness and alter attention according to the activated body (review Holmes & Spence, 2006). Thus, participants ignore stimuli if another bodily stimulus draws attention away from the respective location. Accordingly, detection of changes in a tactile stimulation pattern stay undetected if another tactile pattern on another part of the body is concurrently drawing attention (Gallace, Tan, & Spence, 2006). Even visual spatial distractors cover the detection of tactile pattern changes around the finger (Auvray, Gallace, Hartcher-O'Brien, Tan, & Spence, 2008). Accordingly, activating body awareness, independent from a specific modality, automatically shifts attention to points in space relative to the body, for instance, towards the endpoints of fingers or tools (Collins, Schicke, & Röder, 2008). Thus, imagining or actually perceiving objects as close to body elements draws more attention (Davoli & Abrams, 2009). This general higher attention towards near elements also works across stimuli (e.g., vision, tactile) and across limbs (hand, foot) (Schicke et al., 2009). Several properties of such crosstalk can only be explained by attention guidance in relation to a shared, however high-level representation (Van der Lubbe & Abrahamse, 2011). We suggest that the reference to the structural body serves as such a shared representation.

Due to shared body representations during body processing and cue processing, the current distribution of attention on one's own body is implicitly transferred to observations. Thus, ignoring objects close to the own hand also leads to ignoring objects close to an observed avatar hand (Frischen et al., 2009). Furthermore, the observer's own posture speeds up responses to vibro-tactile stimuli at the thumb of both hands if the respective stimulus appears on the side that the observer currently, even slightly, turns to (Tipper et al., 1998).

Covert activation of the structural body representation during observation appears to be sufficient to shift attention. Accordingly, processing of body related cues, nearby cue presentation, spatial action preparation, or body orientation influences spatial attention and accordingly spacial perception.

2.4.3.4 SBA based attention and perceptual expectation in space

The body not only influences the location where we expect a stimulus but also what kind of stimulus we expect. According to the neuro-scientific framework of attention, four processes are involved in attention: (a) working memory, storing what we recently perceived; (b) top-down sensitivity control, controlling what percepts to prepare for and to ignore; (c) competitive selection between simultaneous input; and (d) automatic bottom-up filtering for salient stimuli (Knudsen, 2007). Voluntary control of attention especially during visual selection and search means recurrently looping from a to c.

For body related processing, top-down sensitivity control is elementary. The SBA is the high-level representation that allows addressing specific body elements and refer sensory expectations to the body. By that, processing or voluntary activation of body elements modulates sensitivity in somatosensory processing on a body part specific level (e.g., Cardini, Longo, & Haggard, 2011). Accordingly, reading about an egg described as standing in front of the body activates the perceptual expectations of an egg seen from that perspective. Thus, identifying an image of an egg as egg slows down if the presented image does not fit the expected view (e.g., frontal=cooked egg, looking down=egg in pan) (Zwaan, Stanfield, & Yaxley, 2002).

Accordingly, processing of unexpected stimuli in a specific spatial area is inhibited when they do not match any typical visual input. Thus, reading words such as head/hat or foot/boot that imply to attend and expect these elements in the related spatial area (e.g., head=above, boot= below) inhibits processing of unrelated cues (such as the letters X and O) in the attended area (Estes, Verges, & Barsalou, 2008).

Thus, the current body related attention both heightens sensitivity for expected cues in the respective spatial area and reduces sensitivity for unexpected stimuli.

2.4.3.5 SBA space valences and emotions

The final connection between SBA and cognition we mention is only indirectly connected to space perception; we will address the involvement of emotional reactions during SBA activating, either by assuming, simulating, or observing bodies.

Body space on the side of the dominant (e.g., right hander, right) hand (Casasanto, 2009) or recently executed up/down movements (review Casasanto & Dijkstra, 2010) usually activates positive thinking whereas space around the less frequently used hand is connected to negative emotions. Thus, the implicitly involved body structure awareness is dividing peripersonal space into positive and negative areas according to the body related valences.

Furthermore, many postures reflect emotions. Thus, participants can easily judge the emotion of avatars taking emotion typical postures of anger, disgust, fear, happiness, sadness, and surprise, and the emotional understanding in the observer is comparable to the emotions in a voice and even most facial expressions (Coulson, 2004). Even anxiety has a direct connection to the current balance feedback of the body in space (Balaban & Thayer, 2001). Moreover, observing unnaturally distorted finger postures automatically creates cerebral activity in the amygdala (besides the normal primary motor cortex, somatosentory cortex and insula (agency) activity) causing a strong uneasy feeling in the observer (Schürmann et al., 2011).

Processing of pleasant and unpleasant images differently influence central processing time and peripheral movement execution (Coombes, Cauraugh, & Janelle, 2007; Coombes, Janelle, & Duley, 2005). Furthermore, movement planning is influenced by emotional aspects by preparing adequate approach or avoidance responses (Eder & Rothermund, 2008). Accordingly, the observer's emotional reaction inhibits and facilitates specific motor execution, an important and frequently used experimental measure of embodiment. Accordingly, emotional aspects of specific body representation activation should be considered during experimental design to distinguish between embodiment and emotion based action effect.

Thus, the bodily perception of space can involve strong emotional associations that themselves influence perception and motor execution, common indicators of embodiment.

2.4.3.6 Summary

What are the most central conclusions from this section?

SBA is deeply involved in *spatial processing*. Thus, spatial stimulus processing refers to SBA and influences stimulus processing. SBA is implicitly involved in spatial processing as frame of reference during spatial processing. Limbs, as well as the full body can serve as spatial frames of reference. Being a frame of reference involves delivering an origin, spatial orientation, and three spatial axes, longitudinal, sagittal, and transversal. Thus, relations such as left, right, above, beneath, before, behind, here, there, near, and far refer to the awareness for one's own spatial body.

However, the structural body representation is not a static representation of the physical body but continuously updated by the current sensory feedback from the body. Thus, proprioception and vision during posture taking, actions, or other stimulation change the state of this body representation. Accordingly, space perceptions depend on the current state of the body representation.

The body defines a central spatial element by separating space into *near* from *far*. Accordingly, distance perception becomes a multimodal concept and overlaps with sensory feedback during actions in near space and by that refers to on the observer's specific body (e.g., arm length) and bodily experiences. Thus, both simulated and actual posture taking change the perception of elements as near or far. Generally, near items are processed with more multisensory details, whereas far objects dominantly with visual and more abstract concepts. Accordingly, representation of elements as near and far significantly influences cognitive processing of the respective elements, even if the distance is perceived on an abstract level (e.g., temporal).

SBA not only delivers a spatial frame of reference but also *guides attention* in relation to the current state of the body. Thus, SBA enables suppression and preparation of matching stimuli in relation to the body. SBA is the key representation to address sensibility control in relation to specific parts of the body (feel/ignore your feet). Thus, attention guidance directly refers to the structural body representation by attending subspaces and spatial features.

Furthermore, the body itself delivers specific *attention distributions*, such as a dominant attention towards the front, and pseudo neglect towards the averted back side. Accordingly, most postures and body parts imply specific distributions of attention (e.g., mentioning the hand shifts attention towards the hand). Furthermore, near elements receive more attention than far objects. Even the observation of others attention distribution leads to mapping the distribution onto the own body, and own attention distribution is transferred to observation of others.

Finally, SBA raises *emotions*. Referring to the SBA can implicitly activate emotions, for instance by emotional postures (e.g., depressed posture) or body part fluency (e.g., handedness). Emotions on the other hand influence processing and response speed. Accordingly, the emotional aspects of the structural body can influence action execution and content processing.

To sum, referring or influencing the structural body of an observer has a broad range of cognitive effects on the observer's visuospatial perception. Accordingly, we will address the degree of plasticity of the body representation in the following section.

2.4.4 Plasticity of SBA: Extending the body

We mentioned several times that SBA influences spatial processing. Despite the subjective impression that the spatial body is invariant and despite its appearance of durability, it is a transitory internal construct that can easily and profoundly be modified (Armel & Ramachandran, 2003). In dramatic cases, body representations change by physical loss of limbs or neurological events like stroke or severe head injury. Accordingly, clinical cases such as neglect, anosognosia for hemiparesis (Baier & Karnath, 2007), and apraxia (Buxbaum, Giovannetti, & Libon, 2000) give important hints to the extent and mechanisms influencing the cognitive representation of the body.

Furthermore, even in healthy people the body representation continuously updates according to the received multisensory input to match the continuously changing, deforming, and moving body. Continuous shape change is induced by breathing, posture taking, temperature, integration of objects (clothes or shoes), or by usage and integration of tools (Maravita & Iriki, 2004).

This flexibility is the most important aspect of body awareness for shaping spatial perception. Thus, one of the most peculiar aspects of SBA flexibility is the remarkable human ability to perceive and use physical elements as if they were parts of the own body.

2.4.4.1 Clothes, rubber limbs, and prostheses

Humans have the ability to integrate elements as if they were part of their physical body. This reaches from integrating shoes, jackets, watches, clothes, backpacks, ornament (rings, necklace) to hair (pony tail), and limb or dental prostheses.

Even a visible rubber hand can become part of the own body representation if the own hidden hand and the observed rubber hand are simultaneously stimulated (Botvinick & Cohen, 1998; see Schwoebel & Coslett, 2005). Mostly tactile sensor stimulation of the own hand and the simultaneous activation of top down structural body representations by visual touch observation of the rubber limb create the illusion that the rubber hand was part of the own body (Tsakiris & Haggard, 2005). Accordingly, the activity of the primary somatosensory cortex modulates with the appearance of the illusion (Schaefer, Flor, Heinze, & Rotte, 2006).

People that lost a limb and want to integrate a synthetic replacement into their body can profit from this representational flexibility. Accordingly, a large body of studies relates to cases of limb loss and addresses the human capacities to integrate and learn to integrate body prostheses (see Holmes & Spence, 2006). According to the rubber hand illusion, upper arm amputees can learn to integrate an external object, for instance a prosthetic arm, into their body representation, when they are simultaneously touched at the stump and see the touch at the prosthetic finger (Ehrsson et al., 2008). Even technical looking prostheses integrate by such synchronous stimulation of the remaining stump during visual surface contact (Rosn et al., 2009). Observers even integrate objects such as a flat table surface by observing the table being touched repeatedly while synchronously being stroked on the own hidden hand for about a minute (Ramachandran & Hirstein, 1998). Accordingly, this connection could be used for a broad range of interactive media devices. Therefore, what are the conditions and reasons for integrating elements into the own body?

Conditions for integration A strong reason why integration illusions like as the rubber limbs appear is seen in the large overlap between the neurophysiological systems used to represent peripersonal space and the own body (review for perihand space, Makin et al., 2008). Accordingly, the separation between elements of near space and body can easily be overcome by special conditions during their presentation.

However, subjects integrate visual dummy elements best into their body representation when those where presented in the visual way, familiar from normal experiences with own body parts (see Schwoebel, Buxbaum, & Coslett, 2004). Accordingly, visual size of the observed hand (presented differently scaled via video) influences the illusion in the way that presenting the visual hand smaller than the veridical hand reduces the illusion (Pavani & Zampini, 2007). This matches the observation that near objects should involve more multisensory encoding than far objects.

Armel & Ramachandran (2003) systematically compared further conditions and their influence on fake limbs or object integration: (a) visual distance of rubber hand; (b) synchronous vs. asynchronous visual and physical touch; (c) touching table instead of rubber hand; (d) rubber hand painful finger angle; and (e) real hand visible vs. real hand invisible. The degree of limb ownership was measured, as usually, by self-report and additionally by skin conductance response (SCR). The results support that a table creates the same illusion as a rubber hand, despite its shape has no similarity with actual parts of the body. Furthermore, bending a visual rubber finger in a painful angel makes participants feel pain although their physical finger is not bended in a painful angle. This effect appears independent from the fingers visual distance, however it is strongest if the hand is presented in an anatomical familiar distance. Furthermore, presenting the physical hand together with the rubber hand significantly reduces the vividness of the illusion.

To summarize, synchronous activation of tactile / proprioceptive feedback and visual input can quite easily lead to acceptance of remote bodily and non-bodily objects as part of the observer's own body, even though they have no visual resemblance to body elements . Accordingly, stimulus combinations allow deformation and extension of the existing SBA by inanimate objects. This ability leads to an even more intriguing human ability, tools use.

2.4.4.2 Tool use

A person's ability to use external objects as if they were an extension of his or her own body is one of the most distinctive aspects of human specific behavior. Humans write with pencils, drink from cups, sit on chairs, play instruments, and use knifes without seeing it as peculiar or extraordinary. Although monkeys can be trained for basic tool-use the intelligent use of complex tools seems specific to human (Maravita & Iriki, 2004).

As for integrating rubber limbs into the body, tool use rests upon synchronous combinations of visual and somatosensory perception that support quick acceptance of external elements as part of the controllable body. Hence, tool-use, as using a pencil for writing, generates specific, synchronous combinations of visual stimuli (the moving pencil) and bodily feedback as vibrations, tactile grip, and proprioception. This bodily feedback is, according to visual capture, cognitively localized at the tip of the pencil on the paper surface.

To integrate into the body, tool-use actually changes the neural areas of structural representation of the body. Accordingly, effects usually found for the fingertips appear around the endpoints of tools (review Maravita & Iriki, 2004). Thus, despite a conceptual distinction between body and extending objects (e.g., pencil) the separation between body and tool vanishes on somatosensory and structural body representation levels. Accordingly, tools are perceived as if they were part of our own body. Thus, spatial perception is altered according to the current state of object integration because the structure of the body, used as frame of reference, changes with object integration.

Tool use, body representation, and distance perception We presented support that the systems that represent (peripersonal) space, tool use, and structural body representation overlap (Knoblich et al., 2006, p. 42).

How can we measure the actual integration of elements into the body on a behavioral level? Altered distance judgments are an important measure for a participant's subjectively perceived size of the own structural body. Accordingly changing the SBA by repeatedly using differently sized mechanical grabbers changes the spatial perception of stimuli according to the grabber length. Thus, participants perceive touch at the elbow and fingertips as more distant after using the device and perform grabbing slower and less accurate than if they related to the enduring representation of their arm with the attached grabber device (Cardinali, Frassinetti, et al., 2009). Simultaneously, body extension changes the application of the spatial words *this* and *that* whenever content processing switches from peripersonal space mode to extrapersonal space mode (review Kemmerer, 1999). Accordingly, repeatedly pointing with a stick (and by that get closer to the target) instead of the own hand makes participants refer to these formerly far elements by the word *this* instead of *that* (Coventry, Valdes, Castillo, & Guijarro-Fuentes, 2008). Accordingly, the representation of space changes by the length of the stick.

To sum, making participants accept tools as part of their own body alters their distance judgment. Accordingly, the altered distance perception delivers several behavioral measures (perceived distance, action accuracy, action speed, verbal description) that can be used to verify and identify the current state of the participant's structural body representations.

2.4.4.3 Summary

What are the most central conclusions from this chapter? The structural body representation is a dynamic, constantly updated representation. Thus, bodily and non-bodily stimuli and objects can easily extend the structural representation of the body. The major mechanism behind this integration is a combination of simultaneous and somatic (proprioceptive/tactile) and visual stimuli. The SBA allows relating internal states such as proprioception and tactility to visual spatial locations and by that creates the subjective impression that feedback, actually coming from within the body, refers to specific locations such as the fingertip, hand, or leg. The same mechanism allows integrating external elements into the body. As soon as an element is integrated, all spatial processes that refer to the SBA change accordingly. Thus, distance, size and relation perception change equivalent to the updated body.

2.5 Motion body awareness (MBA)

Motion body awareness (MBA) is the awareness of voluntarily body movements. Accordingly, body movement is a term frequently referred to as manipulation method (e.g., Alaerts, Heremans, Swinnen, & Wenderoth, 2009) or as behavioral measure (e.g., Brass, Bekkering, Wohlschläger, & Prinz, 2000). In the following section we review cognitive science research to identify the cognitive bases of movement representation and to identify the cognitive impact of activating or changing movement representations.

2.5.1 Elements of MBA

One's conceptual understanding of movement refers mostly to one's own body elements in action. Accordingly, it can relate to any intended movement such as finger movement, tooth-brushing, touching a wall, chewing gum, hand shaking, or turning around. This indicates that our movement concept not only involves the moving physical body limb and the systems necessary to control it, but also knowledge about our intentions, goals, and expected perceptual feedback during moving the limb.

2.5.2 Neurological cases and neuronal basis of MBA

From a neurological point of view, two aspects can support the understanding of MBA, (a) cerebral activity and areas involved in thinking, planning, and processing movements, and (b) comparing the mechanisms that create aware and unaware movements.

2.5.2.1 Dual pathways

Understanding the concept *movement* involves a central challenge: the discrepancy between cognition we are aware of during movement perception, and the actual cognitive processing during movement execution and simulation.

To begin with, the dual structure of cerebral visual processing is giving a first indication of separate processing paths generating different amounts of movement related awareness. From a cerebral point of view there is seeing for perceiving and seeing for executing spatial movements. Only a minor amount of movement related perception is actually reaching awareness during planning, understanding, expecting, and judging movements. A reason might be that only a minor amount of awareness is necessary for actual and simulated movement execution. Accordingly, brain imaging supports that action planning and real time action control use separate cognitive, cerebral systems (Glover, 2004). This split creates partially, although not completely, independent systems (Goodale & Westwood, 2004).

The duality reflects in the separation of visual processing into a dorsal path for spatial and action based processing ("Where" path) and a ventral path for visual feature based processing

("How" path) (Goodale & Milner, 1992; Milner & Goodale, 2008). Accordingly, injuries of this dorsal pathway primarily lead to action and space related impairments such as the loss of motion perception (Akinetopsia), loss of spatial object perception, reduced spatial reaching accuracy, and reduced directed eye movability (e.g., Blanke, Landis, Mermoud, Spinelli, & Safran, 2003). Injuries of the ventral pathway on the other side lead to problems in feature based object recognition as color blindness (achromatopsia) and loss of face recognition (prosopagnosia) (e.g., Bouvier & Engel, 2004). Thus, ventral injuries not necessarily influence action execution.

Accordingly, several (ventral) optical illusions influence action planning and visual perception but not the accuracy of executed action (e.g., Glover, 2002). Thus, subjective distance judgments between an experimenter's index finger and a rubber index finger after inducing a rubber limb illusion suffer from significant visual misjudgments of distances, wheres ballistic actions towards the finger are still performed accurately (Kammers, de Vignemont, Verhagen, & Dijkerman, 2009). Furthermore, participants pinch fingers according to the real size of an object (e.g., Ebbinghouse size illusion size), although they visually perceive it differently sized, exactly as if the visual processing did not create an illusion (Bridgeman, 2008).

Accordingly, action execution partially relies on its own visual processing. The (dorsal) visual information used for guiding action planning involves metric and egocentric knowledge about the body that the ventral processing path lacks (Goodale & Milner, 1992). Thus, the visual patterns guiding action execution usually remain unaware, and we cannot identify or label the visual patterns and properties that made us execute an action the way we did while we, for instance, avoided or touched an object. Accordingly, action execution is influenced by basic, unconscious visual and spatial characteristics of an action target such as its size or shape.

The dual paths of processing create a complex discrepancy between visual processing generating the aware elements of movement and visual elements influencing covert movement simulation and preparation.

2.5.2.2 Comprehend one's own and mirror observed movements

Area activation Due to the cerebral structure, the ability to prepare for, simulate, and visually comprehend movements in space can be related to specific cerebral activity. FMRI and behavioral studies support that especially the primary motor cortex is involved in motor control, motor comprehension, and motor imagery (review Munzert et al., 2009). Furthermore, anticipating sensory effects typically perceived during movement execution plays a fundamental role in movement planning. Thus, the medial frontal cortex is also directly involved in MBA by linking action activation with the expected sensory effects of that action in the somatosensory cortex (review Waszak, Cardoso-Leite, & Hughes, 2011).

Mirror neuron system: activity during observation Interestingly, the same area involved in perceiving the own movements are also active during perceiving others' movements. So, how is an observer able to activate own movements by observing others' movements? The solution for this *correspondence problem* is seen in the directly heightened activation of cerebral pre-motor and motor areas during observation of others' movements (Alaerts, Heremans, Swinnen, & Wenderoth, 2009; Aziz-Zadeh, Wilson, Rizzolatti, & Iacoboni, 2006; Tettamanti et al., 2005). Accordingly, the *direct-matching hypothesis* suggests that the understanding of visually observed actions applies direct activation of the observer's own motor system by visual cues (review Brass & Heyes, 2005; Iacoboni & Dapretto, 2006; Iacoboni et al., 2005; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996).

Single-pulse transcranial stimulation (TMS) supports that this matching happens not only on a general level but on a detailed muscle specific area activation, as if observers executed the action themselves (Aziz-Zadeh, Maeda, Zaidel, Mazziotta, & Iacoboni, 2002; review Cattaneo & Rizzolatti, 2009; Fadiga et al., 2005). Accordingly, TMS above the wrist extensor and flexor muscle area of the primary motor cortex impairs comprehension of either supinated (or palm-up), pronated (or palm-down) wrist motions on video (Alaerts, Swinnen, & Wenderoth, 2009).

Such detailed covert imitation within one's own motor system not only supports understanding of the motor aspects of the movement, it also allows accurate predictions and inferences of higher knowledge such as others' targets, goals, and intentions (Cattaneo & Rizzolatti, 2009).

This overlap between execution and perception system can lead to a measurable inhibition of action execution. Thus, observation of others' actions and its effect on the observer's action execution appears to be one of the strongest, and accordingly most frequent triggers and measures of covert motor activity during content processing (stimulus response compatibility paradigm, e.g., Sebanz, Knoblich, & Prinz, 2005).

Conditions for mirroring However, what are the conditions and limits of covert movement imitation? It appears that specific visual properties are necessary to induce the according motor reflection in an observer.

Vainio & Mustonen (2011) demonstrate that both temporal, postural and spatial properties of an observed hand influences mirroring. Accordingly, participants' responses during an arrow judgment task depends on the respective presentation method of a hand in the background. Responses only interact with hand observation, when the hand is presented for a minimal amount of time ($>$ 400 ms), and when it is presented from egocentric view. The observed hand's posture (pressure vs. precision vs. power grip) does not change mirroring.

Furthermore, an observer's own, physical hand posture (palm-up, palm-down) and the respective perspective the hand is presented from (1_{st} person vs. 3_{rd} person) only mildly influence the activity of simulation related muscle specific cerebral areas (left primary motor cortex) during observation of left or right hand movements on video (Alaerts, Heremans, et al., 2009).

Generally, mirroring seems to be strongest when presenting body elements from egocentric perspectives and in familiar relation to the full body. Accordingly, seeing hands in a natural back view and together with an attached forearm influences action execution strongest (Ottoboni, Tessari, Cubelli, & Umilt, 2005). Despite the difference in size, however, all conditions that presented bodily elements to an observer created at least small amounts of mirroring.

Visible body presentation necessary? However, if visible bodies can initiate covert motor activity perhaps non-bodily visual cues can as well. The duality of visual processing indicated that motor preparation could be influenced by simple visual patterns instead of conceptual categories. Accordingly, it might not be the identification of bodily elements as bodily elements that creates mirroring, but their specific visual properties that activate motor activation in an observer.

All examples we presented involved the presentation of realistic human body limbs. However, even observing a comic-figure executing a response incongruent action reduces a participant's movement execution in the same way observation of real body actions does, whereas observing a robot executing the action does not (Kilner, Paulignan, & Blakemore, 2003). It appears that both the object's identification as 'body' and the visual velocity (linear vs. biologically eased movement) of the bodies observed movement affects (facilitates / impairs) an observer's mirroring (Kilner, Hamilton, & Blakemore, 2007). Thus, the observed 'motor contagion' by visual cues is not independent from the object's semantic. This indicates that motor mirroring involves both bottom up activation and top down processing.

Top down knowledge Mirroring is not direct imitation of an observer's motor activity. Some findings demonstrate an influence of top-down processes as of knowledge about an action's intention (internally or externally triggered) and goal on an observer's resulting motor simulation. Hence, motor priming effects (speed of compatible/incompatible finger response) during judging numbers with the index and middle finger, while seeing an action executing hand in the background, is influenced by pre-experimental training of experiences and assumptions about the action executing person's goals (Liepelt, Cramon, & Brass, 2008).

FMRI studies support this observation. Thus, activity in the pre-motor mirror neuron system changes in relation to the knowledge about another person's action intentions. Seeing a video of the same object (teapot, mug, cookies, jar) in different contexts activates the mirror system according to the context adequate action (Iacoboni et al., 2005). Even the activity in the extrastriate body area, an area known for its specific activation during visual processing of visual body cues, changes according to these intentions. Furthermore, the activity is strongly modulated by limb movements (arm/foot) towards the direction of a target, potentially indicating its meaning as target (Astafiev, Stanley, Shulman, & Corbetta, 2004). This supports that top down activation both by knowledge about the other's plans, intentions, and targets and the observer's own goals changes the mirrored motor activity during visual processing.

2.5.2.3 Language perception and motor activation

An important field for investigating the special connection between high-level, top down concepts and basic cue dependent activation of motor simulation and motor activity is the field of language comprehension.

Besides visual material, verbal descriptions (e.g., push the drawer) are the material mostly found in studies to induce motor activity. Indeed, motor simulation is a central strategy to fill words, originally meaningless visual cues (e.g., black letters), with meaning. Accordingly, language production and comprehension require a great amount of covert motor simulation. Thus, the cerebral activity during language processing and production is an important source of insight into the connection between motor activity and comprehension.

Motor circuits for speech articulation functionally overlap with circuits involved in speech perception and comprehension. Thus, processing of action words like lick, pick, or kick activates the corresponding somatotopic motor and pre-motor areas of tongue, fingers, or feet (Hauk, Johnsrude, & Pulvermüller, 2004). Even the processing of sounds such as *t* or *p* that typically involve specific motor articulation during processing, activates the respective motor and sensory activity (Pulvermüller et al., 2006). Thus, even implicit verbal triggers, without conscious awareness of bodies or motor activity, is sufficient to raise the respective neuronal activity (Pulvermüller, 2005).

However, comprehending not only activates the related areas, it actually needs them to comprehend verbal content that implicitly or explicitly refers to the action. Disturbing the respective area's activity by TMS stimulation of a sound articulation motor area actually reduced perception of the respective sound typically involving the motor activity during production (e.g., D'Ausilio et al., 2009).

The described dependency is not limited to language comprehension. Thus, equivalent interactions can be demonstrated for visual processing. Accordingly seeing specific lip movement influences acoustic perception in the same way as reading does (review Galantucci, Fowler, & Turvey, 2006). Thus, selective motor activity during language comprehension is not limited to language comprehension (e.g., Lotto, Hickok, & Holt, 2009).

2.5.2.4 Relation of MBA to SBA

The last section described the structural body representations (SBA) and repeatedly mentioned that it is based on integrating the multisensory feedback generated by movements. Thus, although from an intuitive point of view the concepts spatial body and body movements seem quite distinct, the sensory feedback combinations necessary for creating the SBA are generated by body movements.

On the other hand, movement comprehension and planning refers to structural body representations. The system encoding the categorical spatial relationships between spatial body elements is involved in action execution (Goldenberg, 2009). Thus, the separation between the static idea of structural body representations and the dynamic idea of movements is not as distinct as potentially assumed.

Impaired access to the structural body representation systems affects movement execution abilities. Accordingly, disturbances in the activity of both visuo-spatial representations of actions and structural body representations in the parietal cortex leads to impaired imitation abilities of observed actions (Chaminade et al., 2005). These patients are unable to refer an observed movement to the observer's own body or to willingly use the accordingly unrepresented limb for action execution. Thus, the patients selective imitation inability indicates that not the motion execution but the access to the own static body representation for action planning is impaired (Sunderland & Sluman, 2000). Accordingly, implicit and explicit reference to the body as target (e.g., move your hand, touch your lip), during imagination of target postures (e.g., take posture to pick an apple), or to execute actions independent from posture change (e.g., looking up while lying on the side, sitting or walking) involves SBA in MBA.

Furthermore, MBA involves SBA whenever it involves awareness for spatial directions and targets within peripersonal space, a representation highly overlapping with the SBA and its application as spatial frame of reference. Accordingly, the primary motor cortex during moving a joystick towards a target attunes relative to the movement's spatial direction in space (Eisenberg, Shmuelof, Vaadia, & Zohary, 2010).

Accordingly, frequently referring to body elements and targets creates a clear dependency between the systems encoding the structural body representations and movement representation.

2.5.2.5 Movement awareness & sensory prediction

A final and important aspect is the relation between movement planning and the creation and comparison with expected sensory events. A large body of neuroimaging evidence, and accordingly activity in motor and sensory structures, supports that a great amount of thinking consists of simulating bodily interactions with the environment by inhibiting the actual execution and predicting the respective sensory outcome (review Hesslow, 2011). Thus, the intention to move, the awareness of having moved and the respective sensory prediction overlap (Blakemore & Decety, 2001; Moore & Haggard, 2008).

This specific connection between cerebral damage, affected sensory prediction accuracy, and motor awareness is observable in patients suffering from anosognosia for hemiplegia. After right hemispheric stroke, these patients selectively become unaware of lost motor control. Accordingly, a specific cerebral system seems responsible for the creation of awareness of motor acts (Pia, Neppi-Modona, Ricci, & Berti, 2004). The location of these lesions indicate that this problem appears in a system responsible for comparing expected sensory input with actually received input during movements. Accordingly, these patients not only have diminished awareness of their paralyzed limb, but also are less sensitive to detect discrepancies between observing an intended and actually executed motion. They can remain unaware of angular discrepancies as large as 20 degrees between observed limb motion (via camera on computer screen) and physical motion (Preston, Jenkinson, & Newport, 2010). Accordingly, they do not detect discrepancies between anticipated and actually executed movement and falsely perceive the simulated movement with a completed action (Fotopoulou et al., 2008).

Thus, symptoms appearing to be a movement execution problem are actually a disturbance of sensory awareness. For the understanding of MBA this means that movement awareness and the interaction between movement and perception could be more about the processes involved in creating and comparing perceptual predictions of movements than about interactions between concurrent motor activity and preparation.

2.5.2.6 Summary

The most central conclusions from this section are: the visual system distinguishes between processing for action execution and processing for visual feature analyses. Accordingly, changes in visual features or optical illusions do not necessarily influence movements. On the other hand, the visual patterns activating movement preparation do not necessarily reach consciousness.

Thus, cerebral motor activity and the visual patterns actually influencing movement usually remain unaware. Furthermore, aware movement lacks detailed awareness of the concrete aspects involved in moving. Thus, tooth brushing involves awareness of its functional goal (e.g., cleaning), targets (e.g., teeth) and specific sensory expectations (anticipation of e.g., mouth and hand feedback), but it lacks awareness of the involved detailed motor plan (specific arm movement) and the detailed movement itself.

This creates a complex discrepancy between an intuitive understanding, when and by what movement simulation is involved and the amount of actual motor activity during perception. Accordingly, a great amount of covert motor simulation, both through visual processing and language processing, influences motor planning and execution without actual awareness of movement simulation.

A central mechanism in processing movement related content and comprehending others' actions is found in the systems mapping observed cues onto one'S own movement planning, and execution systems. This mirror system links perception, execution and understanding of movements directly to the observer's premotor and primary motor cortex. Accordingly, an observer's mirroring activity during movement perception can be measured directly via motor brain activity or indirectly by speed and accuracy of specific response movements.

The actual amount of mirroring during observation of bodies dependents on several factors such as visual perspective, full body, or specific limb observation, duration of presentation, temporal gradient of movement, the observer's posture, and the observer's current general motor activity. Furthermore, top down knowledge as the observer's motor experience and knowledge about the observed persons intentions influence the degree of motor activity. Thus, understanding of observed movements is not limited to the motor cortex but involves activation of additional representations of the body structure, spatial targets, intentions, and the simulation of specific sensory expectations.

Furthermore, access to the structural body representations and sensory anticipation appear to be central mechanisms involved in the ability to execute and perceive movements. Thus, disturbances in the sensory prediction systems or of the SBA lead to disturbances in movement execution despite intact motor systems. Accordingly, movement cannot be reduced to motor activity.

To summarize, referring to an intuitive understanding of movement, involving an actually moving body, easily ignores a major amount of covered movements in an observer. Simultaneously, the deep involvement of perceptual anticipation could create misinterpretations of actually perceptual incompatibilities such as motor incompatibilities.

2.5.3 Sensory anticipation and MBA

Based on the neurological observation that impaired sensory prediction alters movement awareness and ability, it appears that a major mechanism determining movement activation is sensory anticipation and comparison between anticipated and perceived effects during movement execution. Accordingly, in this section we separately examine the connection between both processes and (a) deliver reasons and mechanisms behind sensory anticipation during movement activation, (b) describe an activation relation between effect and movement, and (c) give an overview on the meaning of such simulation and anticipation for understanding others' movements.

2.5.3.1 Reasons and models of sensory anticipation during MBA

Behavioral and neuroscientific studies support that movement planning and execution is fundamentally based on mechanisms to anticipate the sensory effects of the movement (review Kawato, 1999). Three models, namely the feedback, feedforward, and hybrid model, are in the focus of investigation (Desmurget & Grafton, 2000). Accordingly, studies either focus on the involvement of direct sensory body feedback ('online feedback') during action execution, anticipated feedback ('feed-forward', simulation of probable outcome), or the combination of these ('hybrid').

A very important mechanism in this mutual dependency between action and effect is *forward prediction*, the anticipation of upcoming, movement related sensor events as soon as a movement is planned and initiated. According to Wolpert & Miall (1996) such forward prediction allows significant *speed-up* of sensory input processing by preparation for its probable outcome (hurt, press, tickle), they allow to *distinguish* self-produced from externally caused events, (Blakemore & Frith, 2003; Blakemore, Oakley, & Frith, 2003; Synofzik, Thier, & Lindner, 2006), support *attention guidance* by ignoring self generated from non-self generated input (Diedrichsen, Verstynen, Hon, Zhang, & Ivry, 2007), and allow *preparation* for adequate response movements (Desmurget & Grafton, 2000; Sebanz et al., 2006).

Simple walking around, for instance, generates constant head movement that, without an anticipation based stabilizing mechanism, would not allow the visual system to accurately identify the observed environment. Thus, active walking around during observation leads to more accurate visual learning than processing the identical, recorded visual input without actively walking around (Waller, Loomis, & Haun, 2004). Accordingly, the performance while watching a technically stabilized version of the visual input is comparable to the performance during active walking. Furthermore, fast movements such as grasping would not even be possible without forward modeling to prepare upcoming events and responses (Desmurget & Grafton, 2000). Accordingly, anticipation of self-generated effects is an integral aspect of movement planning and execution and MBA is subject to the constant sensory anticipation during self-initiated action execution (e.g., Elsner & Hommel, 2001; Kunde, Hoffmann, & Zellmann, 2002).

A great amount of this sensory movement related forward predictions is automatically processed in the cerebellum (review Blakemore, Wolpert, & Frith, 2000). Thus, self-initiated movements such as stomach activity, heartbeats, balance keeping, head movement, or chest lifting during breathing can be processed automatically and stay unaware because they involve a high degree of sensory predictability. Nevertheless, as we demonstrated with visual processing, they strongly influence cognitive processing. Accordingly, awareness of one's own voluntary movement involves a low awareness for its predictable details that nevertheless influence perception (e.g., Hommel, 2009). Accordingly, the awareness of intentional movements is not the awareness for the action itself but related to the area and nature of unexpected sensory consequences (Wolpert & Ghahramani, 2000).

Especially the simulation of endpoint, e.g., the perceptual feedback as from hitting an object, is an important element of conscious anticipation (Coello & Delevoye-Turrell, 2007). Again comparisons between anticipated and received sensor input determine the resulting awareness. Thus, the aware concept of movement refers to the aware elements during action execution and neglects the large influence of sensory anticipation during movement activation.

2.5.3.2 Cue and movement activation

It appears that there is a bi-directional relation between the representation of movement related sensory effects and the movement representation itself.

The moving body delivers a continuous stream of sensory context information during cognitive stimulus processing. Simultaneous activation of neurons leads to increased bi-directional synaptic connection strength. Accordingly, learning of combinations (e.g., color+shape) biases judgments (e.g., shape's current color) towards the learned prototypical combinations (e.g., red shape) (Goldstone, 1995, in Barsalou, 2008). The great amount of bodily stimuli (e.g., proprioceptive and visual feedback) during action execution and the simultaneous visual processing build corresponding prototypical combinations.

Accordingly, bidirectional connections between action activation and activation of typically perceived stimuli during action execution (effects) have been demonstrated for most stimulus material as sounds or images and is described in several theoretical models such as the *common coding hypothesis* (e.g., Prinz, 1990), and the *action-concept model* (Hommel & Elsner, 2009). Accordingly, listening to a sound frequently perceived as a result of action execution triggers the action representation (review Shin, Proctor, & Capaldi, 2010).

Accordingly, actions can be activated by thinking of or perceiving their typical sensory effects. Thus, processing of cues and the initiated actual movement preparation, with its motor and sensory activity, is embedded into a complex interplay between sensory anticipation, cue adequate movement preparation, and the current system state.

2.5.3.3 Anticipation for understanding others - remote senses and meta cognition

Sensory prediction is not only involved in planning one's own actions but also in comprehending and anticipating others' actions. Thus, patients that lack their sense for cutaneous touch and movements below the neck show a deficit in deriving adequate judgments of box weight from observing somebody lifting these boxes (Bosbach et al., 2005). Observers generate such anticipated movement feedback in real time while they observe, at least under normal visual conditions. Furthermore, anticipation refers to the logical temporal continuation of a movement, thus judgments of an observed action (point-light action sequences on video) even after a short visual gap are related to the correct, hidden continuation of the action (Graf et al., 2007).

Such simulation could be interpreted as understanding others' and own movements directly by low-level motor associations without higher processes involved. However, even rhesus apes and macaques copy postures on a task dependent level and by that are aware of others goals and intentions (review Wood & Hauser, 2008). The cognitive system that allows awareness of one's own actions and to communicate these actions binds the action and its consequences to the intentions of this act (Frith, 2002).

Accordingly, observers covertly attend the goal of their own and others' actions instead of observing the actual body movement. Thus, both when participants actively stack blocks with their right hand to replicate a model, and when they passively observe an actor completing the same task while sitting across the table, the observer's eyes look ahead of the actor's hand towards the goal of each reaching movement (Flanagan & Johansson, 2003).

2.5.3.4 Summary

What are the most central conclusions from this section? Movement preparation, both before movement execution or during movement simulation, involves extensive preparation for expected sensory outcome. Such anticipation has several reasons, such as optimizing the accuracy and speed of cognitive processing and action execution.

Only a small part of the elements involved in movement actually gain consciousness. Accordingly, most self-generated visual and tactile sensory input is automatically processed automatically. Highly predictable movements and effects usually remain unconscious, whereas awareness is guided towards the deviating stimuli. Accordingly, the cognitive system can attend these elements and ignore the *irrelevant* input, an ability significantly supporting functions that involve simultaneous movement, as during tactile shape recognition or visual scene comprehension during walking around. Mostly, targets and external goals receive aware attention.

On the other hand, sensory anticipation of movements are not encoded in isolation but together with the anticipated sensory outcome, sensory feedback, expected effects, spatial targets direction, goals, and intentions. Accordingly, both thinking of actions activates simulation of its sensory effects, and thinking or perceiving sensory effects of movements activates the according movement simulation. Accordingly, we are in a constant stream of movement-effect and execution preparation during perception.

Furthermore, perception of others' actions involves simulation of their perceptual feedback. However, such simulation involves knowledge about their goals and intentions and guides attention towards others' goals and percepts.

Accordingly, movement related sensory anticipation has an impact on a great amount of conscious and unconscious movement related situations, as during preparation for movements, observation of others' movements, and perception of movement related effect cues. Accordingly, this processing influences cognitive processing.

2.5.4 MBA and cognition

The implicit and explicit activation of movement body awareness (MBA) and the associated cognitive processing directly influences other cognitive processes. In the following section we give an overview of the central aspects of this mutual relation: (a) cues affording movement simulation; (b) effect of movement simulation on visual processing and visual attention; (c) effects of movement simulation on motor planning and execution (by visual and verbal cues, necessity of motor preparation, influence of valences); and (d) the effect of the observer's current body posture and state.

2.5.4.1 Cues with movement affordances

Specific sensory combinations create corresponding action preparation in an observer. The most applied term for such cue-based movement preparation is the term *affordance*, coined by James Gibson (1977). His affordance theory states that humans perceive the world not only in terms of shapes and spatial relationships but also in terms of potential actions for object interaction. Recent neuroscience studies support this view by showing corresponding neuronal activity patterns (Hommel, 2009). Accordingly, seeing a cup or a screw activates the matching grasping action simulation (e.g., Tucker & Ellis, 1998), seeing a chair activates the sitting down action, and hearing loud noises can raise the awareness of ducking or turning around (e.g., Fischer & Zwaan, 2008). Even non-visual (e.g., acoustic, verbal) cues activate sensorimotor simulation and by that influence actions and perception (e.g., Richardson, Spivey, Barsalou, & McRae, 2003).

However, the amount of activation depends to a high degree on the observer's action repertoire and on the learned action-cue combinations. Accordingly, single-pulse transcranial magnetic stimulation reveals a heightened cerebral excitability in forearm and hand muscles during imagining tennis actions in professional tennis players but not in novices (Fourkas et al., 2008). Moreover, accuracy during same-different judgments of letter pairs is biased by the difficulty of typing the letter combination in professional typists but not in non-typists (Yang, Gallo, & Beilock, 2009).

Thus, the actual effect of presented cues depends on the observers motor experience. However, since most humans continuously interact with the environment they share an accordingly large amount of affording cues.

2.5.4.2 Effects of MBA on visual object processing and attention

MBA and visual cue expectation Seeing objects that afford movements, bodies performing a movement, or planning movements such as eye motions, hand movements, or sequences of eye, or hand movements systematically biases visual object perception at the respective target location (review Fischer & Zwaan, 2008). Thus, observation of static grasping actions is leading to facilitated identification of grasp congruent objects (Vainio, Symes, Ellis, Tucker, & Ottoboni, 2008). Accordingly, identification of tools (e.g., pan, banjo, pincers) on a photo is facilitated if the participant saw a tool before that afforded a compatible movement (Helbig, Graf, & Kiefer, 2006). Furthermore, an observer's preparation for a grasp, precision, or power grip biases processing towards action-congruent target-object features and facilitates change detection (differently sized fruits and vegetables, e.g., apple-> orange-> apple) on action-congruently sized objects and reduces change detection on incompatible elements (Symes, Tucker, Ellis, Vainio, & Ottoboni, 2008).

Furthermore, task-irrelevant processing of images showing a specific hand action (precision grip, power grip, or neutral open hand) influences the speed of categorizing objects into artificial or natural according to the congruency between the object's typical action (e.g., hammer=power grip, needle=precision grip) and the observed action (Borghi et al., 2007). In line with the observation that motor experience affects the appearance of motor simulation, this effect only appears stronger after prior motor training.

This means that visual processing of objects is sufficient to raise motor simulation, however this simulation interacts with the observer's current state of motor simulation, either by processing other affordant elements or by the general amount of motor activity.

MBA and attention guidance Besides feature and motor based visual preparation, the activation of movement also influences visual attention.

Processing of cues that indicate movements guides attention automatically towards potential goals or movement relevant areas. Accordingly, perception at locations near the future target locations of manual or tool based spatial movements benefit from heightened spatial attention (Collins et al., 2008). Even listening to action verbs (e.g., give=horizontal, respect=vertical) that imply spatial movements facilitates processing of cues presented in the according position on a screen (left, right, up, down) (Richardson et al., 2003). Moreover, hearing about high buildings implies looking along the building and accordingly, an observers eyes and attention predominantly move along the natural, vertical axes (e.g., Spivey & Geng, 2001). Accordingly, tight synchronicity between the eye movement of a listener and the speaker indicates a high degree of shared attention and comprehension during spatial descriptions (Richardson & Matlock, 2007; Richardson & Dale, 2005). Thus, observation of others' actions (e.g., eye movement) biases an observer's attention towards the potential areas and features of interest salient changes in stimulus material on accordingly unattended areas remain unnoticed (Kingstone, Smilek, Ristic, Kelland Friesen, & Eastwood, 2003).

According to the deep connection between action execution and attention guidance the *premotor theory of attention* claims that neuronal systems for planning goal directed movements and guiding spatial attention are not separate but share specific common structures (Adamo & Ferber, 2009; Rizzolatti & Craighero, 2004; Sheliga, Riggio, & Rizzolatti, 1995). For eye movement this was demonstrated by showing that the degree of spatial attention is equivalent to the degree of activation in the cerebral eye control area while planning an eye movement to specific points in space (e.g., Corbetta & Shulman, 2011; Rizzolatti & Craighero, 2004). According overlaps could be demonstrated for planning directed hand movement and spatial attention (Eimer, Forster, Velzen, & Prabhu, 2005; Tipper, Lortie, & Baylis, 1992).

Furthermore, not only targets but manipulable objects themselves draw attention. Electrophysiological and brain imaging studies support that attention shifts towards manipulable objects (Grèzes & Decety, 2002; Handy, Grafton, Shroff, Ketay, & Gazzaniga, 2003). Thus, observers usually attend to objects based on their relevance for potential actions (discussion in Humphreys et al., 2010).

Accordingly, the mere presentation of cues or objects that imply movements influence an observer's attention due to the deep mutual dependency between movement preparation and attention guidance.

2.5.4.3 Effects of MBA on specific motor execution

MBA not only influences visual cue anticipation and attention, it also influences cognitive planning and execution of actions. Due to its importance for media interaction this is a second major influence of content related motor activation.

As already mentioned humans mirror observed actions within their own action execution planning and execution related systems (Mirror neuron system) and continuously simulate movements whenever action related cues are being presented. Accordingly, we will present support for that the connection by examples when visual processing and verbal processing actually influences human movement behavior.

Generally four major movement preparation related aspects create interactions with action execution (a) processing of visual objects showing or affording actions; (b) reading about actions; (c) comparing verbal and visual triggers; (d) influence of movement related valences on action execution

Effects of seeing acting bodies and manipulable objects Two types of visual triggers of movement related cues are frequently used to interact with movement execution, (a) images showing bodies in action and (b) objects handled with specific actions.

Photos of humans in action are the most frequently applied material for raising movement related cognition, a process often related to the mirror neuron system (2.5.2.2, p.43). Accordingly, the congenital human ability to imitate visually observed postures and actions emphasizes the strong ability of visual processing to project observed body information onto the observer's own motor system (Boyer, Samantha Pan, & Bertenthal, 2011; Meltzoff & Moore, 1989; Meltzoff & Keith Moore, 1994).

Such imitation not only leads to measurable changes on a cerebral level but also to a changed motor behavior that additionally accounts for fairly complex contextual conditions. Thus, processing of a photo showing differently clamped fingers, influences the observer's finger simulation according to the respective constraints (Liepelt et al., 2009). Eventually, only responses with the observed constraint finger slows down responses with the respective finger, even though these constraints have no meaning for the actual task. Furthermore, both observation of finger actions on a photo influences finger response execution and simple markers such as a cross or number indicating the moving finger influences the actual finger response (Brass, Bekkering, Wohlschläger, & Prinz, 2000). Furthermore, the imitated action must be part of the observer's repertoire to raise motor resonance and link observed action effects with the learned behavior (e.g., Paulus, Hunnius, Vissers, & Bekkering, 2011).

Besides observation of acting bodies, also the observation of manipulable objects, such as tools, raises motor simulation and accordingly interacts with an observer's action execution. Accordingly, also tool perception activates specific cerebral motor activity (review Lewis, 2006). Thus, left or right orientation of graspable objects such as a cup (or pan, teapot, knife) with the handle on the left or on the right, significantly interferes with responses executed with the respective left or right hand action (Tucker & Ellis, 1998). Furthermore, the wrist turn direction (left/right) typically related to an object interferes with an observer's response wrist turns. Even during abstract categorization of objects that imply specific hand actions (e.g., hammer=grasp; screw=grip) the execution of the according hand action interferes with typical object action compatibility (Tucker & Ellis, 2001).

However, most objects can be used with more than one action. And actually, awareness for both volumetric gestures (e.g., computer mouse=horizontal grasp gesture) and functional gestures (e.g., spray bottle=trigger gesture) is raised by seeing and reading about objects (Bub, Masson, & Cree, 2008). Accordingly, the execution of a specific set of actions with a technical device (e.g., open grasp, closed grasp, poke, trigger and horizontal grasp, vertical grasp, vertical pinch, and horizontal pinch) interacts with an observed object's typical action. Response time and gesture accuracy during responses is highest when the manual response suggested by the object's image or color matches the object's typical functional and volumetric actions (e.g., color green=pinch, objects typical functional action=pinch, or red=horizontal grasp, objects typical volumetric action = grasp) (Bub et al., 2008). Thus, processing of objects and scenes not only necessarily activates specific motor resonance, but multiple. Accordingly, judging the influence of object perception on motor execution should clarify that the activated action matches the intended action.

Accordingly, the effect of visual processing on action execution depends on the currently presented visual bodies, the movement's concrete conditions, manipulable objects, cues learned to indicate actions, the observer's action repertoire, and the amount of concurrently implied actions. Thus, imitation is not a simple bottom up process, but involves complex scene comprehension with processing of bodily and non bodily cues, potential object interaction and experienced movements.

Effects of reading about acting bodies It is not even necessary actually to see objects or bodies to create interferences with action execution. Verbal processing during hearing, producing, or reading a sentence interacts with respective action execution in the same way as visual triggers do.

Several verbal stimuli, containing implicit or explicit action descriptions, have been reported to interact with motor planning (review Fischer & Zwaan, 2008; review Glenberg & Kaschak, 2002). Accordingly, small linguistic cues are sufficient to activate motor simulation in the listener or reader. Implying future actions by adding the words *yet* or *still* to static descriptions of states ("the drawer is (not) yet open/shut") is sufficient to raise action simulation and by that an action-sentence compatibility effect (Kaup, Lüdtke, & Maienborn, 2010).

It appears that the observed effects do not appear due to conflicts in the systems used for actual movement execution but due to conflicts during movement planning. Accordingly, the degree of preparing for action execution influences the actual interaction and holding back information about the exact response action during cue processing eliminates the action-sentence compatibility effect (Borreggine & Kaschak, 2006). They avoided response action preparation by displaying the information about the actual response keys until after presenting the sentence (50ms, 500ms, and 1000ms). Lagging reduced and even erased the effect, supporting the assumption that the interaction with cue perception appears during action planning.

Visual vs. verbal effects Several studies simultaneously used verbal and visual material, and measured the effect of both on action execution. Accordingly, abstract categorization of objects usually grasped by power (e.g., cucumber, bottle) or precision grip (e.g., nut, key) showed the same congruency effect on both speed and accuracy for the presentation of photos, (temporally and visually) reduced photo presentation, and textual name presentation (Tucker & Ellis, 2004). Furthermore, both observing visual rotation (left/right rotating cross) and listening to manual rotation descriptions (turn down volume) create equivalent interactions with left/right turning responses in a color judgment task (Zwaan & Taylor, 2006).

Thus, we may assume equivalent movement simulation during verbal comprehension and visual comprehension. However, linguistic cues such as sentences additionally allow the researcher to determine the point of motor simulation within a sentence. Motor resonance only appears within a small temporal interval during reading the action related sentence elements. Thus, visual observation of a rotating cross only creates an interaction within the part of a sentence that contains a description of a manual rotation related verb region (Zwaan & Taylor, 2006). Adding the adverbs *quickly* or *slowly* expands this range (*linguistic focus*) and creates the respective motor simulation during a bigger part of sentence comprehension (Taylor & Zwaan, 2008). Thus, the appearance of motor simulation can be timed by using verbal material, something not available for visual material.

Valances: Approach and avoidance actions Also seemingly abstract cognitive concepts can induce motor preparation and accordingly influence action execution. Thus, people tend to avoid negative and approach positive elements such as words, pictures, objects, and persons. Specific directional actions can be used as either avoidance or approach actions. Bad valence usually prepares for pushing away and positive valence for drawing towards the observer's own position. Thus, moving a lever towards a screen displaying positive words is faster than moving a lever towards a screen displaying negative words (Seibt, Neumann, Nussinson, & Strack, 2008).

It appears that not the physical body movement itself refers to its function as avoidance or approach action, but the expected visual effects. Accordingly, in some studies, extension is defined as the positive compatible movement whereas in others it is arm flexion. Based on this observation, the observations in TEC, (Hommel et al., 2001), and ideomotor theory, (review Stock & Stock, 2004), it appears that not the physical action itself (arm flexion towards or away from the body) but the expected visual effect creates the effect (van Dantzig, Pecher, & Zwaan, 2008). Thus, even simple key presses that create the corresponding visual movement towards or away have equivalent effect. This again supports the importance of the anticipated effects for movement decisions instead of the awareness of the movement itself.

Interestingly, the interpretation of an action as away or towards refers to the assumed positions in space, meaning that this effect depends on the observer's imagined self-localization. Thus, simple elements such as labels with the participant's name at a position they shall take transfers the approach and avoidance effect to any point in space (Markman & Brendl, 2005). Accordingly, negative valence prepares actions that lead away from the label and not away from the participant's physical position.

2.5.4.4 Effects of body movements on MBA related cognition

Due to the effects of perception on motor activity, and according to the neuronal overlap between systems involved in movement awareness, planning and execution, we should also find interactions between the observer's action execution during cognitive processing.

Accordingly, learning of action words is supported by moving marbles with the dominant hand (left-hander left, right-handers right), whereas it has no effect on learning of non-action words (Casasanto, 2007). Furthermore, retrieval of posture related autobiographic events is faster, while taking a posture congruent with the posture while encoding the memory (Dijkstra, Kaschak, & Zwaan, 2007).

Moreover, changes in the mere exposure effect (MME), where simple repetition leads to higher preference, demonstrate interactions between motor activity (e.g., chewing gum, kneading ball) and content processing that involves covert motor simulation (Topolinski & Strack, 2009). Accordingly, chewing gum or whispering words, two actions consuming the same muscular systems involved in language production, destroys the effect for words, but not for visual characters. Moreover, kneading a ball, an action that consumes muscles neither relevant for visual nor verbal processing, left the effect unaffected. Furthermore, tongue movement destroys the effect for words but not for tunes, whereas humming destroys it for tone sequences but not for words. Accordingly, motor activity is involved in understanding words, tunes, or during memory retrieval, and those interactions between executed and simulated actions can provide a quite complex interaction pattern.

It appears that the processing of content that refers to movement simulation is influenced by concurrent involvement of the motor system, whereas unrelated content is not influenced by it.

2.5.4.5 Summary

What are the most central conclusions from this section? Cognitive processing is deeply connected to movement simulation. However, there is a discrepancy between perceived movement simulation and actual activity during content processing.

Several cues create cognitive movement simulation, above all the observation of bodies, usable objects, movement accompanying effect combinations, and verbal descriptions of actions. Observers cannot control such covert simulation even if it is irrelevant for the task. Furthermore, it usually stays unaware. Thus, cue processing creates movement based interactions by concurrent movement planning related cognition. Thus, it affects the processing of objects that themselves refer to actions (e.g., tools) and the execution of actions itself.

Furthermore, the activation of movement, by visual and verbal cues, influences an observer's attention distribution and the expectation of specific visual features. It prepares for specific spatial areas and visual features in that area which leads to facilitated visual judgment of matching stimuli in the respective area. Especially the overlap between the cognitive systems for spatial attention and motor control creates inter-dependencies. Accordingly, action relevant objects or manipulable objects receive more attention.

The strength and nature of the simulation depends on the observer's motor experience and preparedness for action execution. When it appears, the simulation is very specific and involves additional knowledge about the respective moving conditions (e.g., movement limitations). Thus, higher concepts influence the exact motor simulation during content perception. Even valences induce specific additional action preparation of either avoidance actions for negative content or approaching actions for positive.

On the other hand perception of movement related elements interacts with the observer's concurrent action execution (posture taking, chewing gum) during content processing and encoding.

2.6 Cartesian space body awareness (CBA)

Cartesian body awareness (CBA) is the ability to transfer the body imaginatively to another location in space. It is part of this taxonomy because several body related processes automatically induce imaginative spatial self-transfer. Thus, CBA comprises the cognitive consequences and correlates of taking other body locations in space. Above all, it involves anticipation of visual, somatic, and spatial stimuli as perceived on the taken position and according to the observed body. In the following section we review cognitive science research to identify the cognitive bases of spatial body transfer and to identify the cognitive impact of activating or changing the body location.

2.6.1 Neuronal correlates and cases of CBA

The ability to imagine being in a body somewhere in space refers to specific cortical activity. Three neuronal aspects suggest the existence of distinct CBA activating systems: (a) specific brain activity during voluntary spatial self-transformation; (b) neurological phenomena selectively creating CBA illusions; and (c) specific brain activity during automatic spatial self-transformation while seeing bodies in space.

2.6.1.1 Neural basis of spatial self-localization

In the chapter about SBA we mentioned that people are able to directly map observed bodies, independent from perspective, onto their own motor system. However, under specific circumstances, for instance, when the observed body is executing an action, this direct mapping additionally involves simulating the observed person's location. Accordingly, the observer leaves the physical body position by imagining the alternative location.

Thus, despite identical visual input, the cerebral activity while imagining being at an observed person's position and orientation differs from the activity while looking at the figure as if it was the reflection of one's own physical body (Arzy, Thut, Mohr, Michel, & Blanke, 2006). Accordingly, activity within brain systems known for their specific body processing such as the temporoparietal junction (TPJ) and extrastriate body area (EBA) depends on whether the observer currently identifies with the observed body or imagines being at the observed person's position. The EEG activity in the EBA and TPJ reveals that the region's timing and specific activity is crucial for coding the spatial perception of the self, either in the physical body (EBA) or somewhere in space (TPJ). Accordingly, the activity in the parietal-temporal-occipital junction during spatial reasoning changes according to the observer's current egocentric or imaginatively transformed position and orientation (Zacks, Rypma, Gabrieli, Tversky, & Glover, 1999)

Because imagined self-transformation involves the ability to covertly rotate the own body into another orientation, the idea seems plausible, that it refers to a more general ability to rotate objects. For mental (object) rotation, which may seem unrelated to the body, several studies indicate that it refers to covert hand rotation simulation during imagined object rotation (Ionta, Fourkas, Fiorio, & Aglioti, 2007). However, the neuronal systems involved in mental rotation seem distinct from the ability to transform the own body in space (Zacks, Mires, Tversky, & Hazeltine, 2000). While imagined self-translation in space mainly refers to visual-spatial activity, imagined hand rotation involves parietal and premotor activity (Creem-Regehr, Neil, & Yeh, 2007).

2.6.1.2 Three forms of autoscopic phenomena

Lesions in the specific subsystems involved in imagined self-translation can create specifically modified spatial self-localization.

Autoscopic phenomena, illusions of seeing yourself in space, are an important demonstration of the distinct neuronal systems involved in the human ability to perceive one's own body in space. The cerebral position of the lesions generating these phenomena suggest a connection between failed multisensory integration and illusionary awareness of being somewhere else in space.

Blanke and Mohr (2005) reviewed over 100 patients with autoscopic symptoms and categorized the typical symptoms by three classes: (a) *Out-of-body experience* (OBE) while seeing yourself somewhere outside the physical body ("as if I were at the door, seeing myself lying in the bed"), which comprises feeling outside the physical body with the visuo-spatial impression of seeing the own physical body as if it was in external space; (b) *Autoscopic hallucination* (AH) while seeing a second own body in extrapersonal space, sitting, smiling, standing; and (c) *Heautoscopy* (HAS), which is an intermediate form between a and b, meaning that patients either quickly alternate or mix both views and positions.

Every type refers to distinct pathological cerebral activity. OBE is related to abnormal activity in the temporo-parietal junction, HAS to abnormal activity in left temporo-parietal junction, and AH in extrastriate body area. Particularly HAS and OBE often appear together with vestibular illusions and body schema impairments. Again, TPJ appears to be a key system for creating the feeling of being somewhere else, whereas disturbances of the extrastriate body area create identification with (imaginary) external, visual elements.

The three phenomena support that spatial comprehension involves the ability to identify with the location of the own physical body, the ability to identify with other places and a system coordinating the alternative locations. Accordingly, specific neural activity can be related processes that involve identification with spatial elements while keeping the current physical position and the ability to imagine being at another spatial position.

2.6.1.3 Summary

To summarize, the processes during imagined spatial self-transformation are connected to specific cerebral system activity. The right posterior insula shows activity during identifying with locations in space. Moreover, activity in the temporoparietal junction indicates visually identifying with another spatial location, whereas activity in the extrastiate body area indicates identification with the own physical body during observing others. Lesions in these respective areas induce specific, uncontrolled self-location illusions.

2.6.2 CBA and cognition

CBA transfers cognitive effects known from PBA, SBA, and MBA to a new spatial bodily position, orientation, and size. Thus, it is generating awareness for the body with all the related body awareness levels PBA, SBA, and MBA in relation to taken locations and orientations in space.

Accordingly, CBA reduces the seemingly clear distinction between near (peripersonal) and far (extrapersonal) space. Things in far space come within reach and become tangible (PBA), postures are taken somewhere in space (SBA), and actions are perceived as if being somewhere else (MBA). Thus, neurological and behavioral effects (e.g., cross-modal visuo-tactile interactions) usually appearing in near space around the physical body (see SBA) can be found around the virtual body during spatial self-translation as well.

Not the physical distance from an observer, but the felt distance relative to the imagined location is responsible for several observed spatial effects (Maravita, Spence, Sergent, & Driver, 2002). Accordingly, the typical integration of visual, tactile, and proprioceptive information that usually creates spatial representations around the body and its respective body parts (Maravita et al., 2003) is transferred into other spatial locations and accordingly refers to distant visual cues.

The central cognitive topics in relation to CBA are: (a) cognitive steps during perspective taking and respective cognitive effects, and (b) material and conditions that trigger perspective taking.

2.6.2.1 Steps during spatial perspective taking

Imagining being at locations different from the physical body location can involve three major steps: (a) self-localization; (b) posture taking and self-scene updating; and (c) self-rotation (e.g., Amorim et al., 2006). Accordingly, observing somebody standing on a hill while looking down into a valley makes the observer imagine being at the remote location, tilt the head, and rotate into the person's viewing direction.

From a cognitive point of view, the first step, imagined self-localization, generates the lowest cognitive effort, posture taking a little more, whereas imagining self-rotation is the most difficult cognitive process. Accordingly, concurrent imagined self-rotation reduces accuracy and speed of object-to-object pointing tasks within learned object arrangement significantly stronger than imagined self-localization (imagining standing at a certain point), which only marginally influences performance (Rieser, 1989). According to these three levels, we will discuss the specific cognitive involvement and challenges.

Step 1: Spatial-self-localization: projection and full body illusion The first step during perspective taking is mentally moving the self to another point in space for understanding the environment. From a spatial point of view, this determines the origin of the spatial coordinate system. It is possible to imagine being two meters in front or to the left and think relative to this imaginary position. Simple changes in the construal of instructional sentences (drag lever to yourself vs. drag lever away from screen) or perception of labels with one's own name is sufficient to induce self-localization which then leads to a changed representation of space and to the interpretation of actions as self-approaching or self-avoiding movements (Markman & Brendl, 2005; Seibt et al., 2008).

Self-localization can become very strong. Thus, under specific conditions, the ability to identify with other elements leads to full body illusions. An observer localizes within an observed body instead of one's own physical body. Full body illusion experiments are similar to rubber limb illusions we described in the SBA chapter. Accordingly, stroking participants while they see themselves from another position creates the illusion of being at the camera position instead of the position where participants know to be (Ehrsson, 2007). Moreover, seeing one's own body in space from behind in an HMD (cam recording from behind) while being stroked at the back creates the subjective impression of 'being in front of yourself' (Lenggenhager, Tadi, Metzinger, & Blanke, 2007). It is even possible to measure the degree of re-localization by measuring the participant's expectation of the duration a ball takes to hit the ground after dropping it (e.g., mental-ball-dropping during vertical body illusion) (Lenggenhager, Mouthon, & Blanke, 2009). All authors indicate that the visual system is dominating where the observer assumes to be.

Step 2: Posture taking: posture-vision match and self-to-object update The second step in perspective taking, after imagining being at a location different from the physical location, is to anticipate visual input and structure space according to an imagined physical body and its posture (Amorim et al., 2006). Accordingly, CBA directly refers to SBA.

The important step after perspective taking is updating the self-to-object representations of the environment, to update the visual and spatial representation of objects in space (e.g., Kozhevnikov et al., 2006). Accordingly, scenes are not only represented in relation to the observer's physical perspective but also in relation to the body posture and perspective taken. This means imagining being somewhere involves anticipation of the perceptual proprioceptive, visual and spatial consequences of being there.

Thus, accuracy and speed while comparing object configurations ("has the lamp moved?") between a view from an avatar's position in space and the observer's own physical position increase if the avatar is visible from the observer's own physical position and accordingly anticipation for a distinct position in space is possible (Amorim, 2003). Thus, the viewpoint dependence of spatial judgments nearly vanishes when presenting an avatar at the position of the upcoming image. This supports that small spatial hints about a potential position in space are sufficient to create the according anticipation relative to the implied out-of-body location and posture in an observer.

Interaction simulated and physical body Since small visual cues are sufficient to make an observer imagine one's own body somewhere in space we have to ask if both, the physical and imagined body, interact.

Actually, we find interactions between the physical and the imagined body. Most neurological CBA phenomena and illusions indicate that at any time there can only be one aware body and that the cognitive system either integrates or mixes two conflicting, simultaneously available spatial body representations into one (Ehrsson, 2007; Lenggenhager et al., 2007). Thus, perspective taking involves a mix-up between actual egocentric position and the newly taken perspective so the coordination of out-of-body perspectives and embodied, physical perspective (Amorim, 2003). Thus, taking a congruent posture (torso rotation) facilitates perspective taking in a judgment of rotated object (gun/flower) arrangements, whereas taking an incongruent hinders it (Kessler & Thomson, 2010). This suggests that observers actually simulate according to and by their structural body representation.

Step 3: Mental rotation: object-rotation vs. self-rotation strategy The third step during perspective taking is imagined self-rotation, so it matches a scene. The high effort generated by imagined self-rotation is a reason why several alternative cognitive strategies could be applied to avoid self-rotation.

Basically, solving spatial rotation challenges can involve rotating the self into the position of the target, meaning that the scene is fixed and the self is mobile, or it involves rotation of the scene or object so it fits the current position of the observer, meaning that the scene is mobile and the self is fixed (Wohlschläger, 2000; Wohlschläger & Wohlschläger, 1998). The simulation of actual body rotation and translation might correspondingly involve two, however overlapping systems for imagination of *object-based spatial transformations* and *egocentric perspective transformations* (Zacks et al., 2000). Since rotation of human figures is less familiar than the rotation of small objects such as letters, observers favor perspective taking during the observation of humans and mental object rotation during observation of objects (Zacks et al., 2000).

Accordingly, the application of alternative strategies as mental rotation have to be considered during tasks that seemingly involve a self-rotation strategy. Thus, Kessler & Thomson (2010) additionally demonstrated in their experiments that the speed and accuracy results when comparing a rotated object arrangement (gun/flower) with another arrangement (which strongly implied an object rotation strategy) by rotating the objects yields (= the observer is fixed) a completely different speed and accuracy pattern than when participants imaginatively rotate themselves (= the scene is fixed).

2.6.2.2 Initiating CBA – bringing the body into space

The central question for judging the influence of CBA is an understanding of the material and conditions for induces actually inducing perspective taking.

In addition to the voluntary imagination of being somewhere else, specific visual input combinations also can alter the subjective self-localization. Simple setups with mirrors, prisms, or cameras allow presenting an observer's own body as if it was an external element. This means that although the visual input is distorted, the tactile, vestibular, and proprioceptive real time stimuli delivered by the observer's own body remain the same.

Such altered visual presentation induces several unexpected illusions about the observer's own body in space, above all an altered subjective location of his or her body parts (review Holmes & Spence, 2006). Accordingly, observers feel distant from themselves and perceive themselves in different sizes and orientations. Thus, if available, the visual system dominates the felt spatial localization of the body ('visual capture') and, at least as long as visual information is available, associates the stream of somatic sensory impressions felt during observation with the observed visual locations (Pavani, Spence, & Driver, 2000).

Perspective-taking and the related simulation of the body in space have been activated by different manipulation methods such as (a) presentation of images or descriptions of acting anthropomorphic bodies and body parts such as dolls, avatars, hands or faces; (b) presentation of elements that implicitly afford body movement such as tools or chairs; and (c) explicit action instructions/descriptions. Thus, in the famous three-mountain task, (Piaget & Inhelder, 1967), an anthropomorphic doll indicates the new position and orientation and an explicit instruction is given to imagine seeing from that location. Accordingly, visual human artifacts facilitate spatial self-localization by giving additional body information.

Thus, explicit instructions to imagine being somewhere without presentation of human elements leads to representation of the scene according to the new body position (e.g., Hegarty & Waller, 2004; Kozhevnikov, Motes, Rasch, & Blajenkova, 2006). However, above all, seeing someone performing or preparing an action in space leads to bodily perspective taking, even without any instruction to do so (Lozano, Hard, & Tversky, 2007; Tversky & Hard, 2009).

Observing or implying spatial actions as key element Observing or implying actions in space appears to be the strongest trigger of implicit and nearly automatic transfer of the body into space (CBA). Cues indicating actions in space change the way observers think about objects in a scene. Accordingly, facing an acting person triggers perspective taking and by that representation of target object relative to the other's perspective (Lozano et al., 2007; Tversky & Hard, 2009). Accordingly, an observer ("in relation to the bottle, where is the book?") switches from the observer's point of view to the point of view of an observed person, as soon as this person is grasping for an object (book). This automatic perspective taking only appears when the observer person is in action, however keeps the physical view if the man is simply looking at the book, or when presenting the objects without anybody in the image.

Furthermore, tiny changes in textual material elicit and influence bodily perspective taking. Accordingly, the pronouns in an action description either imply an egocentric ('I am cutting the tomato') or an allocentric ('He is cutting the tomato') perspective, and accordingly facilitate judgments of images that show the action from the compatible perspective (either as actor or observer) (Bruny, Ditman, Mahoney, Augustyn, & Taylor, 2009).

Motor experience dependency The connection between implicit perspective taking and action perception suggests that effects found with material that implies MBA should be checked against their origin in embodied perspective taking instead of motor activation. On the other side, the implicit involvement of MBA involves a dependency between motor experience and the activation of perspective taking. Lozano et al. (2007) found indicators that perspective taking only takes place when the handedness of the observer (left/right) matches the hand the actor uses for action execution. They suggest that motor experience might be the trigger for automatic spatial perspective taking when observing familiar actions usually performed with the observed body parts.

Actually, the degree of familiarity with an observed action and expectation of an action in the presented context makes perspective taking more probable. Thus, it makes a difference if seeing someone on the opposite side of a table that grasps for a full glass of milk, an empty glass of milk, together with either an open or closed milk carton. Familiar combinations (glass empty->grasp for milk carton to pore in, full glass-> grasp for glass to drink) are more likely to induce perspective taking (left-right confusion) whereas unfamiliar actions do not (Lozano et al., 2008). The same effect appears for long-term action experience (image of man with either basketball/football) and for short-term action experience (image of woman writing on pad and bottle).

2.6.2.3 Summary

What are the most central conclusions from this section?

To summarize, the ability to identify with other spatial locations collapses the separation between near (peripersonal) and far (extrapersal) space. Accordingly, several cognitive effects known around the physical body can also be found relative to the imagined body location. This bodily perspective taking can involve three steps: (a) simulated self-localization relative to the observer's current orientation; (b) simulating the observed body structure with its posture, body elements, and according to its relation to SBA, visual input and spatial structuring according to the structural body; and (c) simulate the observed bodies orientation by self-rotation. Whether all steps are actually processed depends on the specific task. Especially the cognitive effort of imagined self-rotation supports the application of alternative cognitive strategies for avoiding this step, such as for example rotating the observed objects instead of rotating the self into the required perspective.

Furthermore, specific material is appropriate for initiating perspective taking in an observer. Above all, visual observation of bodies in action is the key for raising and altering CBA. Due to visual capture the feedback from the own body (e.g., tactile, arousal, shiver) is usually felt at the observed position and not identified with the own physical body. Identification can become so strong that an observer completely identifies with an observed body instead of the own (rubber body). A similar effect appears during identification with characters and observed bodies during watching movies while the awareness for the own physical body is replaced by the perception of the character identified with.

However, the degree of CBA created by cues depends on the observer's experience with the observed action (e.g., handedness, action familiar as football). Furthermore, the observer's current posture or location interact with the imagination of alternate locations and postures.

As soon as CBA appears, it can involve three steps: self-localization, posture taking, and self-rotation. Self-rotation is the most effortful element and accordingly avoided if possible. Thus, imagining seeing the environment from another point in space can be done by moving the self to the point in space or by rotating and translating the arrangement according to the physical point in space.

According to spatial self-transformation, several cognitive processes are influence. On the one hand, the spatial representation of an environment is represented in relation to the taken and not to the actual body. Accordingly, judgments of distances and relations change. Furthermore, perspective taking involves visual anticipation. Thus, judgments of visual patterns or arrangements from an anticipated point of view are facilitated. Generally, CBA is often implicitly involved and except for full self-rotations easily executed and does not often remain unattended.

2.7 Major summary and conclusion: Level dependency and awareness discrepancy

We presented a broad range of support that the concept *body* and our intuitive understanding of the body is a major challenge for cognition research. Although the involvement of the physical body seems to be a clear and measurable indicator of embodiment, its actual involvement by activating body related cognitive representations is neither directly observable nor aware.

Accordingly, we demonstrated that despite the long history of body related cognitive research both linguistic concepts and classification systems often implicitly refer to an intuitive, insufficiently defined understanding of embodiment. This leads to heterogeneous interpretations of observed effects and overlapping terminology.

Especially the discrepancy between aware and unaware body related processes might be an important reasons for this problem. Thus, the existing linguistic resolution and classifications seem to be derived from aware bodily aspects, whereas research more and more addresses the involvement of the mostly unaware systems that cognitively represent these functions (e.g., neural correlates). This creates a problematic and challenging duality between aware and actual body participation.

We identified and discussed four major groups of concepts frequently referred to when classifying findings as *embodied*, namely bodily percepts (PBA), spatial structural body elements (SBA), body movement (MBA), and body location (CBA). This comprises studies that derive their embodiment idea from using bodily percepts (e.g., by using touch, proprioception), structural body elements (e.g., by showing hands or feet), movements (e.g., by having participants move or imagine movement), and bodily perspective taking (e.g., by identifying with an observed body location). According to these ideas of embodiment we reviewed and discussed the neuroanatomical, neurological, and cognitive support for these concepts in a common PSMC taxonomy.

This overview delivers on the one hand support for the level's partial distinguishability, mostly based on each levels specific neuronal system involvement and specific cognitive effects, but on the other hand, it disclosed a broad range of mutual dependencies rarely considered in study designs as mutual activation, referencing, and updating.

Taken together, this overview supports the general applicability of the current terms, however, also indicates that their mutual dependencies requires more distinct operationalizations that allow, at least partially, a separation between these concepts.

One idea to separate between the singe levels could be the creation of material that explicitly controls the other body levels' influences while investigating a single one.

2.7.1 Conclusion

Despite myriads of studies demonstrating interactions between body and cognition, we lack models identifying the origin of these interactions. A probable reasons for this discrepancy is the limited linguistic and cognitive consciousness for the actual involvement of cognitive body representation systems during perception. Accordingly, we cannot identify the cognitive dependencies potentially responsible for observed effects. This problematic suggests that future operationalizations for investigation body related effects require additional consciousness and control of the involved levels of body representation, something rarely found in embodiment studies.

Our detailed determination of triggers, elements, and dependencies according to the PSMC taxonomy is a precondition for such integrated operationalizations investigating the actual connection between body representation activation and perception. Naturally this review is only a first, although necessary, step in developing an adequate conceptual separation for embodied cognition research.

From a media application perspective on the other hand, this review presents a broad range of support for how media content and what kind of media content alters an observer's current state of body awareness and accordingly media perception. Thus, these observations support the importance of investigating the interactions between active body and media content perception.

This leads us to the next challenge for cognitive media research: the lack of available experimental environments.

Part III

Framework and Experiments

Abstract

The body is the major element addressed during media perception. Specifically, interactive media perception offers a large amount of potential body related compatibilities and incompatibilities that, although highly relevant for understanding media perception, have merely been investigated.

From a scientific point of view two reasons are responsible for this: (a) a lack of experimental environments that allow the rapid development of the necessary interactive multimedia experiments and (b) the lack of studies actually demonstrating the impact of body related incompatibilities onto media perception.

The following chapters address and contribute to these problems by (a) introducing our development framework Inter|act3D and by (b) demonstrating the influence of body representations on spatial media perception within normal media environments.

Chapter 3

Inter|act3D: A development framework for embodied media research

Abstract

Media research is only possible within the limits of available experimental environments to conduct adequate studies. The broad range of media based cognitive science research and the speed of media development requires an experimental environment that allows fluent integration of a broad range of media, hardware, and platforms, together with the internet. This chapter describes the browser-based experimental framework named Inter|act3D that implements these demands by delivering an easy programmable, light weight framework for the development of platform independent and web accessible embodiment studies. With a high level of independence from location, hardware, structure, and special programming skills, it opens the web and a broad range of media content for embodied media research.

The internal modules delivered by Inter|act directly support established sequential study organization and elements. Accordingly, secure network based data-storage, experiment control, and user interaction is provided. This paper presents Inter|act's overall implementation and design with several reference implementations of major dependent variables and material used in embodied media cognition research.

3.1 Introduction: A RIA study environment

Media perception is connected to covert and overt body representation activation although recipients rarely become aware of it. Both content perception and media interaction involve activity of the respective body representation systems. Thus, the investigation of this connection is important for designing media feedback, interaction, and content. However, the bandwidth of media content, forms of bodily interaction, and technical platforms (mobile, laptop, smart-board) requires special experimental environments.

We suggest and implemented the experimental framework Inter|act for the rapid development of such experiments. Accordingly, it offers modules and functions to investigate body related cognitive phenomena within realistic and familiar online media processing environments, and reaches a broad range of technical devices participants know from their everyday media life.

Researchers can quickly develop new experiments or reuse Inter|act's functional components by composing, adapting or learning from the provided components. These components cover all functions typically necessary for running a complete browser study. We explain the structures and modules necessary for rapid study prototyping, the major architecture, design, language, classes, and functions.

3.1.1 Light-weight web environment

Inter|act is a light-weight rich internet application (RIA) environment to become as mobile, platform independent, web based, modular, and simple as possible. This defers from many existing environments that prefer monolithic, statically localized, platform dependent designs with overwhelming functionality and programming complexity. Despite good reasons for such environments, as for instance, performance maximization, such complexity confronts researchers with an unnecessarily high level of complexity. Accordingly, cognitive studies are mostly conducted in laboratory environments due to special hardware and software requirements usually unavailable on standard computers.

Rich internet applications (RIA) allow complex studies directly within a web-browser. They offer specific benefits, such as broader user accessibility (browser) and studies in the digital field (www). Traditional web applications, based on HTML 4 and Javascript, offer only limited interactivity, client-sided resources, feedback accuracy, and multimedia functionality. Implementing an environment by technologies as Flash, HTML 5, JavaFX, Silverlight, or Java applets, offers sophisticated user interaction, client-sided processing, asynchronous communications, and multimedia within the browser (Fraternali, Rossi, & Sanchez-Figueroa, 2010). Thus, more functions and a broader range of interactive media become available within a browser environment (overview Busch & Koch, 2009).

As already mentioned, RIAs run directly within web browsers, such as Firefox, Chrome, Internet Explorer, and Safari, and offer interface quality and interactive experiences similar to native desktop applications. Thus, they integrate advantages of online and offline capabilities (Preciado, Linaje, Comai, & Sanchez-Figueroa, 2007). Moreover, RIAs strongly reduce problems of platform dependency and avoid complex installation procedures and outdated program versions by automatically loading the most current version.

However, developing web referring applications also requires being part of the constant development and change of browser technology, web internet infrastructure, protocol standards, software engineering methods, and application trends (Jazayeri, 2007). This creates additional challenges to software designers potentially leading to security issues, higher development flexibility effort, and latency challenges. Furthermore, conducting an experiment from the distance limits control of the experimental context and accordingly of the immeasurable aspects in the participant's behavior and environment. Thus, Inter|act delivers modules to control and record the participants' actions, to assess the available computer platform, and to ensure a basic security strategy.

3.2 Experimental functionality

Cognitive research Cognitive sciences are a multi-disciplinary effort. Thus, investigating the connection between spatial media cognition and body representation involves the integration of multiple methodologies and approaches from linguistics, computer science, robotics, neurobiology, cognitive psychology, and applied philosophy. From each point of view, different aspects become important in an online research environment. Naturally, a browser based environment can only cover a subset of available methods and measures.

Naturally, direct physiological measures as FMRI, EEG, EKG, EMG, or TrMS are not available in net-based experimental scenarios. Indirect measures, however, such as accuracy, memory retrieval, attention, and reaction time measurement are available. Accordingly, the presentation of bodily triggers such as images showing bodies in space, bodies in action, and action affording cues, together with these available measures creates versatile options for investigating interactions between interactive body and media perception in a browser-based environment. Furthermore, most media types such as 2D and 3D images, text, video/webcam, and animation are available. Taken together with the complete programmability of media presentation, this allows complex interactive settings and experiments. This decreases the gap between lab and web. Thus, a significant part of embodied cognition research gains access to rich, web-based environments.

Several manipulation methods repeatedly used to investigate the connection between embodiment, cognitive processing and behavior are also available in the browser. Accordingly, seeing images (e.g.,, Lozano, Hard, & Tversky, 2008), reading (e.g.,, Borreggine & Kaschak, 2006), and preparing interaction with the environment (e.g.,, Borghi, 2004) were applied to manipulate body related representation activation during cognition. Thus, a browser-based experimental environment provides both (a) necessary bodily user interactions as touch, gestures, hand postures, and general actions such as moving objects to certain positions, and (b) body representation activating material presentation, such as images, videos, or descriptions of objects, bodies, or environments.

Especially for spatial media research Inter|act offers a wide range of experimental capabilities by measuring the effect of gestures, body related content, and visual feedback on media comprehension. This means the effects of both visually triggered bottom up (e.g.,, sensory feedback, visual input), otherwise triggered top down simulation body activation (e.g.,, action planning), and content processing. Accordingly, interact offers a broad range of 2D, 3D, and interactive content

To measure the impact of differently activated body representations several dependent variables have been used, as self-report questionnaires (e.g.,, Longo, Schüür, Kammers, Tsakiris, & Haggard, 2008), response accuracy (e.g.,, Hegarty & Waller, 2004), response time (e.g.,, Ionta, Fourkas, Fiorio, & Aglioti, 2007), limb/posture specific response time (e.g.,, same hand, postures) (Brass, Bekkering, Wohlschläger, & Prinz, 2000), and cerebral (motor, premotor) activity (e.g., Lorey et al., 2009). Except cerebral activity measurement, all measures, such as self-reports, response accuracy, and speed, are available within web based environments. Furthermore, the accuracy of browser based response time measurement browsers has been demonstrated to be sufficient for scientific studies (Reimers & Stewart, 2007).

3.2.1 Functional requirements for experimental environment Inter|act3D

Experimental environments limit and shape studies by their specific limitations and properties such as (a) degree of accessibility (study is mobile, stationary, hardware independent vs. specific (e.g., Intel CPU only), platform independent vs. specific (e.g., Mac OS only), (b) ability to control access to environment and data (e.g., ID check system), (c) available material presentation methods (timing, types, e.g., 2D, 3D, text, and multimedia), (d) amount of interactivity (e.g., mouse, text or touch input), (e) data collection, separation, and storage, (f) user and experiment separation, (g) measurement accuracy (e.g., limited touch point resolution, time measurement, and hardware jitter).

To fulfill these functional and developmental requirements, Inter|act was designed as a rapid web application that offers: *Accessibility* to participants by running Inter|act within the a common browser's flash plug-in that is available on nearly all computers. According to the Millward Brown survey 99% of computers have this plug-in installed (Adobe statistics, 2011). Thus, a study platform based on this technology reaches a broad range of local and remote systems and participants.

Nevertheless, creating a framework for web studies involves additional effort to control access to the study, allow secure remote data storage, to instruct participants, and to monitor participants, computer, and environment.

Access control is implemented by an identification code (ID) based user separation and additional password verification. Neither local nor remote data is accessible or modifiable by an unauthorized participant.

Material presentation is granted by flash's genuine ability to present and program animated and static graphics, film, multimodal content, and text. However, the conditions of media presentation, such as maximum presentation frequency, minimal responsiveness, and maximal content size are limited by the respective computer hardware available on the remote computer. Thus, Inter|act implements additional tests in order to verify that the remote computer is actually capable of presenting the study material as intended.

Interactivity is provided by the ability to use standard input devices such as mouse, keyboards, and touch surfaces to perform clicks, touch and gestures. Furthermore, several libraries allow the integration of additional interaction devices, such as joysticks, cameras, and the WiiController. The latter requires that the remote participants download and install additional software.

Data collection within Inter|act is implemented by recording any interaction between user and system. This enables data collection via questionnaire, interactive tests, camera movement, and response time measurement. The data is stored both locally in memory and remotely in a mySQL database.

Finally, *user separation* distinguishes between users by referring to unique userIDs. Furthermore, administrators own passwords to enter the administration area of Inter|act to perform administrative tasks such as data observation, data download, and settings adjustment, for example, to the list of allowed ExperimentIDs and UserIDs.

3.2.2 Developmental requirements for Inter|act

Besides functional requirements, the power of an experimental framework is determined by the conditions for implementing, developing, and extending the studies. To provide the conditions for quick development and sustainable maintainability, the development of this framework was designed so it limits factors that typically decelerate study development, such as:

- Difficulty of programming language
- Missing state-of-the-art developer tools
- Missing documentation
- License restrictions (e.g., distribution limitations)

The programming language used for developing with Inter|act is Action-Script 3.0, an ECMA Script dialect designed for client-sided programming of content presentation and interaction. The language is closely related to the common language JavaScript and easy to understand. It avoids direct contact with complex programming concepts often found in higher languages such as Java or C++ (Crawford & Boese, 2006). Furthermore, experience with JavaScript alike programming is quite widespread. Accordingly, it is the language of choice for supporting scientists, who usually have no profound computer scientific background. Furthermore, a great amount of documented and freely accessible online resources and code examples is available for Action-Script based programming. Moreover, multiple frameworks and functional libraries (e.g., for integrating devices, animating content) are freely accessible. By that it is a good choice next to alternative web application technologies based as HTML5/AJAX (JavaScript/HTML/CSS), .NET/Silverlight, or Java/ JavaFX.

Availability of tools and libraries is an important precondition for study development. Accordingly, development quality depends on the quality and availability of advanced programming tools such as debugger, profiler, documentation generators, tools for teamwork and distributed development, and functional libraries. For Inter|act this is provided by both free and commercial programming environments (IDE), usually based on established programming frameworks as the eclipse platform, to allow advanced Flex/Actionscript development. Furthermore, Adobe© provides fundamental tools as debugger, profiler, test suits, and documentation generator. However, tools are not as sophisticated as, for instance, the equivalents established for C++ development. This is acceptable since the web studies we have in mind should be manageable by scientists without specific computer-scientific background. Accordingly, they should not reach the complexity of full grown C++ projects that would additionally require complex development functions.

Documentation of the flash API, Flex API and flash based libraries is usually good and accessible via free online resources. Accordingly, Inter|act itself offers a complete documentation of its attributes, methods, and classes.

License restrictions are an easily overlooked aspect of software design. They define the limits and rights of providing and marketing developed products. The core libraries available for ActionScript such as Flex are open source and under Mozilla Public License, version 1.1 (MPL). Accordingly, compiled programs do not have to be distributed with the complete source code (see http://opensource.adobe.com/) and can be used and redistributed without further cost. Thus, proprietary software may be built on top of the included libraries, and the institution responsible for its implementation can keep their intellectual and developmental property.

Potential drawbacks of the chosen web based development is the additional developmental effort for implementing the necessary Client-Server architecture handling concurrent processes, network fluctuations such as loss of net connection, and inconsistent response times of remote function calls during data requisition and transmission. Furthermore, running the environment in a browser limits priority of hardware access, Thus, concurrent services and programs (e.g., virus scanner) could potentially lead to delays. Accordingly, the development of Inter|act involves implementing additional functions to assess the current system load and network quality to be able to react on the described challenges (e.g., by pausing or terminating the experiment).

3.3 Design and architecture

To fulfill the requirements for implementing web studies Inter|act consists of two major systems, a client-sided *front-end*, running in a web browser, and a server-sided *back-end* running remotely on an HTTP web-server (Figure 3.1, p.72). Thus, the developed studies run on any computer with net access and Flash compatible browser.

The front-end is the client-sided part of Inter|act. This means that this part is visible to the participant, contains the study modules, and records user interactions. The platform abstraction generated by Flash allows displaying and running Inter|act based studies with a broad range of display and input devices, such as mouse, keyboard, touch-pad, camera, smartboards, touch-tables, tablets, and laptops. More complex input such as 2D and 3D gestures, as typically found on multi-touch screens, are processed and interpreted by Inter|act itself. The locally stored data, such as the participant's text input, gestures, mouse clicks, and touch events are transferred to the back-end by modules automatically performing network connections at configurable points in time.

Furthermore, the front-end contacts functional web interfaces (web APIs) offered by web-service providers such as Flicker, Google, or Twitter. Dependent on the service, data is transferred either in JSON, XML, or clear text format via HTTP services. Accordingly, each module in an experiment can format and transfer its own data type. To sum, participants can reach Inter|act from most available computers, use most available hardware without additional installation, and interact with web content and remote services from within the environment while executing a study.

The back-end processes and stores received data after checking the validity of a simultaneously transmitted password. Data entries are disassembled according to the send data format and stored into the respective MySQL database tables. Each entry contains additional information, such as time of recording, owner (UserID), and experiment (ExperimentID). For performing statistical analyses in programs as R or SPSS the respective data can be exported and downloaded as a commonly structured data file (.csv).

3.3.1 General

Functions Inter|act provides the major functions necessary for conducting web based experiments referring data storage, settings, data administration, study entry control, main procedures, and checks (Figure 3.2, p.73). The provided functionality is partially based on existing packages, and encapsulated in respective *system* and *study* modules.

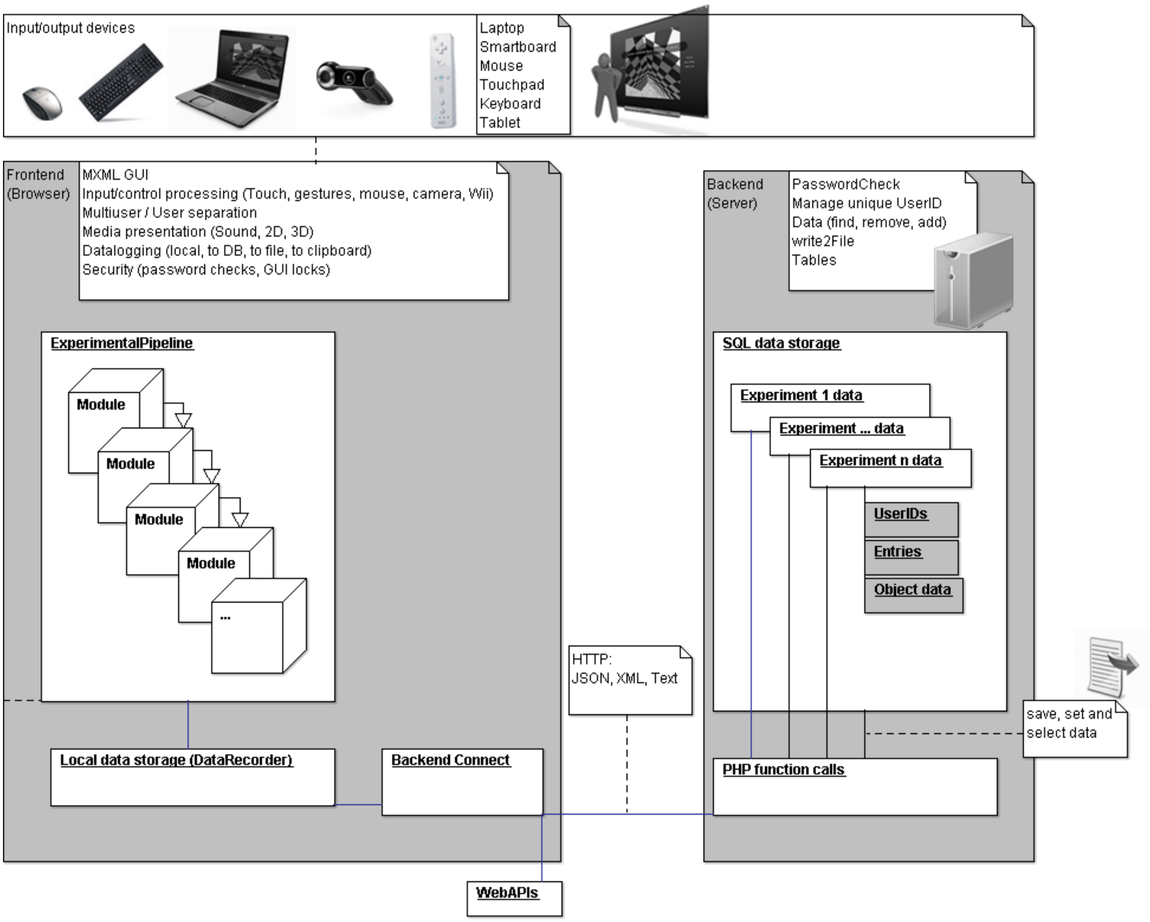


Figure 3.1. Logical structure of Inter|act with input device interfaces (upper box), user visible front-end (left box), and database related back-end (right box).

3.3.2 System vs. study modules

Packages integrated in Interact: For implementing the required functionality both self-developed and external libraries are used. Accordingly, Inter|act includes the open-source action script framework *Flex*, offering the application of graphical user interface components (e.g., Drawing Canvas) via MXML description language. Flex is under Mozilla Public License (MPL) and provides services for GUI design, event management, content display, web connections (e.g., HTTP services), and multiple smaller RIA related features. *Papervision3D*™is an open-source action script library under MIT license allowing 3D object integration within Flash environments. The current Flash version only supports limited 3D programming functionality. The *Tweener* class allows animation of parameter change over time, which is necessary for creating natural spatial object movement (e.g., smooth movement of a pushed image on screen). Finally, Inter|act includes the *FLARtoolkit*, a flash based augmented reality toolkit allowing the usage of image-based markers in front of web-cams to interact with virtual objects within web-cam video images. On top of these libraries, Inter|act implements the great amount of func-

Store data (local/remote)	Administration	Enter Study: Checks	Run study	Access restriction/checks

• Local data storage
  • Timer based
  • Event based
  • Store to RAM/ file/clipboard
  • Log Display
  • Send to database (mySQL)
  • Add metainformation to data (Timestamps, Unique ID, studyName, step name)
  • Data format design
• Remote data storage
  • Web Database (JSON / XML/Text)
  • Log Database
  • Remote get/write data
  • Create/delete tables
  • Filter entries
	• Set current IDs (userID, ExperimentID)
	• Allow/prohibit ID access (add, remove, list)
	• Activate/deactivate data storage
	• Load/unload modules
	• Jump to module
	• Check current data content (local data, remote data)
	• Load datasets (all, current user)
	• Set general settings (font size, controls visibility,...)
	• Save selected dataset as file (.csv)
		• Web accessibility by special web link
		• Generate unique user IDs
		• Check given ExperimentIDs
		• Control presentation (e.g. fullscreen modi, concurrent activities)
		• System check
		  • Browser compatibility (Type and Version)
		  • platform (CPU, OS, browser,...)
		  • additional installations (e.g. Add-ons,...)
		  • Network speed
		  • Display quality (color depth, framerate)
		  • Input device functionality
		  • Ask for extraordinary events
			• parallel running of multiple studies
			• parallel running of multiple participants
			• Present GUI (Images, Text, Container)
			• Material presentation (timer, 2D,3D, animation, video)
			• Structure study element (modules) presentation (by order, by time)
			• Timer for automatic data synchronisation
			• Controller contact (Mouse, Keyboard, webcam, Wii, Multitouch)
			• Control mouse cursor
			• Study modules integration
				• User separation
				• Password checks
				• Hidden functionality
				• Object disable (e.g. buttons)

Figure 3.2. Major functions provided by Inter|act in relation to typical functions necessary in a web experiment.

tions necessary for actually running and developing complex studies.

Inter|act implements its functional elements within a compact class structure assembled by both system and study function modules (Figure 3.3, p.74). System modules are directly embedded into *Interact3D*, whereas study modules are embedded into the system module *ExperimentalPipeline*.

The internal structure with the respective functions, attributes, and dependencies is illustrated according to the Unified Modeling Language (UML). Each box represents a distinct functional unit (classes) and contains three areas containing the unit name (e.g., *Settings*), and a subset of the adjustable attributes (e.g., *myUserID*) and functions provided by the unit (e.g., *clearData()*). The boxes are connected by arrows (aggregations) that indicate that the objects at the diamond shaped end (white) are composed of the elements at the thin end. The numbers indicate the amount of minimal and maximal instances of the respective unit.

3.3.2.1 System modules

Interact3D - parent module The parent module that owns all other modules is the *Interact3D* module. Accordingly, all modules communicate with each other exclusively through Interact3D. Moreover, it is responsible for creating other modules when they are necessary and destroys then when they are not used anymore. Accordingly, using functions provided by other system modules involves referencing it in relation to *Interact3D* (e.g., *Interact3D.systemmodule.method()*).

System modules To provide the central functionality of an experimental environment, Inter|act contains modules for local data storage (*DataRecorder*), administration of settings and data storage (*Settings*), communication with remote logging database (*LogDatabaseConnect*), connection to content provided by remote servers (e.g., *ImageServerContact*), connection to external hardware (e.g., *WiiConnect*), visual administration (*ConfiguratorArranger*), and presenting modules as structured experiments (*ExperimentPipeline*) (Figure 3.3, p.74).

DataRecorder is the central module for client-side data-storage. It stores arrays of entries (entryArr, entriesArrC). Each entry consists of 10 elements, experimentID, userID, entryType, five free data value fields, a time–stamp with date and time, and a time–stamp with milliseconds. To synchronize local and online data the attribute ‘newEntriesArrC’ stores all entries added since the last successfully approved synchroniza-

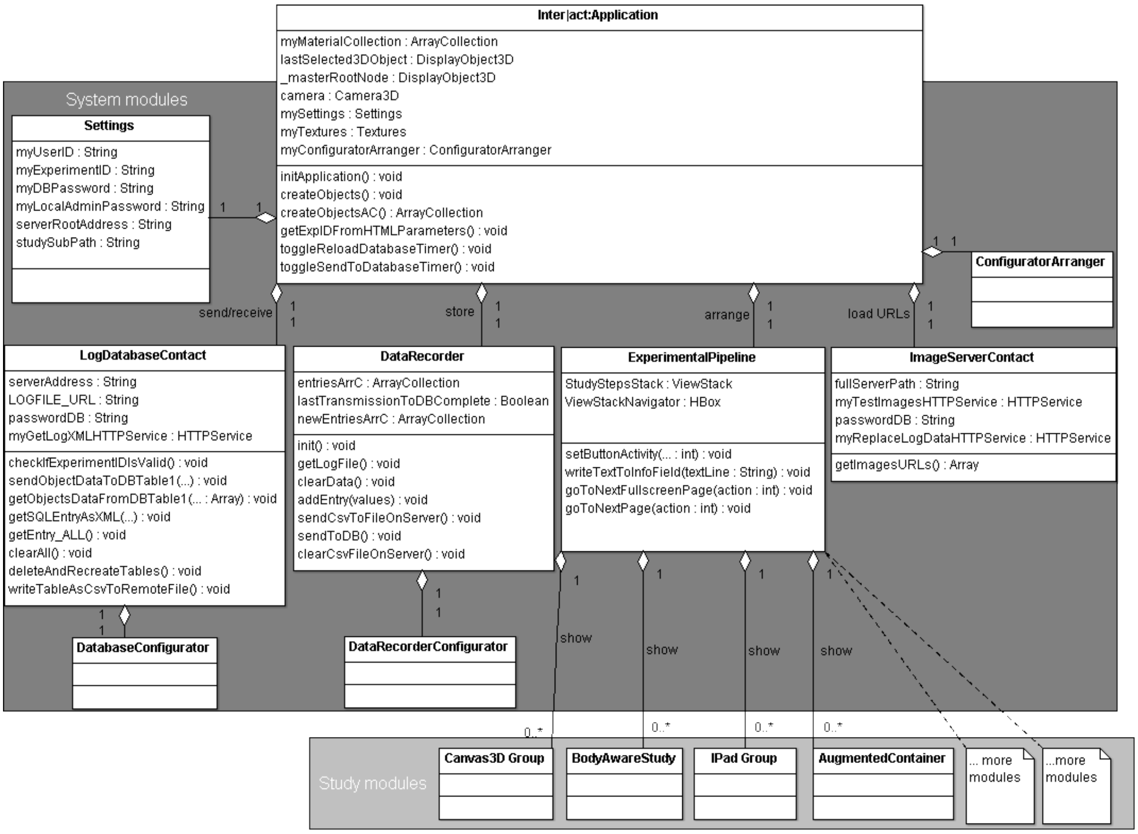


Figure 3.3. Inter|act, internal class organizational (UML) with examples of major methods and attributes. The major class Inter|act (top, center) consists of specified classes for storing settings, contacting the remote database for data recording, recording data locally, showing experiments with their respective components, contacting remote data services, and providing an interface for administration. Each of these functional system units are singleton classes, meaning they only exist once in the environment to avoid conflicts, indicated by the small numbers.

tion process. The module offers methods to add entries, initialize, clear, and send the local dataset. For accessing the web-server and sending the data, the DataRecorder module accesses the logDatabaseContact module.

DataRecorderConfigurator offers a GUI for the DataRecorder. It offers interface elements to add entries, clear entries, send entries to the database (DB), write entries to a file, and to download the current user's data as log .csv file. Furthermore, a window presents the respective data selection either as XML or clear text entries to allow direct monitoring of the locally and remotely stored entries.

LogDatabaseConnect is the central module for communication between Inter|act's client and server components. The module implements multiple HTTP services to allow synchronous server contacts, as for instance concurrent reading and sending of data. For communicating with the database, it transfers a password via HTTP service to the server (found in location stored in ServerAdress). If the server rejects the password, LogDatabaseConnect rejects any further communication. The major remote functions called through this connector concern data logging of user events, for instance, creating the tables to store data, getting entries from the database formatted as XML, clear the database data, replace entries in the database, store selected database entries to online files, send log entries to the database, and send object data to the database. Furthermore, the remote database checks the initially provided experiment identification number (ID sent via URL), administrates a list of currently aloud experiment IDs, and removes IDs from this list if an experimentIDs is marked as out of date.

DatabaseConfigurator is a GUI for the LogDatabaseConnect module. It offers interface elements to clear SQL tables, to recreate SQL tables request and present entries stored in the database, for instance all entries, userID specific entries, userIDcounter state, chat entries, or object coordinates.

ImageServerContact is the service returning a list of URLs to files currently lying on a specific path (fullAssetsPath) on the server. These images are either used within studies or for setting up the graphical environment of the study environment.

WiiConnect makes it possible to connect Inter|act to a special hardware input device, sending three dimensional motion information of a participant's controller movement (Wii bluetooth controller). Accordingly, such controllers allow 3D content interaction within study modules of Inter|act. WiiConnect is built on top of the public WiiFlash (bytearray.org) library, delivering both an API for accessing Wii controller events and a local server (WiiFlash Server) to transmit information from the controller to Flash applications. Accordingly, the remote computer must grant access to Bluetooth connections to connect the remote control device to the computer and the server recording the data sent by the controller. This separation into local server and client is a fundamental concept for connecting hardware controllers to Inter|act.

ConfiguratorArranger is the central GUI element grouping and presenting configuration related modules of other functional modules. This involves calling module specific administrative functions, changing settings, or reading status and data. The ConfiguratorArranger itself offers functions for global Inter|act adjustments such as adjusting global font-sizes, set and read userID information, set the environment into full-screen mode, load parameters delivered with the HTML links, set visibility of other configuration modules in the surface, show and set current experimentID, and remove experimentIDs.

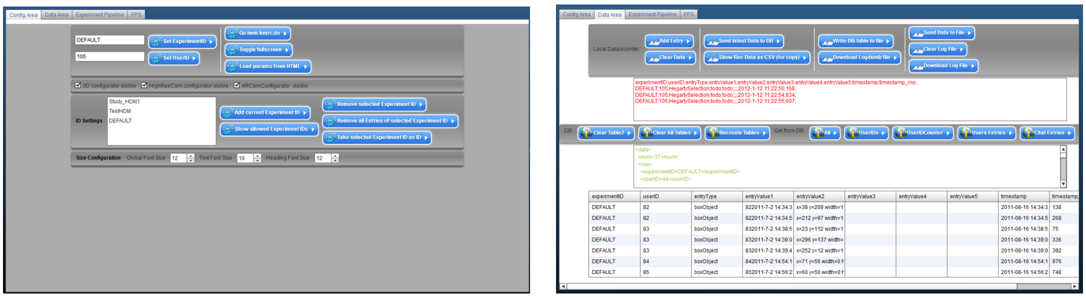
ExperimentPipeline: is the central module responsible for structured experiment presentation by allowing ordered presentation of study elements and pages. It is a stack containing the multiple elements a study consists of (study modules). According to the stack logic, the module offers both an optional visible navigation and an invisible navigation between the modules triggered by function calls. Accordingly, study modules reach the next or prior module by calling the goToNextFullscreenPage() function.

3.3.2.2 Study modules

The *ExperimentPipeline* module contains all elements presented to a participant in a study. Study modules can implement any functionality such as basic text presentation, questionnaire completion, image presentation, up to full blown interactive 3D environments. The following example study explains the conceptual connections between modules during study presentation.

Experimental pipeline: Posture study example Using the example of the body aware perspectives study (next chapter), we will explain the major elements involved in a typical Inter|act based study.

A typical study includes a declaration of admission, an instruction sequence, a pretest questionnaire, a training session, the study trials, and a post-test. Accordingly, the body awareness study pipeline contains nine modules: *Page_Welcome*, *SystemTest*, *Page_KeysTest*, *Page_Agreement*, *Page_ProbandDataQuestionaire*, *BAPInstruction*, *BodyAwarenessStudy*, *Page_ProbandDataPostSurvey*, and *Page_Goodbye*.



(a) GUI settings (b) Database and data configurator

Figure 3.4. Interact3D administration modules

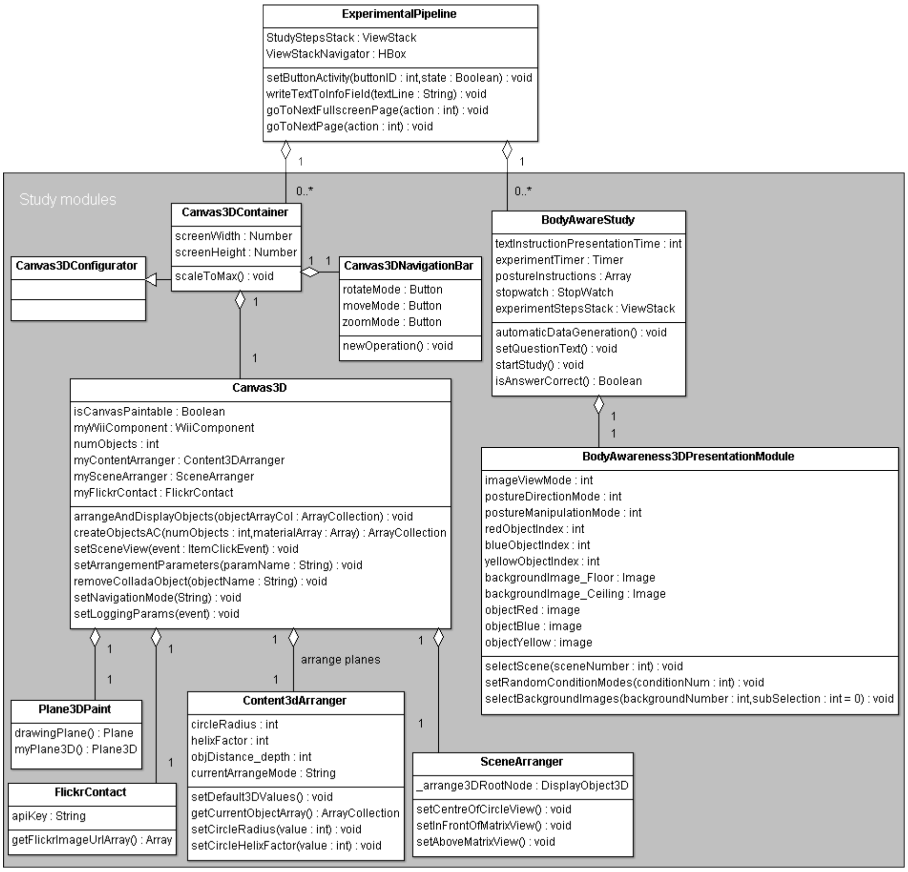


Figure 3.5. Group of classes (UML) implementing the modules Canvas3D and BodyAwareness with the major dependencies, attributes, and functions.

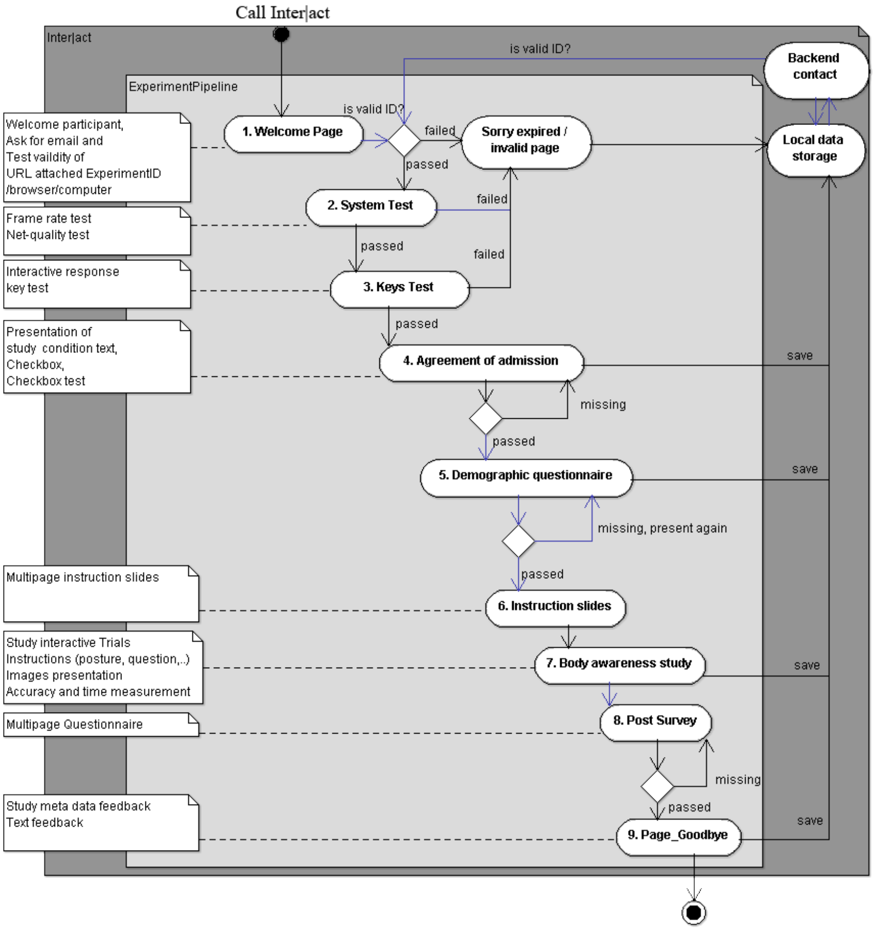


Figure 3.6. Example for module presentation order in body aware perspectives study. The order starts at the black circle (top) and traverses the pages according to the checks. A successful run ends at the circle at the bottom. The left most boxes describe the involved functions during module execution.

A typical order of a web based Inter|act study is described in Figure 3.6, p.77. Participants call up the study by clicking a special web link they receive by email. The link contains a unique experiment identifier (experimentID) attached to the end of the link (e.g., www.domain.de/ Interact3D.html#experimentID). Inter|act tests the validity of the attached ExperimentID by sending (via *LogDatabaseContact*) a request to the server. If the experimenID is identified as expired or invalid a fail page is presented and the study ends. If the experimentID is validated, the server returns a unique userID to the client. Any subsequently recorded data is marked with both unique experimentID and userID to identify the origin of the respective data entry.

The experimenter can enter the admin area at any time by typing a password on the top left corner of the input field and change the list of allowed or prohibited IDs. After positive ID check, the module containing the elements of the study is presented (*ExperimentPipeline* module).

The first module automatically presented to the participant by Inter|act's *Experiment-*

Pipeline is the *Page_Welcome* module. It covertly executes basic technical checks to assure that the system currently running the study fulfills the requirements for the upcoming study modules. This involves checking the browser version, CPU architecture, operating system, current screen resolution, installed flash version, and amount of installed plugins. As soon as the system check passes, a welcome text and email input field are presented. After the participant has entered and sent a valid e-mail address, the next module is presented by using the ExperimentPipeline's internal module navigation functions.

The second module, and accordingly the second step of the study, is provided by the *SystemTest* module. It presents a button to start a test of the system's visual frame rate and web based data throughput for a given period of time (standard 30 seconds) to assure that the system's graphic display and network connection is fast enough for the study. The test results are stored, send to the online database, and the next module is presented if the test result indicates that the system fulfills the requirements.

The third module is the *Page_KeysTest* module. It presents instructions to press the keys used for responding during the upcoming study to assure that the keys are available on the keyboard and that the participant knows their location. As soon as all keys have been pressed, results are stored, sent to the online database, and the next module is presented by Inter|act.

The fourth module is the *Page_AdmissionDeclaration*. It presents a text with conditions and regulations for study participation and a check box to agree with the conditions. Checking the box stores the user response and presents the next module.

The fifth module is the Page_ProbandDataQuestionaire, a questionnaire collecting demographics data such as age or gender. The completion status of the fields is checked and as soon as all fields are filled in, the data is stored and the next module is presented.

The sixth module is the *BAPInstruction* module, presenting instruction slides and navigation elements allowing the participant to read and switch between the slides.

The seventh module is the *BodyAwarenessStudy* module. It contains the actual study and presents a welcome text with final instructions, a radio selection to choose between two possible groups of participants, and buttons to start one of three possible trial blocks (Practice, Block 1, Block 2). Only one button can be pressed; the others are unlocked after having passed the other blocks. After clicking the only unlocked button, the semi-automatic trial presentation, containing a mixture of instructions and image judgments starts. Each user judgment is stored locally. At the end of each block the recorded data is send to the remote database. After the last block is finished a textual feedback and a button are presented. Pressing the button starts the next module.

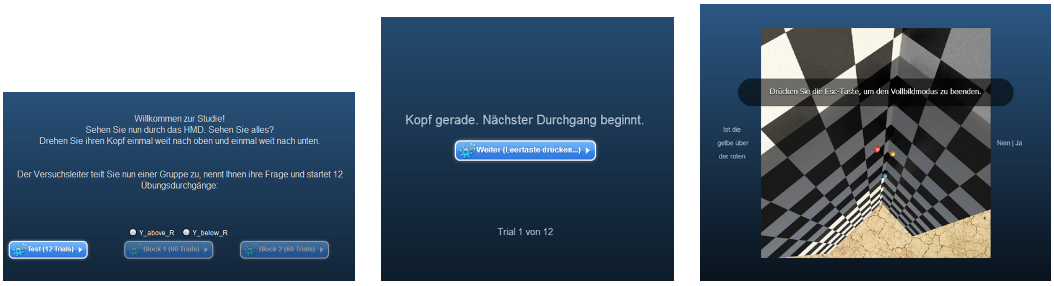
Modules typically store the user input (e.g., demographic data entries) in the local data recorder that is automatically synchronized with the online database.

The eighth module is the *Page_ProbandDatePostSurvey*, a questionnaire collecting information about potential problems during the study and final judgments of material samples. After completion, the next module is presented.

The ninth and final module is *Page_Goodbye*. It presents data to identify the recorded data in the study (e.g., userID, ExperimentalID) for potential questions and shows short goodbye message.

In all modules Inter|act provides the mechanisms to present the experimental modules to the participant (automatically or by active interaction), store the generated data, and handle interaction and synchronization with the remote database to assure correct and complete data recording.

Canvas3DContainer Another powerful module in Inter|act is Canvas3D. It is a collection of modules allowing interactive presentation of textual and visual material in an interactive 3D environment. Since a great amount of embodied effects is expected to appear due to the cognitive intersection between spatial perception and action execution, this module provides the bases for developing studies that



(a) Welcome screen (b) Posture instruction (c) Visual judgement task

Figure 3.7. Screenshots of modules used in body aware perspectives study

focus on these interactions.

Accordingly, Canvas3D consists of several necessary modules (Figure 3.5, p.76). It provides 3D object presentation (creation, imports), scene storage (camera view), automatic object arrangements (as cube, as matrix, as circle), 3D interactions (rotate, zoom, move, go to, resize, 3D responses), 3D animation, paint objects by clicking in space, texture selection (images/video/webcam, load from flickr), object visibility adjustment, mouse cursor adjustment, and logging of user interaction. Accordingly, it offers multiple ways to present action related primes and stimuli during interacting with the spatial environment.

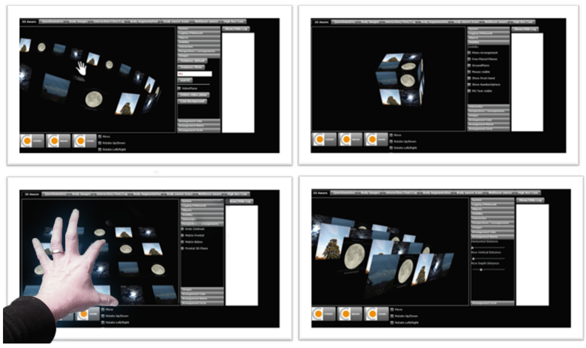


Figure 3.8. Screenshot: Canvas3D

The *Canvas3DContainer* module is the GUI element integrating the three major GUI elements in one resizable frame (Figure 3.8, p.79). The *Canvas3D* module is the 3D viewport containing all presented 3D objects and providing all functions for creating, manipulating, and interacting with spatial objects. The Canvas3DNavigationbar module provides elements to switch between interaction modes, such as spatial move, zoom, rotate, and to set several spatial movement constraints (e.g., limit movement to x-axis). The *Canvas3DConfigurator* module contains the GUI elements that allow access to the functions provided by *Canvas3D* by providing buttons, checkboxes, and input fields organized in a special arrangement called Accordion.

The Canvas3D module is accessible to the participant by the GUI elements of *Canvas3DConfigurator*. It provides broad functionality for loading, viewing, and interacting with 3D content. Furthermore, some functions are executed by specialized modules such as the *Content3DArranger, SceneArranger, Plane3DPaint* and *FlickrContact*. The available functions can be grouped as follows: (a) system functions, to set visibility of user navigation elements, set camera mode (orthographic/3D, xyz-position), reset scene to default values (reset camera, objects,...), and activate Wii support; (b) data logging functions, to enable and disable logging of user interaction as clicks in space; (c) object creation functions, to load static or animated 3D objects (e.g.,Collada import), and to paint 3D objects onto other spatial objects (*Plane3DPaint* module); (d) set visibility functions, to set the visibility of scene objects such as the ground-plane, mouse curser, and mouse-over-text-display; (e) response functions, to change the reaction of objects after being touched, and to enable and disable click response, push response, move2point response, move response, and zoom response; (f) perspectives and arrangements (*Content3DArranger* module) functions, to arrange multiple objects in a specific shape such as circle, matrix, or cube, set arrangement parameters such as object distance, radius, and spatial depth, and save viewpoints within spatial scenes (*SceneArranger* module); (g) object texture functions, to select images from lists, search on and load from flicker (FlickrContact), use images as object texture and load video as texture; and (h) canvas background functions, to select background images and set the image's transparency.

Further study modules Besides posture taking and 3D material, multiple elements can be and have been used to study body awareness during media perception. Accordingly, Inter|act implements basic examples for most aspects used to alter body awareness as gestures performance (e.g., Casasanto, 2007), altered self-observation via camera (e.g., Lenggenhager, Tadi, Metzinger, & Blanke, 2007), present spatial ability tests (e.g., Hegarty & Waller, 2004), or of several components such as questionnaires and system tests.

Augmented Webcam enriches the image delivered by a webcam by 2D and 3D objects (papervision3D) that moves with movement of a marked object in front of the webcam (see FLARtoolkit) (Figure 3.9, p.80).

Furthermore, there are modules involved in assessing specific abilities. *Vividness questionnaire:* is a digital version of the Visual Imagery Questionnaire (VVIQ), a standardized questionnaire to assess vividness of the participant's visual imagery (Figure 3.10, a).

HegartyPerspectiveTaking test is a digital version of a perspective taking ability test. It is used to assess the participant's ability to imagine at other points in space (Figure 3.10, b).

BodyAwareSearch task allows time controlled content presentation with optional fixation cross presentation and user click event recording (Figure 3.10, c).

Chat tool allows user communication via

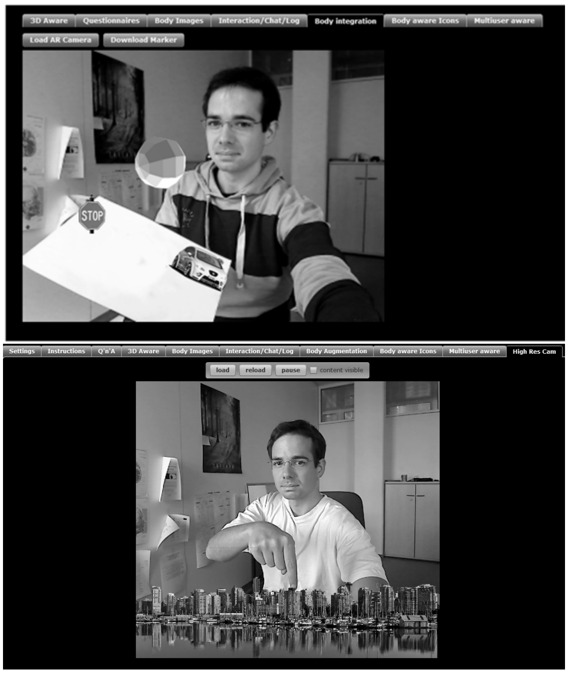


Figure 3.9. Screenshot: Augmented Webcam with virtual interactive elements.

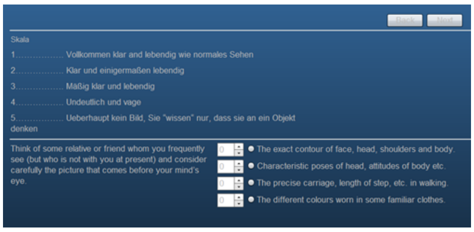
database. The module periodically sends and receives messages after a configurable interval (Figure 3.11, a).

Multiuser plane allows automatic exchange of data from multiple participants that click and create objects on a shared area. The area is automatically updated to allow cooperative working (Figure 3.11, b).

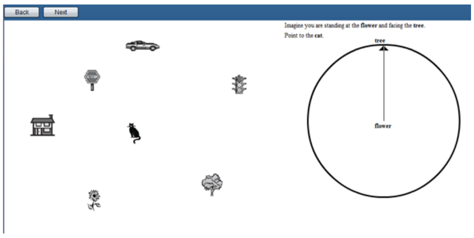
Box collect is a shared surface presenting multiple movable objects at positions synchronized over network between multiple users (Figure 3.11, c).

WordAction presenter reads mouse gestures and actions within a specific area and executes content presentation on correct gesture execution (Figure 3.12, a).

IPad component is a gesture controlled surface that allows interactions by left/right swift gestures. Moreover, additional elements such as spatial backgrounds or figures can be added to investigate the influence of spatial perception, gesture execution, or figure observation on im-



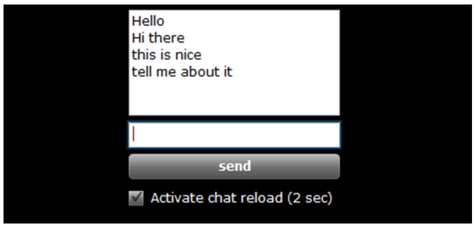
(a) Vividness questionnaire



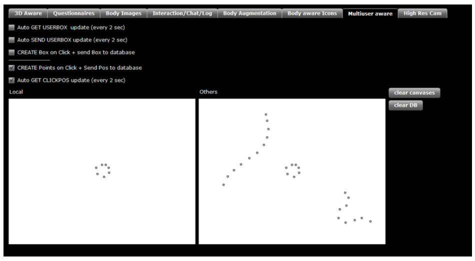
(b) HegartyPerspectiveTaking test

(c) BodyAwareSearch task

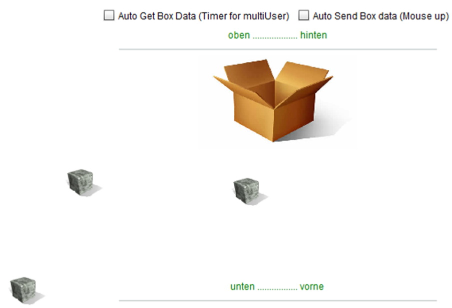
Figure 3.10. Screenshots: Study modules for user assessment



(a) Chat tool



(b) Multiuser plane



(c) Box collect presenter

Figure 3.11. Screenshots: Study modules for multiple user interaction

age perception (Figure 3.12, b).

Iconizer allows replacement of the mouse cursors by other body related or body unrelated cursors such as a rotated hand or simple arrow to investigate the influence of task irrelevant bodily cues (Figure 3.12, c).

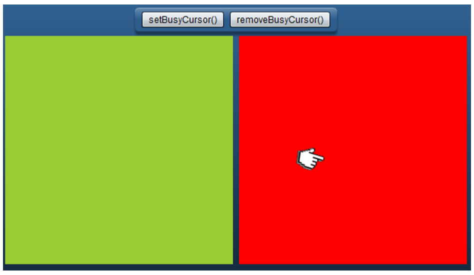
Assessment Center is a module for serial content presentation where participant rate presented material on a given rating scale. Navigation buttons and automatic storage of data is provided by the module.

3.4 Summary and conclusion

We presented the functions and requirements of a browser oriented experimental environment focusing embodied cognition research within applied interactive media platforms. According to these requirements, we developed the Inter|act3D framework, an efficiently structured framework for rapid experiment development and remote experiment conduction of embodied media perception research. It enables researchers to bring experiments commonly restricted to lab conditions quickly into a browser,

(a) WordAction presenter

(b) IPad component



(c) Iconizer

Figure 3.12. Study modules for action manipulation

allowing both lab and web studies. Accordingly, the gap between lab and web environments is significantly reduced.

Experiments running in Inter|act reach a broad range of technical platforms allowing to run studies in participants' familiar media environments and on their typically used media platform. Inter|act provides a broad range of modules allowing the investigation of interactions between many conceivable ways of bodily interaction (e.g., head postures, manual gestures, eye movement) and perception of media content (text, images, video, sound, 3D animation) within the recipient's natural habitat. Thus, the provided and presented modules and the overall system design significantly supports media oriented embodied media cognition research.

Chapter 4

Experiments: Concurrent body simulation

Abstract

The conducted Experiments followed two general purposes: (a) to demonstrate, that perspective image perception, a process hypothesized to involve a high amount of body posture simulation, interacts in a specific way with both simulated and taken postures, and (b) to deliver support that successful investigation of embodied media perception in common media environments is possible by using the experimental framework Inter|act3D.

4.1 Introduction

Future media is continuously merging media perception and media interaction. Thus, perception is typically accompanied by an observer's simultaneous movements, for instance by hand gestures or head movements. Accordingly, understanding the inherent connection between body and perception has particular meaning for current and future media cognition research.

Comprehending perspective images presents an important challenge for such interactive media perception. An observer's physical posture (finger gestures, head movement) is continuously changing and often discrepant from the posture implied by content such as a perspective image. For example, when looking straight ahead at a screen displaying an image of an arched cathedral ceiling captured from below, the perspective cues in the image would imply craning one's neck to look up. Actual posture, however, would not supply this information. Until today, the effect of both simulated and assumed posture taking on image perception has not been investigated.

How does an observer make sense of a visually implied perspective in light of contradictory postural cues? Established links between perception and motor activation suggest that the perspective implied by one's own posture and the perspective implied by an image are likely to be intimately linked. For example, observing someone taking a certain posture activates the same cerebral pre-motor and motor areas as when actually performing and processing the related vestibular and proprioceptive cues of the observed action (Alaerts, Heremans, Swinnen, & Wenderoth, 2009; Aziz-Zadeh, Wilson, Rizzolatti, & Iacoboni, 2006; Tettamanti et al., 2005). Due to that connection, observation of bodies can facilitate action execution. For instance, seeing a task-irrelevant left or right hand in the background during a color-judgment task facilitates responses with this hand (Ottoboni, Tessari, Cubelli, & Umilt, 2005; Tessari, Ottoboni, Symes, & Cubelli, 2010).

Such facilitation also occurs in more naturalistic and subtle contexts. Seeing a teapot with handle on the left or on the right facilitates later responses with the left or right hand respectively, and seeing objects typically handled with a specific grip facilitates performing that grip (Ellis & Tucker, 2000; Ellis, Tucker, Symes, &

Vainio, 2007; Tucker & Ellis, 1998, 2004). Even reading sentences that implicitly describe certain movements will later facilitate such movement planning (Fischer & Zwaan, 2008; Glenberg & Kaschak, 2002). Thus, visual and conceptual perceptual processes automatically influence sensorimotor representations and later action.

Critically, body representation activity itself can influence later visual perception and comprehension of posture related cues. Hence, even blind folded motor training affects visual recognition of movements within moving point lights (Casile & Giese, 2006). Even covert action activation when seeing hands performing a power or precision grip facilitates later categorization of objects as natural or artificial depending on the way these objects are typically handled (Borghi et al., 2007). In sum, perceptual and motor information are not independent, but rather perception informs body representations, and body representations inform perception (see Hommel, Musseler, Aschersleben, & Prinz, 2001 for a comprehensive framework).

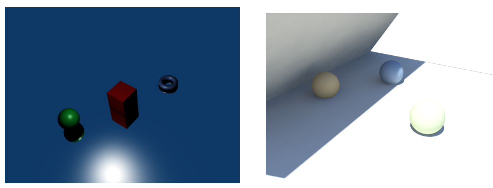
We apply this view of the interrelationship between perceptual and body representation processes to perspective images and suggest that accurately perceiving a perspective implied by an image involves simulating the posture that would be consistent with such a perspective. That is, we suggest that understanding the perspective presented by an image of an arched cathedral ceiling from the comfort of an office chair involves covertly simulating a head and neck posture congruent with the upwardly oriented perspective presented by the image. This relationship between perspective image comprehension and posture representation makes the clear prediction that assuming or simulating a posture consistent with the perspective implied by a perspective image should facilitate comprehension of that image relative to assuming or simulating a posture inconsistent with the perspective implied by an image.

That is, we predict a Posture-Image Compatibility (PIC) effect in the comprehension of perspective images without even presenting any bodies or action affording target objects. We tested this hypothesis in a series of five experiments, manipulating the compatibility of actual and simulated head and neck posture with the perspective implied by perspective images, and measuring the speed and accuracy with which the perspective images were comprehended.

4.2 Material development

In the following section we describe central considerations and steps involved in developing the visual stimulus material finally used in the experiments (Section 4.4.4, p. 90), to investigate the interaction between perception and posture taking.

Rendering All images were created in Autodesk© Maya© 2008, rendered by the photorealistic rendering software mental ray©. We decided against classical shading techniques such as Phong or Gouraud shading to preserve the impression of a natural environment. Realistic photographs on the other hand would not have allowed the necessary control of visual cues in our material. Accordingly, our synthetic images use a realistic lighting simulation based on global illumination, with sun simulation and the according surface reflections, shading, and shadows, preserving the impression of a natural environment (Figure 4.1).



(a) Phong shading (b) Global illumination

Figure 4.1. Selection of alternative lighting and shading options

4.2.0.3 Body and space perception

To identify the effect of posture taking on perspective image processing, we constructed special perspective material we could expect to involve covert head posture simulation without confounding side-effects. Accordingly, processing of these images should interact with both concurrently actually assumed posture taking, and concurrently simulated posture taking. We designed the material according to the subspaces created by body referential space perception, as described in Section 1.2 (p.6).

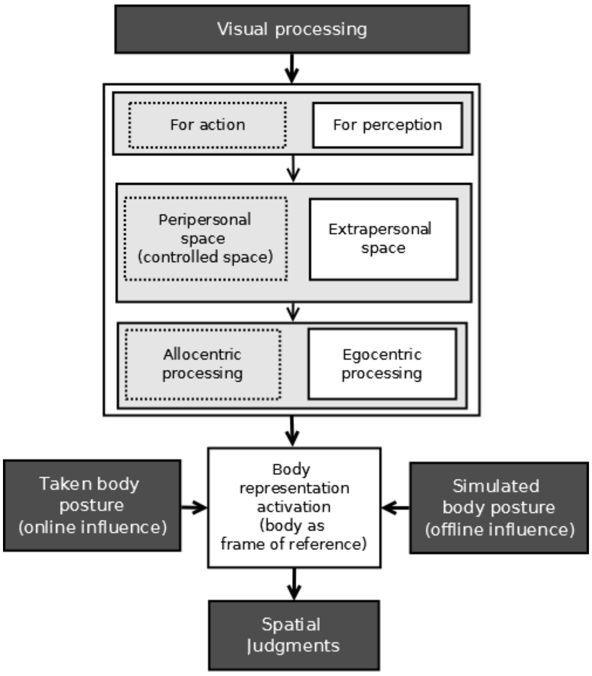


Figure 4.2. Space and body - subspace focused for construction of adequate visual material. We addressed the effect of both actual and simulated posture taking on spatial judgments of visual elements in extrapersonal space, seen from an egocentrical perspective during perceptual judgments.

Accordingly, our material addresses the following sub space (Figure 4.2, p.85):

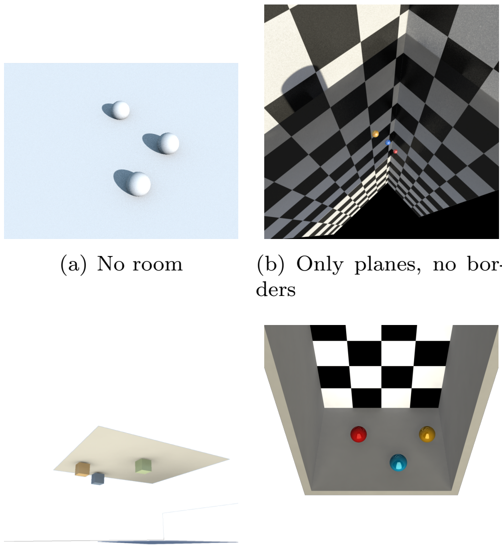
1. Visual targets are presented from an *egocentric* perspective
2. No presentation of concurrent action preparing cues
   (a) Targets are presented in *extrapersonal* space
   (b) No body elements or manipulable object presentation
   (c) View independent response action

Egocentrism vs. allocentrism A great amount of studies (see introduction) supports the strong connection between visual processing and body simulation. Since perspective visual impressions are widely found in both interactive media and embodiment research, interactions between posture-taking and perspective images are meaningful both for research and application.

Using specifically egocentric visual views is mandatory, because perspective images are necessarily egocentric, meaning that the observed scene is comprehended according to the physical point of view. Allocentric views would involve additional perspective taking, which we explicitly wanted to eliminate. However, avoiding allocentrism requires abandoning any presentation of objects suggesting perspective-taking, manipulable objects, tools, or people in action. These elements have been repeatedly identified to induce simulated perspective taking (e.g., Kessler & Thomson, 2010). Thus, we minimize the appearance of such objects presented in the stimulus material (Figure 4.3).

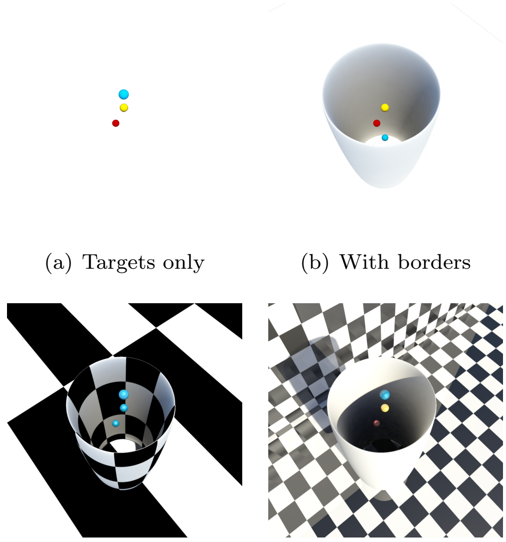
Body as frame of reference - 2D reduction The observer's physical body serves as a natural frame of reference in egocentric views. The comprehension of a visual setup (target arrangement) accordingly requires referring the spatial elements to the observer's own body. Accordingly, our material has to provide sufficient spatial cues and scene elements to allow this process (Figure 4.4).

To assure that participants make such self referencing, we reduced the amount of visual shortcuts that would have allowed image classification without such self-referencing by using 2D properties such as typical spatial positions, colors, brightness, complexity, and shape. For example, a night scene can be distinguished from a day scene simply by the amount of dark areas in the image. Furthermore, mutual object occlusion could be enough to make near far judgments without actual 3D comprehension. Such



(a) No room (b) Only planes, no borders (c) Ground (d) Partial box

Figure 4.3. Selection of alternative room options



(a) Targets only (b) With borders (c) With ground and texture (d) Complex texture

Figure 4.4. Selection of different amounts of spatial cues in material.

shortcuts typically disburden the cognitive system, and were expected to potentially reduce the size of the PIC effect. Accordingly, we chose arrangements of spherical target objects with no predictable color, hue, or order.

This additionally involved limiting the amount of perspective cues (perspective lines, relative size, occlusion, dust, depth of field (DOF), fog, relational objects, self-relation) to adjust the average difficulty of image perspective identification.

However, such limitation of cues automatically creates a certain degree of perceptual ambiguity (e.g., perceive looking up as down). Accordingly, finding the right balance between cue reduction and ambiguity was important.

Avoiding action preparation Finally, the absence of tools (e.g., cup, chair) and acting visual bodies additionally assured that no visual objects covertly induce action simulation. This additionally involves presenting targets not in near space (e.g., Figure 4.5) since perception of objects as within reach (near, peripersonal space) is known to relate to covert action preparation. Accordingly, processing of objects within reach affects attention (Davoli & Abrams, 2009; Eimer, Forster, Velzen, & Prabhu, 2005), spatial categorization (Coventry, Valdes, Castillo, & Guijarro-Fuentes, 2008), and visual processing accuracy (Abrams, Davoli, Du, Knapp III, & Paull, 2008). For extrapersonal space, these effects have only been reported with specific training.

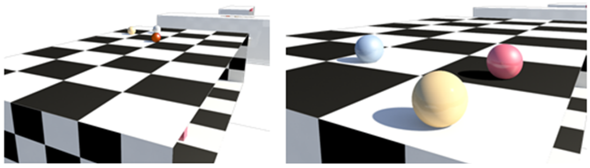


Figure 4.5. Stimulus material, peripersonal vs. extrapersonal targets in realistic light simulation)

However, since our own material was meant to understand the effect of posture taking on perspective image perception and not interactions between implied and executed response action, we additionally chose a response action unrelated to head posture taking and perspective viewing. Participants respond by horizontal hand actions (left/right hand key press), unrelated to explicit or implicit head tilting.

4.2.0.4 Compensating attention and perceptual preparation

Besides these general spatial considerations body perception also induces attention shifts and perceptual anticipation according to the current body awareness (review Summerfield & Egner, 2009). For example, seeing a person in an image usually guides attention towards the persons facial region and accordingly prepares for perceiving the expected facial features. Our material was designed to rule out or at least minimize the following three factors, since they would deliver alternative sources of an Posture-Image compatibility effect:

1. *Shift of attention* toward a target and away from the rest according to posture
2. *Anticipation* of expected stimuli and suppression of unexpected stimuli
3. *Motor preparation* for shift related movements (e.g., head tilt, eye movement, visual muscle preparation for near/distance/convergence)

Attention shifts according to an observer's posture, especially during eye positions and head postures. Accordingly, head up postures must be expected to involve covert attention towards the upper visual field, whereas down postures towards the lower field. Accordingly, perception of our stimulus material intends to avoid systematic advantages by covert downward or upward attention shift. This involves presentation of targets objects at random positions.

Furthermore, the attention bias involves the anticipation of expected features in the specific area. Thus, identification of an object is fastest if its silhouette matches the perspective primed by a verbal description of a perspective (Zwaan, Stanfield, & Yaxley, 2002). In a like manner, motor execution such as handwriting creates specific visual anticipation of matching upcoming visual result (e.g., Orliaguet, Kandel, & Boë, 1997). Moreover, attention shifting not only facilitates the identification of anticipated objects but also hinders identification of unexpected objects (Estes, Verges, & Barsalou, 2008). This suggests that the anticipation induced by posture taking could facilitate or impair object detection in the respectively compatible or incompatible part of the images. Accordingly, our chosen material allowed transformation of one perspective into the other simply by 180°rotation. Thus, the overall complexity and most image properties stay stable between perspective changes because images are identical except their rotation.

Finally, attention shifting can prepare the muscles necessary for scanning the image. Thus, imagining a vertical viewing direction prepares the according vertical eye movements involved in reckoning an object (e.g., Spivey & Geng, 2001). Moreover, observing someone's actions leads to preparation for looking at the next logical point of action (Flanagan & Johansson, 2003). Even thinking of spatial stimuli creates the according anticipatory eye movement (McMurray & Aslin, 2004).

To summarize, both posture taking (simulated and assumed) and perspective image comprehension create great amounts of attentional, perceptual, and motor expectations. Any compatible preparation could facilitate image processing. We rule out that an observed posture-image compatibility effect was simply based on incompatible attention, perceptual anticipation, or motor execution by designing stimulus material insensitive to these effects of posture-taking. Thus, the spherical target objects appear randomly around the image center. Furthermore, our targets were presented from viewing angles allowing the presentation of targets objects in a fix area around the center, independent from the current perspective. Accordingly, the targets were equally likely to appear in the upper and lower image part, regardless of the perspective of the image. Thus, no specific attention bias, perceptual expectation, or head and eye movement preparation would systematically facilitates judgments.

With this material we started running the experiments according to our specified goals.

4.3. Goals and hypotheses

To repeat, the following experiments had three major goals:

1. Demonstrate that perspective image comprehension involves body simulation by demonstrating interactions with assumed and simulated postures.

2. Demonstrate that embodied cognition research is possible in browser-based environments without special hardware.

3. Demonstrate integrity and reliability of the experimental framework Inter|act to perform such experiments.

As mentioned, the three major triggers of body awareness are (a) body action simulation, (b) body action execution, and (c) processing of body related content, such as seeing a body or a cup (Figure 4.6).

We expected that according to this concurrent body representation relatedness, both simulated and executed posture taking would generate interactions with the perception of perspective images as well. Accordingly, we assume that perspective image processing is facilitated in compatible and hinders perspective image processing in incompatible body reference conditions. The following methods and designs were chosen according to these assumptions.

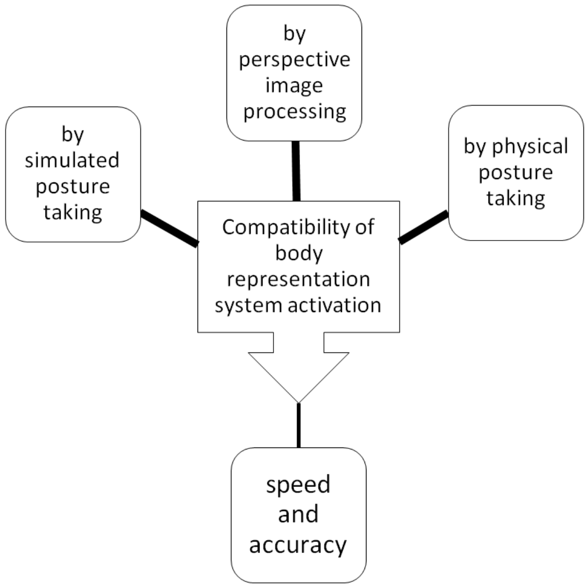


Figure 4.6. Interactions between simulated and physical body representations

4.4 General Methods

4.4.1 Design and participants

Design The chosen study design has to be capable of (a) identifying interactions between posture simulation and image processing and (b) compare the effect of actually assumed with simulated posture taking. Thus, all experiments employ a 2 (Posture manipulation: posture taken or posture simulated) by 2 (posture-image compatibility: compatible or incompatible) design. The design consists of the factors *Posture-taking-method* (PM), to distinguish simulated from executed posture taking, and *Posture-image-compatibility* (Comp), to distinguish between compatible and incompatible posture-view conditions (see Table 4.1, p.88).

Posture-taking-method describes the two possible posture taking strategies, the actual assumption of postures by physically bringing the body into a new posture and the simulation of posture taking while keeping the current pos-

Factor/Level:	**Level 1**	**Level 2**
Posture Manipulation (PM)	physical	simulated
Posture Direction (PD)	down	up
View Mode (VM)	floor	ceiling
Compatibility (Comp)	compatible	incomp.

Table 4.1. Table of factors and levels

ture. The factor *Comp* on the other hand describes the compatibility between the participant's currently processed visual perspective and his simulated or assumed posture. Thus, Comp is compiled by the two factors *view-mode* (VM) and *posture-direction* (PD). Compatible means, accordingly, that the presented image view matches the currently taken posture. We expect a significant, accordingly shaped interaction between taken-posture and content-perspective for both answer accuracy and response time.

Basically, we only consider upward and downward postures. The straight posture conditions were not considered in the compatibility analyses. According to our hypothesis, the processing of perspective images during straight posture is a hybrid that we would call semi-incompatible, whereas for the other viewing conditions only compatible or incompatible conditions exist. Furthermore, the straight posture serves as initial posture to assure that all posture taking starts from a common posture. Thus, the straight posture taking conditions are different from all other conditions in that they allow the participant to keep the initial straight posture, whereas for up and down postures an explicit posture taking is necessary. Thus, we focus on the more reliable up and down combinations and leave out the straight posture results in our analyses of the compatibility effect. Nevertheless, we will use them as an indicator for potential material problems.

Subjects All participants were native German speakers, had normal or corrected-to-normal vision, and showed no head related mobility impairments. In exchange for their participation, participants received a small payment of 7€, course credits, or volunteered (experiment 3 'mensa' and 4 'mobile').

4.4.2 Stimuli and apparatus

All experiments contain several major elements. Participants see a verbal posture taking instruction, see a perspective 3D scene containing three objects arranged in space and execute as fast as possible yes/no judgements about the relative position of the objects.

4.4.2.1 Apparatus

Screen setups and HMD The apparatus for presenting the material in Experiments 1, 3, and 4 is illustrated in Figure 4.8 (p.89) and Figure 4.7 (p.90, left panel). Participants sat in front of three vertically mounted and numbered flat screens (18 inch, 1280 x 1024, 75 Hz) with the middle screen directly in front of the participant at eye level. Looking at the upper or lower screen required tilting the head approximately 45 degrees upward or downward. All screens displayed the same content.

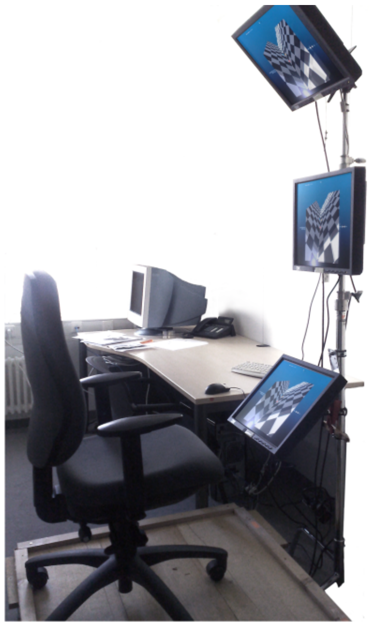


Figure 4.8. Three screen setup with screens directly facing the participant either while looking up by 45°, straight forward, or looking down by -45°.

The apparatus for presenting the material in Experiment 2 is illustrated in Figure 4.7 (p.90, center panel). The experiment was adapted to be conducted in a mobile lab constructed near a university cafeteria. Participants sat in front of a normal laptop screen (HP EliteBook 8530p) po-

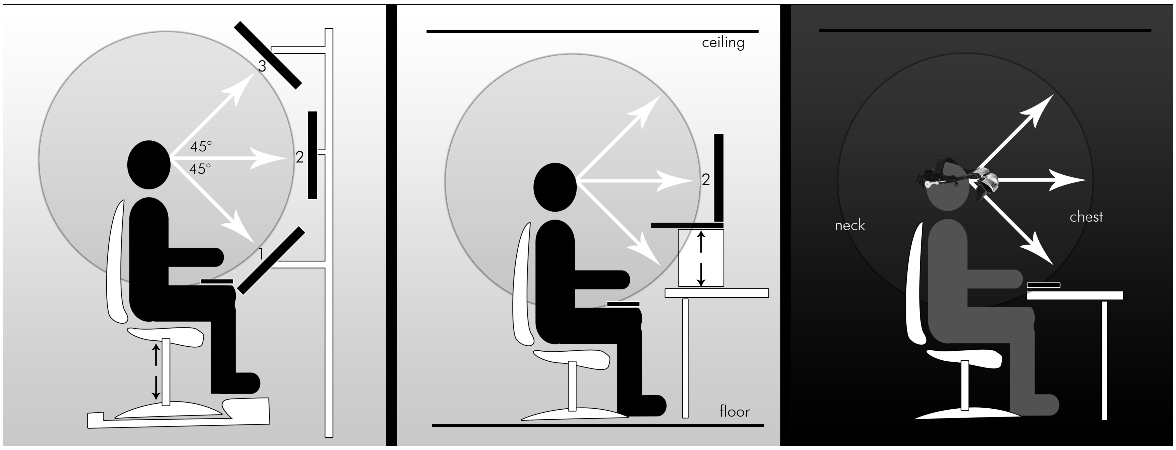


Figure 4.7. Experimental apparatus in Experiments 1,3 and 4 (left) with three screens, in experiment 2 with a single screen (center) and in Experiment 5 with an HMD in a darkened room (right).

sitioned in front of the participants. The screen had a 15.4-inch diagonal with a resolution of 1280 x 800. Participants sat in a cubical built with mobile walls.

In Experiment 5, the three screens were replaced with a Head Mounted Display (HMD; an eMagin Z800 3Dvisor with 800 x 600 resolution in each micro-display). This experiment was conducted in a completely dark laboratory.

In all experiments, participants responded via a USB keyboard resting on their knees or on a table in front of them (experiment 5).

4.4.3 Computer equipment - Special experiential target conditions

As a first step towards web experiments of posture related perception, the experiments were run on technical equipment typically available to future web-participants. Accordingly, the studies were run on computers typically found in homes with average speed CPU, normal sized laptops, and screens of average quality *(Desktop PC*: Pentium 4, 3GHz, 1 GB RAM, Windows XP, *Laptop PC*: HP EliteBook 8530p Notebook PC, Intel Core^{TM}2 Duo, 4GB RAM, Windows XP).

All experiments were based on the framework Inter|act3D. Accordingly, the experiments were conducted within Inter|act3D in a standard web-browser environment (minimum Firefox 3.6 / Internet Explorer 8) with Flash plugin (minimum Flash 10.1) installed, a combination available on 99% of laptop and desktop computers.

4.4.4 Images

The stimulus images consisted of 800 x 800 (600 x 600, Exp.5) pixel 2D images showing three colored spheres at random positions from either upward or downward perspective (Figure 4.10, p.91). The image background was black with two overlapping checkerboard colored planes seen from either above (downward oriented images) or below (upward oriented images). The upward and downward oriented images were identical except for a 180° rotation.

Each image contained three visual cues that support cognitive reconstruction of 3D interpretation: (a) vanishing lines, (b) object sizes, and (c) texture density.

The three colored spheres (red, yellow, and blue) appeared at distinct positions without mutual occlusion within a 5x5 grid centered at position (3, 3) (Figure 4.9, p.91).

The theoretically possible 15625 ball position combinations of the three balls were limited by the following rules: (a) the three balls must

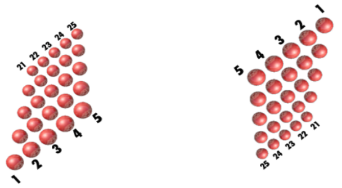


Figure 4.9. Possible ball positions and indices for upward (left) and downward view (right)

each have different positions and (b) the yellow and red target balls must always be on different rows (to give a meaning to the term textitabove). Learning of specific sphere arrangements was avoided by selecting from the allowed 11500 (=25*20*23) random combinations around the image center. An observer's potential preference for specific locations within an image would therefore not influence task difficulty.

4.4.5 Verbal instructions

There are several alternatives for how to present implicit posture taking instructions. Participants can read a textual description silently, aloud, listen to them from a recording, or hear them from the instructor. Since motor activation is involved in seeing (Buccino et al., 2001), listening to (Buccino et al., 2005), and by reading (Zwaan & Taylor, 2006), we decided for practical reasons to let participants read silently by themselves.

We additionally left out any words such as head, finger, body, or any explicit body reference in the instructions to avoid that the instruction itself would suggest using the body as spatial frame of reference during the task. A great amount of studies supports that even implicit presentation of bodily cues in verbal content activates cerebral motor activity (Fischer & Zwaan, 2008). Such activation is even stronger for explicit motor imagery, for example when imagining finger tapping (e.g., Porro et al., 1996). Instead of referring to the body the posture-taking instructions referred to external elements (e.g., look at screen 1). Only in the last

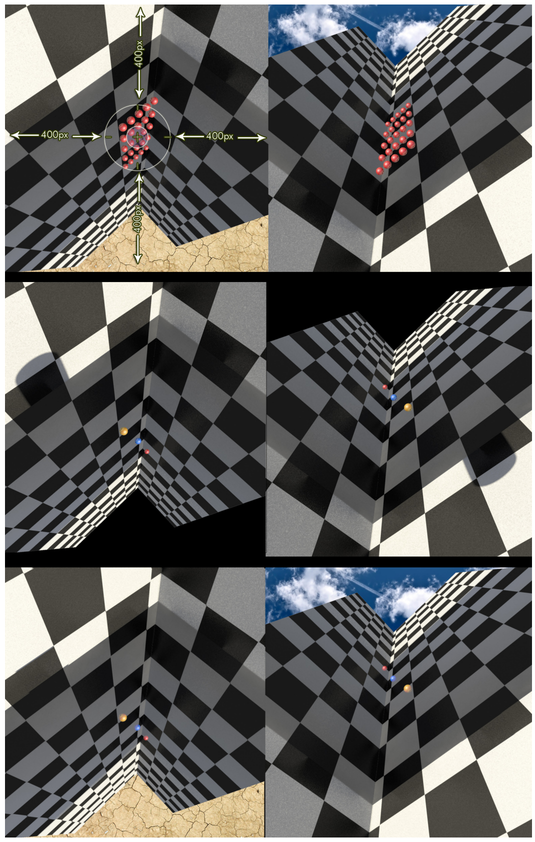


Figure 4.10. Stimulus perspective images. The upper panels show the 25 possible sphere positions in both perspective images. The middle panels show example stimulus configurations with no sky or ground added. The bottom panels show an example stimulus configuration with sky and ground added (Experiments 4 and 5).

experiment (Experiment 5), explicitly reference to the body was used again.

4.4.6 Procedure

After initial instruction, participants completed 120 judgments of perspective images preceded by 12 practice judgments and with a 60-second break halfway through the main judgments. Every participant was exposed to each condition in random order. Practice trials were one trial of each condition in random order, whereas the study trials consist of 10 randomly ordered trials per condition.

Before making each judgment, participants were instructed to actually take or to simulate taking an upward, straight or downward oriented posture. As mentioned in the methods section the straight postures were not included into the compatibility effect analysis

In Experiments 1, 2, and 4, posture manipulation happened by asking participants to look at the lower screen (identified as 'screen 1') or at the upper screen (identified as 'screen 3'). In Experiment 3, participants were advised to look at the ceiling or floor. In Experiment 5, we initiated posture taking by short behavioral instructions such as put your "head to chest" or "head to neck." In all Experiments, participants simulated posture taking after reading an instruction to simulate the respective posture manipulation.

All practice and study trials followed the same procedure. Instructions were delivered after participants were in a natural, forward oriented posture.

Participant indicated that they had complied with postural instructions by pressing the space bar, at which point a 1 second or 500ms (only Experiment 5) fixation cross appeared in the center of the screen immediately followed by an upward or downward oriented stimulus image. The task was to answer the following questions correctly as quickly as possible: "Is the yellow behind the red sphere?" (pilot study, Experiment 1); "Is the yellow above the red sphere?" (all later experiments); or "Is the yellow below the red sphere?" (2nd part, HMD study). Participants answered by pressing the left arrow key for *no* and the right arrow key for *yes*.

After completion participants were debriefed and interviewed in a questionnaire with respect to their subjective interpretation of the perspective cues present in the images and to ensure that all instructions were clearly and easily understood. They labeled examples of the stimulus images as one of five possible perspectives (steep down, down, straight, up, steep up).

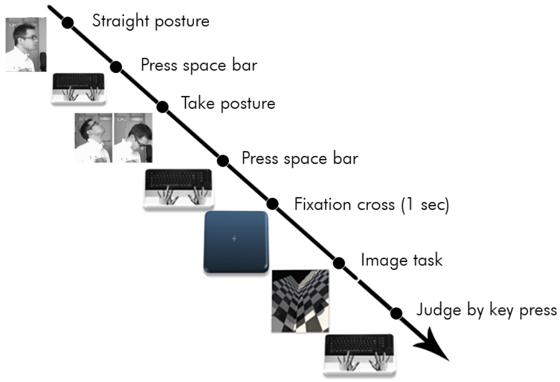


Figure 4.11. Trial steps with participant action, instructions and response

4.4.7 Data Screening & Coding

4.4.7.1 Dependent measures: speed, accuracy, reading time

Perspective image comprehension was assessed with response speed and accuracy in Experiments 1 to 4, and response speed in Experiment 5.

Before analyzing the data was filtered by excluding (a) initial training trials, (b) straight trials, (c) responses faster than 150ms, (d) responses slower than 10 seconds, and (e) responses after reading instructions slower than 10 seconds (less than 0.5% of trials in any given experiment) and the remaining response latencies were log transformed (J. Cohen & Cohen, 1983; Tabachnick & Fidell, 2006). Responses faster than 150ms were seen as responses without possible image comprehension, whereas delays of 10 seconds were seen as a loss of concentration.

Mean response latencies before transformation in pilot study and Experiments 1, 2, 3, 4, and 5 respectively were 3436ms (SD=1995ms, Pilot), 3173ms (SD=1709m, Experiment 1), 1440ms (SD=802, Experiment 2), 1938ms (SD=1415, Experiment 3), 1811ms (SD=1009, Experiment 4), and 2088ms (SD=1278, Experiment 5) .

Relative (M_{rel}=percentage of accuracy) and absolute accuracy measures (M_{num}=number of errors) from pilot study (M_{num}=16.7, SD=8.9; M_{rel} =.86, SD=.344) and Experiment 1 (M_{num}=29.5, SD=22, M_{rel}=.76, SD=.43) absolute (num) and relative (rel) response errors were relatively infrequent in Experiment 2 (M_{num} = 3.36, *SD* =3.7) and Experiment 3 (M_{num} = 8.1, SD=8.58, M_{rel}=.91), even less frequent in Experiment 4 (M_{num}= 2.5, SD =2.7), and were nearly non-existent in Experiment 5 (M_{num}=1.44, SD=1.8). Because of this increasingly restricted range, we did not consider answer accuracy in Experiment 5.

To control whether participants actually read our instructions, we additionally analyzed the time participants took to read and follow the posture taking instruction. This reading time was quite stable for pilot study (M=2198ms, SD=1181ms), Experiment 1 (1861ms, SD=1163ms), Experiment 2 (M=1902ms, SD=1047ms), Experiment 3 (M=3138ms, SD=1530ms), Experiment 4 (M=2009ms, SD=624ms), Experiment 5 (M=2350ms, SD=499ms). The long reading time in Experiment 3 might be the effect of the intended generally higher degree of distraction during this experiment.

4.4.7.2 Standardization and Compatibility

In order to compare across measures, we standardized both response time and answer accuracy are reverse scored response latency so that higher numbers indicated better image comprehension for both measures. Both measures were then coded according to whether the head posture direction and image viewing direction were compatible (upward perspective with upward posture and downward perspective with downward posture) or incompatible (upward perspective with downward posture and downward perspective with upward posture, (Estes, Verges, & Barsalou, 2008), although original posture direction was retained as a methodological factor in analysis.

Data were coded according to whether the taken posture was *compatible* or *incompatible* to the presented image perspective. *Compatible* conditions included either taking a looking up posture followed by a looking up image perspective or taking a looking down posture followed by a looking down posture whereas *incompatible* conditions included either taking a looking up posture followed by a looking down image perspective or taking a looking down posture followed by a looking up image perspective.

Expectation	Compatible	Incompatible
Assumed	+	-
	+	-
Simulated	+	-
	+	-

Table 4.2. Table of expected performance in conditions. '+' means higher accuracy and faster responses, '-' lower accuracy and slower responses.

Generally, we expect the following pattern of image comprehension scores reflecting that performance in compatible trials is higher than in incompatible trials (Table 4.2, p.93):

4.5 Experiments

The following experiments are intended to deliver support for an interaction between posture taking and perspective image comprehension. The experiments investigate the effect with different material such as material with reduced perspective cues (Pilot, Experiment 1), slightly ambiguous material (Experiment 2 and 3), and unambiguous material (Experiment 4), and under different conditions, either in a normal lab (Pilot, Experiment 1,2, and 4), dark lab (Experiment 5), or under web equivalent conditions (Experiment 3) (see Figure 4.12).

4.6 Pilot study

The pilot study assesses the experimental environment Inter|act, the validity of recorded data, and the participants' comprehension of task and instructions, and looks for first indicators of the posture-image compatibility effect.

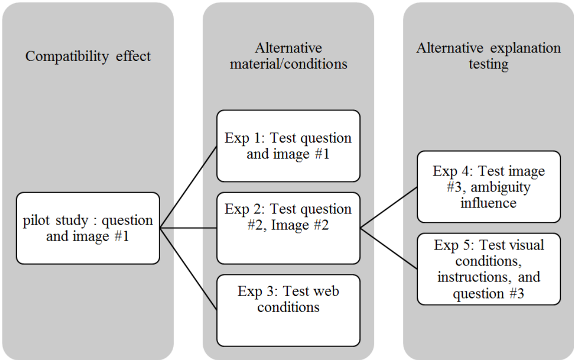
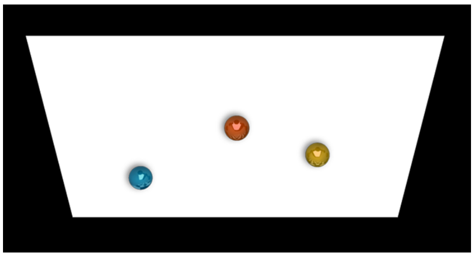
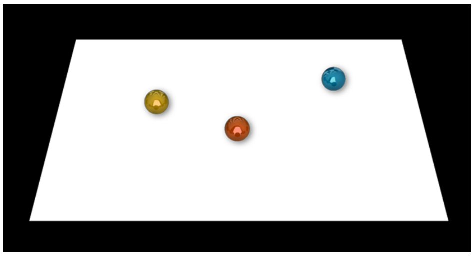


Figure 4.12. Experiments, steps, and targets



(a) Upward view



(b) Downward view

Figure 4.13. Material used in pilot study

4.6.1 Method

Participants and design Ten participants (70% female) completed 120 judgment trials in front of a three-screen setup (Figure 4.7, left panel, p.90)

Apparatus, material, and procedures The perspective image material used in the spatial task consisted of three colored balls (blue, red, yellow) in front of a white background (Figure 4.13). The cues providing spatial information about the arrangement of the balls, the shape of the plane, the shadow of the balls, and minimal size differences.

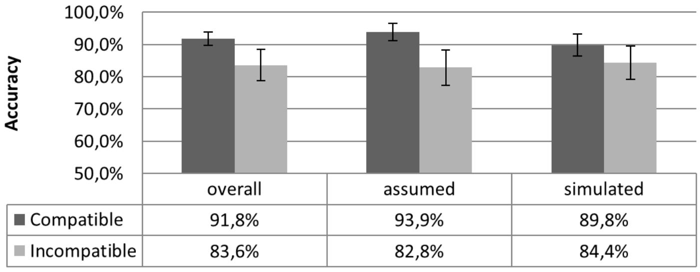
Participants answered correctly and as fast as they could to the question "Is the yellow ball behind the red ball" after assuming ("Bitte schauen Sie auf Bildschirm 1, 2, 3") or simulating ("Bitte stellen Sie sich vor, Sie schauen auf Bildschirm 1/ einen Bildschirm/ Bildschirm 2") taking a posture.

4.6.2 Results

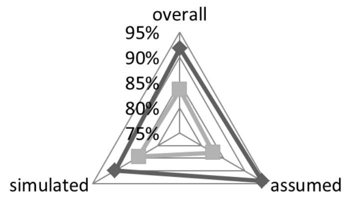
Despite a limited number of participants, we analyzed the resulting data to identify potential problems and look for early indicators of the PIC effect.

Technical From a technical point of view, the experiments environment worked faultlessly. According to our questionnaire, reports and data records no unintended data modification, temporal, or visual interruptions appeared during presentation, and participants immediately read and understood instructions and tasks as intended.

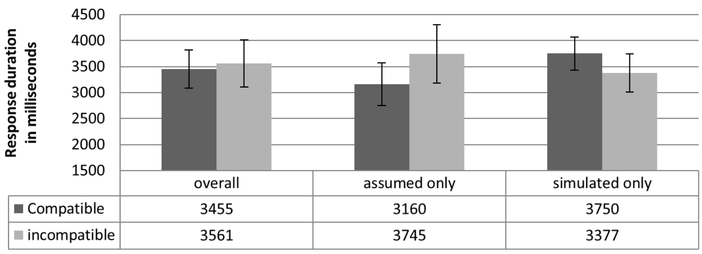
Results Accuracy (120 trials) A 2 (posture-image compatibility: compatible or incompatible) x 2 (posture manipulation: posture taken or posture simulated) within-subjects ANOVA on accuracy yielded neither a main effects of posture manipulation method, F(1,9)=103, p=.756, partial η^2 =.011, nor of posture-image compatibility, F(1,9)=3.203, p=.107, partial η^2 =.262. However, the pattern of absolute values meets our compatibility effect assumptions. Accordingly, participants showed a high accuracy of 91.8% in compatible posture-image conditions, whereas low accuracy in incompatible trials (83.6%, Figure 4.14, (a) and (b), p.95). The equivalent pattern appears for assumed and imagined posture taking trials.



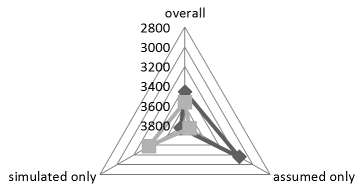
(a) Accuracy, higher accuracy in compatible than in incompatible conditions.



(b) Accuracy as radar chart. Outlying values mean higher performance. All compatible conditions show higher accuracy.



(c) Response time shows compatibility effect between actually assumed posture taking and perspective image processing



(d) Response time as radar chart. Outlying values mean higher performance. Only actually assumed posture condition shows faster responses in compatible conditions

Figure 4.14. Results pilot study, accuracy (a,b) and response time (c,d) overall (a), as general posture compatibility (overall), during actually assumed posture (assumed), and during simulated posture taking trials (simulated).

Results RT (pure, 120 trials) A 2 (posture-image compatibility: compatible or incompatible) x 2 (posture manipulation: posture taken or posture simulated) within-subjects ANOVA on response speed yielded no main effects. However, a significant interaction between posture manipulation and compatibility effect appeared, F(1,9)=6.722, p=.029, partial η^2 =.428. The expected compatibility effect appears for physical posture taking (incompatible -585ms) and reverses for imagined posture taking (compatible -373ms)(Figure 4.14, (c) and (d), p.95).

Results Reading Time A 2 (posture-image compatibility: compatible or incompatible) x 2 (posture manipulation: posture taken or posture simulated) within-subjects ANOVA on reading time yielded a significant main effect of manipulation method, F(1,9)=5.300, p=.047, partial η^2 =.371.

This reflects the different duration of reading instructions for imagining and assuming postures . Accordingly, the effect supports that the participants really read the instructions as we intended.

4.6.3 Discussion and conclusion

Analyzing the pilot study data supports that the technical equipment is ready for a complete experiment. The overall accuracy and parts of the response speed data matches the expected compatibility pattern. However, the limited number of participants does not really allow further interpretation of these results. With additional participants, we might find a significant compatibility effect. Moreover, the reading time pattern suggests that participants, although the instructions repeat, constantly read the instructions. Accordingly, the next experiment is identical to the pilot but involves more participants.

4.7 Experiment 1

Experiment 1 is the first experiment fully investigating the appearance of a compatibility effect between posture taking and perspective image comprehension. Accordingly, it intends to determine whether posture taking influences perception of images typically perceived with either a compatible or incompatible posture.

4.7.1 Methods

Participants and Design Twenty-nine participants (9 male, 20 female (=69%), Mean age = 23.41, SD= 3.3) were presented with two types of perspective images after either actually assuming or imagining one of three head postures.

The following detailed analyses have been conducted to explore and check several aspects of the applied material and procedures. Accordingly, both a 2 (Posture manipulation: posture taken or posture imagined) by 2 (posture-image compatibility: compatible or incompatible) design and a 2 (posture manipulation: posture taken or posture simulated) x 3 (posture direction: downward, straight or upward) x 2 (image view: downward view or upward view) design will be used.

Apparatus, materials, and procedures The apparatus and procedures were identical to the pilot study.

4.7.2 Results (PM*VM*COMP)

Posture-Image Compatibility We analyzed the response time data with a 2 (posture manipulation: posture taken or posture simulated) x 2 (image view: upward view or downward view) x (image-posture compatibility: compatible or incompatible within-subject analysis of variance (ANOVA) on response speed results (Figure 4.15, p.97).

The ANOVA on response time revealed a marginal main effect of viewing mode, $F(1,28)= 3.621$, $p=.067$, partial $\eta^2 =.115$), and a significant interaction between posture taking method and compatibility effect, $F(1,28)= 5.083$, $p=.032$, partial $\eta^2 =.154$. Both are qualified by a significant three way interaction between Posture Manipulation method, View Mode and Compatibility effect, $F(1,28)= 4.377$, $p=.046$, partial $\eta^2 =.135$. These results indicate that participants had problems with upward images. Thus, the compatibility effect, if at all, could only appear in the less problematic down image trials. This is supported by simple comparisons. The only significant simple effect appears between compatible and incompatible trials for imagined downward view conditions, $F(1,28)= 4.322$, $p=.047$, partial $\eta^2 =.134$. Judgments after imagined compatible postures (2999ms) are performed significantly faster (-311ms) than imagined incompatible postures (3310ms). None of the other compatibility comparisons (Upward+physical, upward+imagined, downward+assumed) were significant.

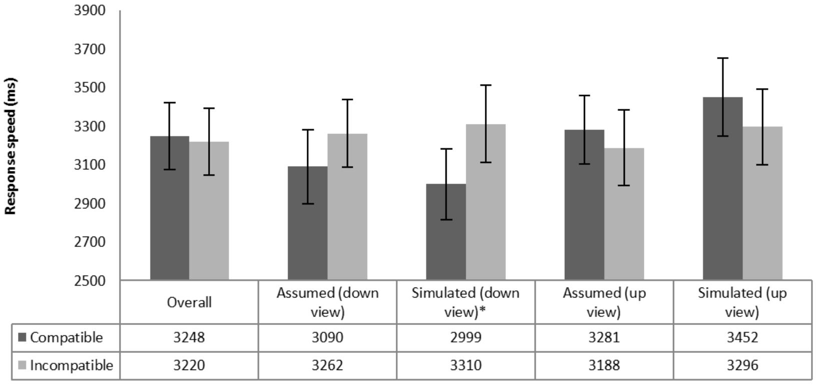
The equivalent analysis of response accuracy showed no significant effects (ps>.212).

4.7.2.1 Summary

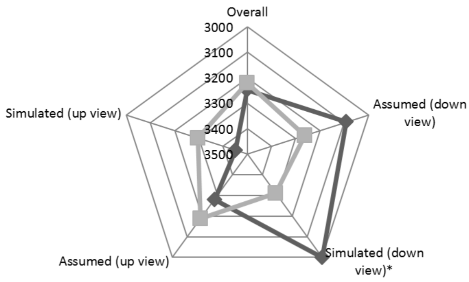
The results from this analyses suggests that the processing of upward view images creates problems. Since we are interested in the appearance of a posture-image compatibility effect, we analyze the data split by upward and downward views, again without the straight posture trials involved.

4.7.3 Results (straight trials only, split by VM)

To receive additional information about potentially problematic properties of down and up image perception we additionally analyzed the results from straight posture trials only, in a 2 (posture manipulation: posture taken or pos-



(a) Response speed, combined up and downward view, split by image type.



(b) Response speed, PIC effect for both assumed and simulated posture taking in down views (right half), but not for up views (left half). Accordingly, responses are faster in compatible down views

Figure 4.15. Results Experiment 1, speed overall, during assumed posture and during simulated posture trials

ture simulated) x 2 (image view: downward view or upward view) within-subject analysis of variance (ANOVA) on response time. The ANOVA yields the main effect of viewing mode, F(1,28)= 10.308, p=.003, partial η^2 =.269, where judgments of downward views (2955ms) where executed faster than upward views (3249ms). Furthermore, we found a trend for an interaction between viewing mode and posture taking method, F(1,28)=3.122, p=.088, partial η^2 =.1, that indicates that this difference was driven by the imagined posture taking, where the difference between down and up view was 480ms (2893ms vs. 3374ms), whereas for physical posture taking only 106ms (3017ms vs. 3124ms).

We correspondingly analyzed the accuracy data and found a strong trend indicating that the accuracy of judgments in upward images (M=.70) was clearly worse than in downward images (M=.80) image perspective, F(1,28)= 4.176, p=.051, partial η^2 =.130.

We correspondingly analyzed the instruction reading time, finding the main effect of manipulation method that reflects the different instruction length leading to longer reading times for imagined trials (1830ms) compared to assumed trials (1392ms), F(1,28)=31.451 , p<.001, partial η^2 =.529.

4.7.3.1 Summary

To summarize, the image processing in straight conditions supports our interpretation that the two image perspectives were processed differently. Participants had problems with interpreting the upward images which leads to less accurate and slower responses.

4.7.4 Results (120 trials, split PD and VM)

To additionally investigate whether participants actually followed the instructions as intended, we performed a 2 (posture manipulation: posture taken or posture simulated) x 3 (posture direction: downward, straight or upward) x 2 (viewing mode: downward perspective or upward perspective) within-subjects ANOVA with separate factors Posture Direction and View Mode.

Results ReadingTime The 2x3x2 within-subjects ANOVA on reading time yielded a main effect of posture direction, $F(1,28)= 34.038$, $p<.001$, partial $\eta^2=.549$, a main effect of Posture Manipulation, F(1,28)= 7.589, p=.010, partial $\eta=.213$ and the qualifying interaction between Posture Direction and Posture Manipulation, $F(1,28)= 9.181$, $p<.001$, partial $\eta^2=.247$. This indicates that participants read instruction throughout the experiment as intended.

This reflects our expectation that different instruction length leads to respective reading time differences. Accordingly, if participants read the instructions as intended, the respective pattern appears (Table 4.3, p.98). The main effect of posture manipulation appears because the rather short assume posture instructions are read faster (1897ms) than the longer simulate posture instructions (2164ms). Moreover, we find the main effect of posture manipulation. Physical straight instructions are read fastest (1582ms) reflecting that participants only had to stay in their prior posture without specific additional understanding. Taken together we receive the observed interaction between Posture Manipulation* Posture Direction and the main effect of Posture Direction.

Expected duration	Down	Straight	Up
Assumed	+	0	+
Simulated	++	++	++
Received duration	Down	Straight	Up
Assumed	+	0	+
	(2075)	(1582)	(2034)
Simulated	++	+*	++
	(2237)	(2078*)	(2187)

Table 4.3. Pattern of expected and received reading time for checking participant compliance per condition.

A small but surprising result is that judgments after imagined straight posture taking was faster than expected (2078ms). This was probably due to the instruction "imagine there was a screen in front of you") and might indicate that participants did not completely read the instruction.

To summarize, participants reading duration results support that they generally followed the instructions as expected. Only for the imagined 'straight' instruction, participants appear not to read and accordingly not simulate the described element as intended. One explanation might be the object they had to imagine (screen) was already visible in front of them. Additionally, participants reported this aspect as irritating in the post questionnaire. Since in all other conditions the addressed element was a screen, we wanted to keep the element stable. Accordingly to the observed irritation, we will replace the imagination element 'screen' by something not already visible.

4.7.5 Results questionnaire

The results from the questionnaires presented at the end of the experiment confirm the conclusions from the statistical analyses. Answering the question "is the yellow ball behind the red ball" and the overall task was often described as difficult. Participants were uncertain what was meant by 'behind' in this task and asked from what position they should decide that. This delivers strong support that the question implies perspective taking we did not intend. Furthermore, some participants completely failed to see a spatial order in the presented images, a precondition for executing spatial judgments. Accordingly, participants started additional cognitive processes such as looking for 'the trick' to solve that seemingly difficult task or taking irrelevant image properties as a supposed indicator for the correct answer such as shadow or colors.

In addition, the posture taking instruction related to the numbers on the screens (e.g., look at screen 1). This lead to two reported strategies, the first group covertly translated the number into up, straight and down, which made our effort in avoiding these concepts useless. A second group tended to perform small control looks at the numbered screen before imagining looking at the screen to verify they think of the correct one. This caused actual posture taking in the imagined posture taking condition.

According to the perceived task difficulty, most participants desired additional practice trials.

4.7.6 Discussion and Conclusion

To summarize, we did not find a general compatibility effect. Above all, problems with image interpretation and question comprehension seem to have covered the effect.

We found clear differences for perception of upward and downward images. Although most participants had insurmountable problems with image interpretation, others, especially with upward images, could not interpret the spatial scene due to perspective ambiguity. These participants reinterpreted the images by simulating other or multiple alternative spatial perspectives. According to our hypothesis, this involves the simulation of different postures during image comprehension. Thus, no stable bodily frame of reference was provided during spatial image interpretation, making both the image interpretation and the judgment task more difficult than intended.

However, analyses split by image perspective indicate that the posture-image compatibility effect can appear if the conditions do not involve the problematic image view mode, in our case the upward image. Accordingly, we identified the posture-image compatibility effect for judgments in downward view images after imagined posture taking. Thus, the next experiment uses (a) easier spatial image material, (b) a task that does not refer to the ambiguous behind and in front logic, and (c) more intuitive screen labels to avoid head movement before imagination.

To determine if this effect was caused by our manipulation we repeat the study with accordingly adjusted material, namely easier image material, and a more intuitive question.

4.8 Experiment 2

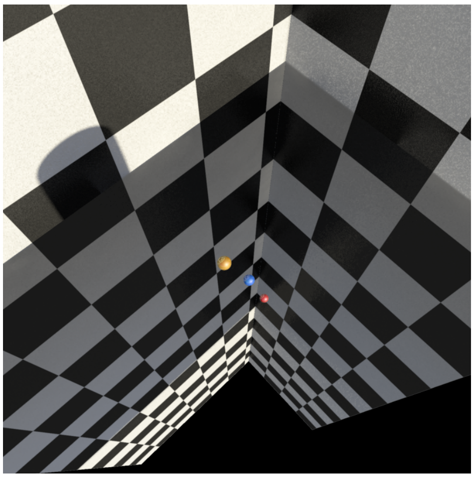
In Experiment 1 we identified that participants perceived our judgment question "is the red ball behind the yellow ball?" as unambiguous. Furthermore, spatial interpretation of the presented images was difficult for some participants. In Experiment 2 we replaced the judgment question and stimulus material by versions we expected to eliminate the observed ambiguity problems.

4.8.1 Methods

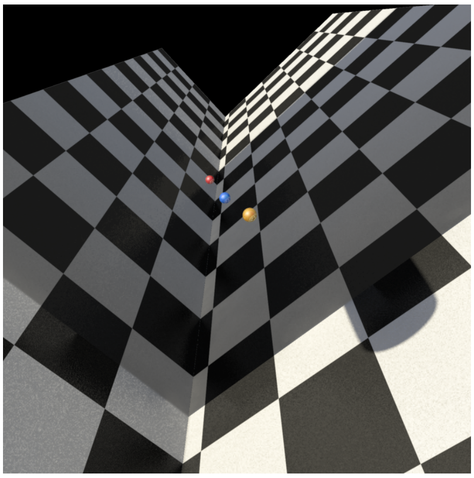
Participants and design Thirty participants (mean age = 24.6, SD=2.67, 70% female, 90% right handed) completed the procedures using a screen based stimulus display and stimulus images without ground or sky present (Figure 4.16, p.100). During post-experimental interview, two participants indicated that they interpreted the perspective in the images differently than intended and were excluded from analysis. The experimental design was similar to that used in experiment 1, except that we disregarded straight posture trials and the first 12 practice trials in further analyses.

Apparatus, material and procedures The apparatus is exactly the same three-screen setup as in Experiment 1 (Figure 4.7, left panel, p.90). However, to avoid the observed problems during Experiment 1, we changed several study elements. A new question was provided, thus participants answered to "is the yellow above the red sphere?" instead of "is the yellow behind the red sphere?". The vertical judgments were intended to be easier than the confusing distance judgments we used in Experiment 1.

Moreover, we replaced the perspective image stimuli by versions with stronger perspective cues such as background, textures, shadows, and lines to generate a more realistic integration of the target spheres into a more realistic lighted scene (Figure 4.16, p.100).



(a) Downward view image



(b) Upward view image

Figure 4.16. Perspective material used in Experiment 1

Participants answered correctly and as fast as they could to the question “Is the yellow ball above the red ball” after assuming (“Bitte schauen Sie auf Bildschirm 1, 2, 3”) or simulating (“Bitte stellen Sie sich vor, Sie schauen auf den unteren Bildschirm / ein Haus/ oberen Bildschirm“) a posture.

4.8.2 Results (straight)

Before analyzing the differences between up and down posture taking trials, we verify that both types of images (upward, downward) are processed without significant differences. Thus, we again compare judgments during straight posture taking.

The analyses involved 1120 (28*40) trials of 28 participants. The mean accuracy of trials was at 97% (M=.97, SD=.075). Reaction time showed a normal latency (Mean RT=1450ms, SD=570). The mean reading time was at 1811ms (SD=805).

We analyzed these data with a 2 (posture manipulation: posture taken or posture simulated) x 2 (image view: upward view or downward view) within-subject analysis of variance (ANOVA) on the pure response speed. The ANOVA yields a main effect of manipulation method, $F(1,27)= 4.565$, $p=.042$, partial $\eta^2 =.145$. Accordingly, additional imagination slowed down judgments significantly (assumed=1377ms, simulated=1523ms). In contrast to Experiment 1, judgments of upward perspectives (1476ms) did not differ from judgments of downward images (1425ms), $F(1,27)= 1.517$, $p=.229$, partial $\eta^2 =.053$. Thus, the applied material solves the problem of asymmetric perception observed in Experiment 1.

We accordingly analyzed the accuracy data and neither found a significant difference between physical trials (.975) and imagined trials (.973), $F(1,27)= 0.053$, $p=.820$, partial $\eta^2 =.002$ nor between downward (.984) and upward images (.964), $F(1,27)= 2.604$, $p=.118$, partial $\eta^2 =.088$. Accuracy data only shows very slight indicators (-2% accuracy, p=.118) that processing of upward images might have a tendency to be slightly more demanding than processing of downward images.

To summarize, the results support that the new image material is appropriate for investigating the compatibility effect. Both accuracy and speed under both viewing perspectives is comparable in the neutral straight condition.

4.8.3 Results (up+down)

Posture-Image Compatibility The effect of actually assumed and simulated posture taking on image comprehension is graphed in Figure 4.17 (p.102). We analyzed these data with a 2 (posture manipulation: posture taken or posture simulated) x 2 (posture-image compatibility: compatible or incompatible) x 2 (posture direction: downward or upward) within-subject multivariate analysis of variance (MANOVA) on standardized response speed and accuracy as recommended by Davidson (1972) and O'Brien & Kaiser (1985). The MANOVA revealed only the predicted significant main effect of posture-image compatibility, $F(1,27)= 6.175$, $p=.019$, partial $\eta^2 =.186$. Image compatible posture led to better image comprehension than image incompatible posture. Looked at separately (Figure 4.17, panel c and d, p.102), response speed was marginally significant, $F(1,27)= 3.875$, $p=.059$, partial $\eta^2 =.126$, and answer accuracy reached significance, $F(1,27)=4.751$, $p=.038$, partial $\eta^2 =.150$. Both posture taken, $F(1,27)=1.249$, $p=.256$, partial $\eta^2 =.048$, and posture simulated, $F(1,27)=8.493$, $p=.007$, partial $\eta^2 =.239$ reached significance and created a significant compatibility effect.

4.8.4 Summary

Our results provided initial support for the predicted PIC effect. However, that two subjects misinterpreted the perspective implied by the images indicated that still some degree of perspective ambiguity is implied by the stimulus images. In order to verify that the PIC effect generalizes to image comprehension with non-ambiguous images, and thus does not solely reflect posture-dependent image reinterpretation, we will conduct Experiment 4 and use visual material with even more cues supporting the image interpretation. However, before that we test the robustness of this effect within typical conditions during web based experiments.

4.9 Experiment 3

In Experiment 2 we demonstrated the PIC effect for the first time. To determine if the effect is robust enough to appear in web environments, the primary goal in Experiment 3 ("cafeteria study") was to replicate the effect under typical conditions found in such environments. This involves sitting in front of a single screen, with additional distraction provided by environmental noise and social interactions. Accordingly, this experiment was conducted in a room of the university cafeteria.

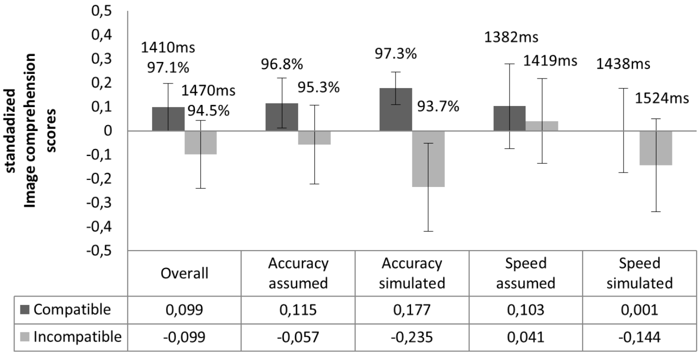
4.9.1 Methods

Participants and design Twenty-seven participants, mean age 21.78 (SD=3.32), 12 male, 15 female, 89% right handed, were presented with images of spatial object arrangements and asked "Is the yellow ball above the red ball?". The experimental design was similar to that used in Experiment 2.

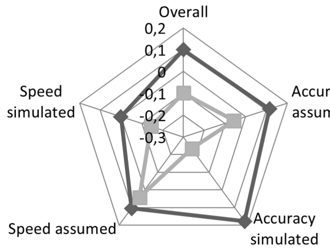
Apparatus, Materials The applied material was exactly as in Experiment 2 (the no-sky-ground material), whereas the three screen array was replaced by a single laptop screen (Figure 4.7, center panel, p.90).

To test the robustness of the compatibility effect in distractive and web-like environments, we replaced the three screen array with a normal single laptop screen. In order to demonstrate the influence of prior posture taking on image perception, participants always returned into straight posture after posture taking (e.g., look to the ceiling). We expected equivalent posture taking effects because head posture taking still generates a typical continuous stream of feedback from muscles and ligaments in the upper back, neck, and head musculature, and from the vestibular organ; an effect easily perceivable after turning around one's own axis by sitting on a rotating chair.

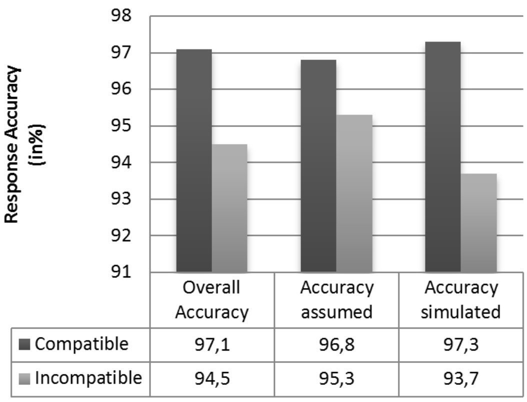
Moreover, we used a cafeteria environment where participants were more distracted than in a controlled lab environment and usually in the mean of doing concurrent activities. Accordingly, this time participants volunteered to



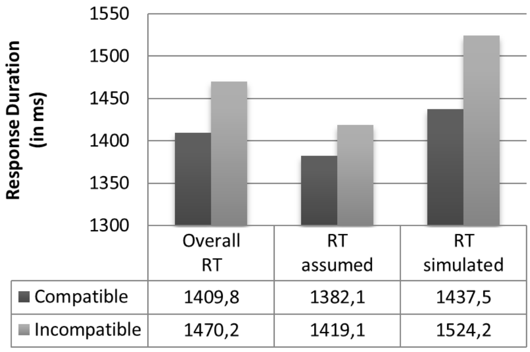
(a) Results showing compatibility pattern in all conditions.



(b) Radar chart of results. Distance between compatible and incompatible results indicates strength of compatibility pattern in accuracy results after simlated posture taking



(c) Accuracy, real values show that compatible trials create mor accurate responses



(d) Response time, real values show that compatible trials create faster responses

Figure 4.17. Standardized image comprehension collapsed across measure and conditions ("Overall") as well as by measure (Accuracy, Speed) and posture manipulation (Assumed, Simulated), Experiment 2.

approximate the higher degree of necessary voluntariness of web participants.

Procedures Participants were tested in groups of up to three people. Each participant listened to a verbal instruction given by one of three instructors, describing the upcoming material and control usage. They were instructed to answer correctly to the question "is the yellow ball above the red ball?" as fast as they could as soon as the image appeared. Procedures where identical to those used in the other experiments except for returning into a straight posture after having assumed a posture, indicated by "look at the floor/ceiling". The only gratification given for the experiment was a bar of chocolate.

Participants answered correctly and as fast as they could to the (german equivalents of the) question "Is the yellow ball behind the red ball?" after assuming ("Please look at the floor / screen / ceiling") or simulating ("Please imagine looking at the … “) posture taking.

4.9.2 Results

Posture-Image Compatibility The effect of assumed and simulated posture taking on image comprehension is graphed in Figure 4.18, (p.104). We analyzed these data according to the other experiments with a 2 (posture manipulation: posture taken or posture simulated) x 2 (posture-image compatibility: compatible or incompatible) within-subject multivariate analysis of variance (MANOVA) on standardized response speed and accuracy. This yielded a main effect of Posture-Image Compatibility, $F(1,26)$=5.150, p=.032, partial η^2=.165, Wilke's lambda=.835, in which compatible images were more easily understood than incompatible images. However, the effect was qualified by a significant 3-way interaction of Dependent Variable, Posture Manipulation method and Compatibility, $F(1,26)$=4.946, p=.035, partial η^2=.160, Wilke's lambda=.840.

Looking at the simple comparisons indicates that simulating inconsistent posture taking significantly increases response errors relative to simulating consistent postures, F(1,26)=6.777, p=.015, partial η^2=.207, whereas actually assuming an image inconsistent posture increases response errors relative to image consistent physical posture only on absolute, non significant values, F(1,26)=.356, p=.556, partial η^2=.014 (Figure 4.18, panel c, p.104).

This indicates that the PIC effect is primarily caused by response errors in the imagined posture conditions. However, an equivalent, although non-significant, compatibility pattern appears in judgment speed between image inconsistently and consistently assumed posture taking judgments, $F(1,26)$=2.506, p=.126, partial η^2=.088, and between simulating incompatible and compatible posture taking, $F(1,26)$=.829, p=.371, partial η^2=.031 (Figure 4.18, panel d, p.104).

Analyzing the results separately by the respective manipulation methods, we find the significant compatibility effect in simulated posture taking trials alone, $F(1,26)$=5.493, p=.027, partial η^2=.174, but not for physical posture taking trials alone, $F(1,26)$=.1.833, p=.187, partial η^2=.066.

Analyzing separately by single dependent variables we find the significant compatibility effect in simulated posture taking in the accuracy data, $F(1,26)$=4.670, p=.040, partial η^2=.174, but not for actually assumed posture taking, $F(1,26)$=2.744, p=.110, partial η^2=.066.

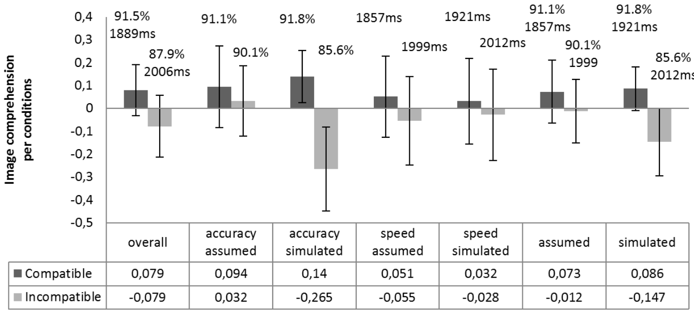
4.9.3 Discussion and conclusion

Despite the amount of additional challenges and distractions added in Experiment 3, the compatibility pattern appeared. However, this pattern was significant only for simulated posture accuracy results. Nevertheless, both variables (accuracy and time) contain the predicted pattern. Accordingly, we generally may expect this effect in web studies with the amount of additional distraction.

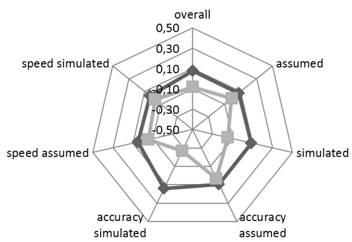
The chosen method for actual posture taking appears to be less effective than the posture taking in front of the three-screen array in Experiment 2. Fortunately, we received no reports of problematic ambiguity in the image material. However, we received some reports of dizziness due to the bidirectional head movement. Potentially, this irritation was the reason why effects in assumed posture taking trials were weaker than in simulated trials. To summarize, web studies seem to be possible with the chosen setup.

4.10 Experiment 4

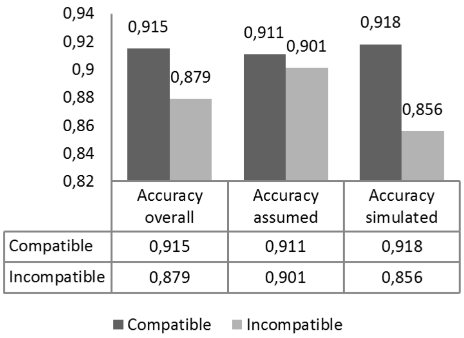
In Experiment 1, 2, and 3 image ambiguities were identified as a specific challenge to spatial stimulus material. Although we adapted the stimulus material, we still received a single participant's feedback about a remaining ambiguity. Although this ambiguity did not lead to an inability to comprehend the image, it might have led to specific delays and irritation. Experiment 4 focused on reducing image ambiguity to generalize that the observed PIC effect in Experiment 1, 2, and 3 do not appear solely due to posture dependent image reinterpretation. To eliminate perspective ambiguity, we significantly simplified image identification by adding sky el-



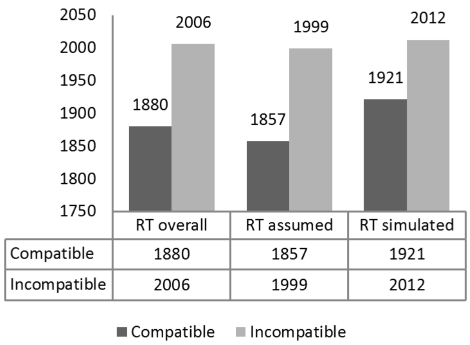
(a) Results split by DV for the eight conditions



(b) Results as radar chart, closer to the center means worse.



(c) Accuracy, as real data



(d) Response time, as real data

Figure 4.18. Standardized image comprehension collapsed across measure and conditions ("Overall") as well as by measure (Accuracy, Speed) and posture manipulation (Physical, Simulated), Experiment 3.

ements to upward images and earth elements to downward images.

4.10.1 Methods

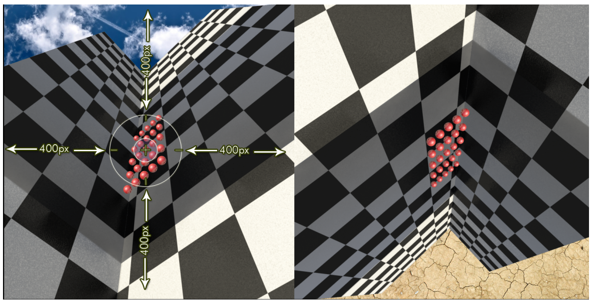
Participants and design Twenty-two participants (mean age = 28.27 years, SD=7.363, 14 female, 8 male) completed the procedures using a screen based stimulus display and stimulus images with ground or sky added in order to eliminate ambiguity in the image perspective. Participants reported no confusion regarding the intended image perspective.

Apparatus and material The applied material was identical to the material used in Experiment 2, except we added sky and ground images in the background to reduce viewing direction ambiguity (Figure 4.19, p.105).

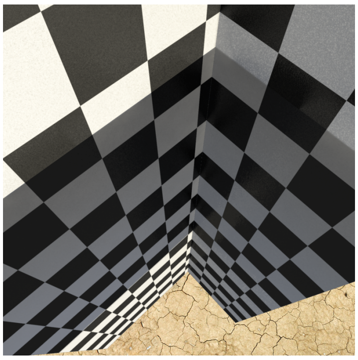
Procedures The procedure was identical to experiment 3. We only limited the presentation of the fixation cross to 500ms to reduce the interval between imagining a posture and presenting the image. The intention was only to reduce the overall length of the study.

4.10.2 Results

Posture-Image Compatibility The effect of actual and simulated posture on image comprehension is graphed in Figure 4.20, p.106. A 2 (posture-image compatibility: compatible or incompatible) x 2 (posture manipulation: pos-



(a) Possible target possitions in up and down views



(b) Downward view image

(c) Upward view image

Figure 4.19. Image material with additional sky and ground elements

ture taken or posture simulated) x 2 (posture direction: downward or upward) within-subjects MANOVA on image comprehension yielded only two main effects, a main effect of posture-image compatibility (PIC), $F(1,21)= 10.647$, $p=.004$, partial η^2 =.336, and a main effect of posture manipulation, F(1,21)=6.014, p=.023, partial η^2 =.223. No additional interactions qualified this effect (DV*PM*Comp, F(1,21)=.01, p=.921, partial η^2 <.001) or 2-way interactions (DV*Comp, F(1,21)=.615 p=.442, partial $\eta^2 a$ =.028) and PM*Comp, F(1,21)=.024, p=.877, partial η^2=.001).

As predicted, the main effect of posture-image compatibility indicated that compatible posture facilitated image comprehension relative to incompatible posture.

Looked at separately, the compatibility effect was significant for both response speed, $F(1,21)=$ 5.490, p=.029, partial η^2 =.207 (Figure 4.20, panel c, p.106), and answer accuracy, F(1,21)=5.446, p=.030, partial η^2 =.206 (Figure 4.20, panel d, p.106). Posture taken, F(1,21)=7.689, p=.011, partial η^2 =.268, was significant and posture imagined, F(1,21)=3.738, p=.067, partial η^2 =.151 was marginally significant.

4.10.3 Discussion

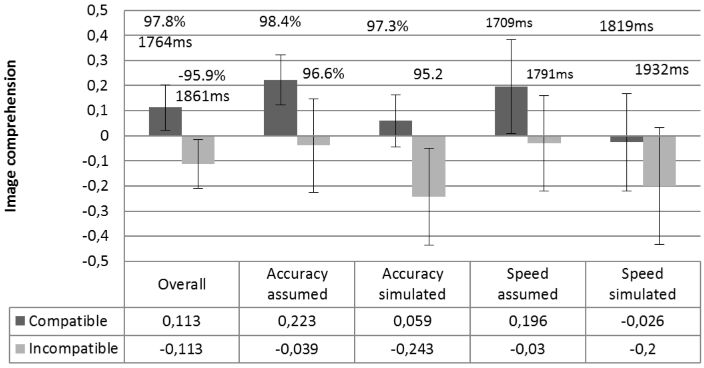
The main effect of posture manipulation indicated that simulated posture reduced image comprehension relative to assumed posture, perhaps reflecting greater mental effort in complying with the posture simulation instructions. Critically, this effect was independent of the observed incompatibility effect.

These results provide a further demonstration of the hypothesized PIC effect, this time with unambiguous perspective images.

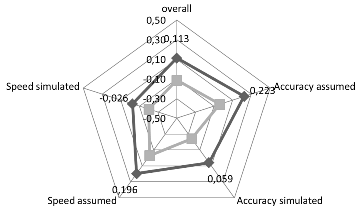
We replicated the PIC effects successfully after reducing the images ambiguity. This indicates that scene ambiguity is no precondition for the observed posture-image compatibility effect in image processing.

The PIC effect is significant both for answer accuracy and for speed. This means that incompatible posture taking makes spatial image judgment slower and increases the probability of making errors.

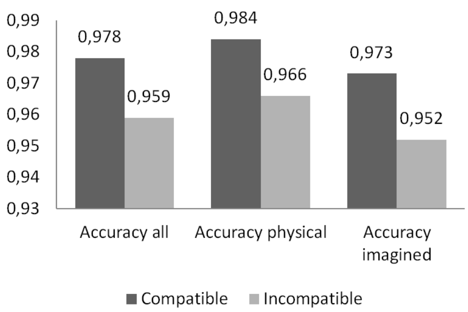
The results we demonstrated make it plausible that the PIC is caused by colliding posture representation activation. However, several visual alternative explanations come in mind, which we discuss and rule out with the following



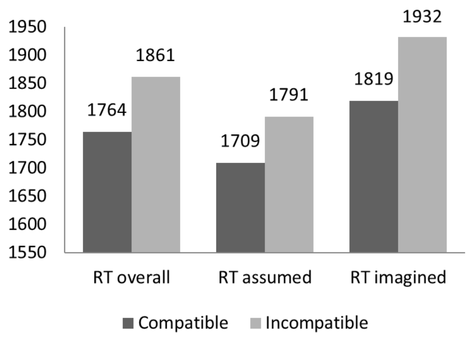
(a) Standardized image comprehension collapsed across measure and conditions ("Overall") as well as by measure (Accuracy, Speed) and posture manipulation (Physical, Simulated)



(b) Results as radar chart illustrating the general better performance in compatible trials (dark point) compoared to inicompatible scores (light point).



(c) PIC pattern in response accuracy.



(d) PIC pattern in response time.

Figure 4.20. Results showing posture-image compatibility (PIC) patterns, Experiment 4

experiment by using a head mounted display.

4.11 Experiment 5

Experiment 5 focused on ruling out visual, rather than postural, explanations for the PIC effect. Looking between different screens all prior Experiments required participants to adjust their field of vision, that is, to look in different places. Thus, the perspective images were not only consistent or inconsistent with the posture created by looking at different screens, but also with the eye movements and the flow of optical information created by looking from screen to screen, and they involved the visual perception of a matching or non-matching perspective view.

In order to rule out that optical explanations might solely explain the PIC effect, we replaced the three-screen array with an HMD used in a completely darkened room. Thus, the visual field remained constant despite changes in posture.

As an added advantage of an HMD display, we were also able to track the orientation of participants' heads in space and thus confirm the efficacy of our posture manipulation despite the darkened environment.

We also changed posture-taking instructions by now referring to the participants' body instead of external vertical screens to prevent vertical biases by the instruction and covert recoding of the instruction into looking-up or looking-down.

Finally, a second group of participants answered a spatially reversed question (below instead of above) in order to support that the PIC effect generalizes independent from the question, material and procedure.

4.11.1 Methods

Participants and design Forty-four participants (mean age 24.65 years, SD=3.67, 34 female, 10 male (79%) completed the procedures using an HMD display and stimulus images with ground or sky added. Participants reported no confusion regarding the intended image perspective.

Apparatus, material and procedures In Experiment 5, posture was manipulated with short behavioral instructions "head to chest" or "head to neck" instead of the prior used "look at screen 1/floor/ceiling" to avoid spatial oriented and external reference point activation. There were two groups of participants, one answering the question "is yellow above red", as in the other Experiments, and one answering the question "is yellow below red". All further procedures were the same as in prior Experiments.

4.11.2 Results

Data Screening Two participants were excluded from the analysis due to technical problems with the head mounted display. Response errors showed a ceiling effect and were infrequent (M=1.44, SD=1.8). The mean response time of 2088ms (SD=1278) was slower than in the last experiments, which might explain the very high accuracy level. Hence, further analyses were calculated with response duration only.

Head posture taking We analyzed the degree of head tilt in a 3 (posture direction: down, straight or up) x 2 (posture manipulation: posture taken or posture simulated) x 2 (image view direction: downward or upward) within-subjects ANOVA. The straight level in the factor posture direction addressed the posture during simulated posture taking.

Within the limits of the HMD's tilt measurement accuracy head posture recordings confirmed that participants took simulated and assumed postures as intended. Participants moved their heads up and down in actual posture taking conditions (up+45°, down-46.9°) and kept them in a nearly straight posture (+-0.5°) while imagining the posture. This shows up as a significant main effect of posture direction, $F(1,41)=777.2$, $p<.001$, partial $\eta^2 = .949$, qualified by a significant interaction between posture manipulation and posture direction, $F(1,41)=848.3$, $p<.001$, partial $\eta^2 = .953$. The results support that participants executed posture-taking as instructed.

Posture-Image Compatibility As noted, answer accuracy approached ceiling, perhaps as a result of reduced answer speed. Thus, we analyzed only answer speed. The effect of posture compatibility on answer speed is graphed in Figure 4.21, (p.109). A 2 (posture-image compatibility: compatible or incompatible) x 2 (posture manipulation: posture taken or posture simulated) x 2 (posture direction: downward or upward) within-subjects ANOVA yielded only 2 main effects, a main effect of posture compatibility, $F(1,41)=8.476$, $p=.006$, partial $\eta^2 = .175$, and a main effect of posture manipulation, $F(1,41)=7.602$, $p=.009$, partial $\eta^2 = .160$. No significant 4-way, 3- way or 2-way interactions qualified this effect. The main effect of compatibility supports the predicted impaired image comprehension after incompatible posture taking. As in Experiment 4, the main effect of posture manipulation indicated that comprehension was better after assumed posture than after imagined posture.

Looked separately at the compatibility effects split by posture taking method reveals additionally that both simulated posture taking trials alone yielded a significant PIC effect, $F(1,41)=6.743$, $p=.013$, partial $\eta^2 = .144$, whereas the actually assumed posture taking alone did not, $F(1,41)=1.596$, $p=.214$, partial $\eta^2 = .038$.

The counterbalanced question with, "Is the yellow ball below the red ball?", showed no effect and no interaction by other factors, especially no effect of group x compatibility x posture type, $F(1,41)=.388$, $p=.537$, partial $\eta^2=.009$.

These results provide a further demonstration of the PIC effect when visual, rather than postural, consistency cannot explain the findings.

4.11.3 Discussion

We replicated the PIC effect and by that ruled out systematically accompanying visual input as explanation for the PIC effect. Darkening the lab and presenting the material via HMD both abandoned optical flow, avoided that subjects could see their own body from different angles while tilting the head and involved no presentation of perspective visual impressions (e.g., view screen from specific perspective).

We additionally tested if our specific question was necessary to create the PIC effect. One half of the participants answered to the spatially inverted question where we replaced *above* by *below* which we expected to create an identical compatibility effect. The absence of any interaction by question type supports this. Hence, the PIC effect is independent from the spatial orientation of the question.

Also replacing the posture taking instructions to spatially equal ones did not affect the PIC effect.

This all strengthens that proprioceptive and vestibular activation caused by physical and imagined head posture tilt creates the PIC effect and not the accompanying visual elements, question orientation or posture instruction type.

As before, imagining posture taking created lower image comprehension than physical posture taking and again showed no interaction with the PIC effect.

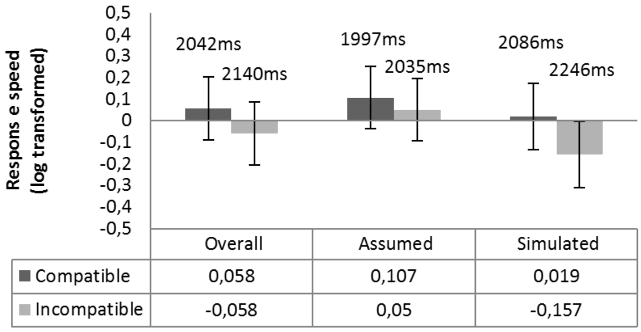
4.12 General Discussion

In five experiments, we demonstrated that posture representation affects the comprehension of perspective images. Specific incompatibilities between participants' simulated postures, actual postures and posture simulations necessary for comprehending presented images influence image comprehension.

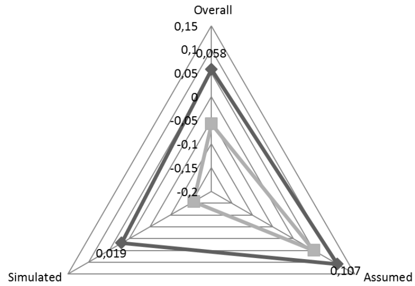
According to these findings we can say that compatible postures facilitate the comprehension of perspective images relative to incompatible postures, a connection we term the PIC effect (posture-image compatibility effect). Experiment 1 delivered support for the potential complexity and possible ambiguity of perspective image interpretation that lead us to providing more spatial cues in our visual material. Experiments 2 and 4 provided demonstrations of the PIC effect using onscreen displays of perspective images when image perspective was strongly implied but still somewhat ambiguous (Experiment 2). In addition, we demonstrated the PIC effect when perspective was disambiguated by the ground and sky (Experiment 4). Experiment 5 replicated the PIC effect with unambiguous images using an HMD display, allowing us to additionally deconfound posture and the visual input normally associated with posture.

This was important because generally, three major sensory systems can deliver information about the current assumed and simulated posture: (a) proprioceptive input from receptors located in fibers and muscles, (b) vestibular organ containing the semicircular canal system for 3D rotation perception, the macula organ with *Maculae utriculi* for horizontal acceleration perception and the *Maculae sacculi* for vertical acceleration perception, and (c) visual input accompanying the moving body. We chose head posture taking instead of the frequently applied manipulation of hand positions for two reasons: (a) head posture involves all the mentioned input channels, and (b) the highest proprioceptive receptor density in the body is found in the region of head joints, jaw joints, masticate musculature and neck musculature (e.g., Purves et al., 2001). Accordingly, head posture taking allows stimulating proprioceptive, visual and vestibular organ at the same time. Excluding the visual flow during head movement by using a HMD in Experiment 5 suggests, on a sensory level, that either the proprioceptive or vestibular information but not the accompanying visual input could explain the observed PIC effect.

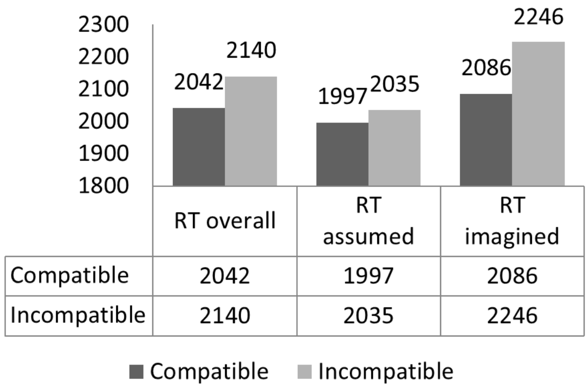
Note that these results do not suggest that the compatibility of a perspective image with preceding optical input is unrelated to image



(a) Log transformed response speed results used for analyses



(b) Results as radar chart reflecting the PIC pattern by showing lower performance (closer to the center) in incompatible conditions and higher performance in compatible conditions.



(c) Results as actual response speed values

Figure 4.21. Results Experiment 5 collapsed across posture manipulation ("overall") and by posture manipulation (Physical, Simulated)

comprehension. Rather we find the existence of compatibility effects based on visual information plausible. For example, the flow of input across the retina influences vestibular and proprioceptive stimulus processing (Koenderink, 1986). Consistency or inconsistency between such optical flow and the perspective implied by an image might also create a compatibility effect in image comprehension. Strictly visual inconsistency, however, is outside the scope of our current theorizing and investigation.

Traditionally most studies that investigate the connection between body and cognition by measuring the execution of specific action execution (e.g., grasp action) (e.g., Ellis & Tucker, 2000). However, according to the dual pathway theory of visual processing (Milner & Goodale, 2008) this only supports interactions between the action related (dorsal) visual perception with action execution. In our Experiments we demonstrate the PIC effect under in a rather abstract visual judgment task. This indicates that, different from most existing studies, that not the dorsal, action related visual processing could have created the observed interaction but that the ventral processing responsible for aware feature perception must have been taken during image judgment. Accordingly, our Experiments add an interesting addition to the existing body of research that directly refers to visual media perception instead of action execution.

Furthermore, we controlled additional aspects in our material and procedures to eliminate attention shifts during posture taking as a possible reason for the observed effect. The stimulus images were carefully constructed to keep the sphere configuration centered and invariant except for features related to changes in perspective. Additionally, in no case did the manipulations of posture refer to the semantic concepts of *up* and *down*. Rather posture was manipulated in reference to numbered screens in Experiments 2 and 3 and in relation to participants' own bodies in Experiment 5. Of course, we cannot definitively rule out that participants covertly translated our instructions into these semantic concepts. However, the unprompted translation of instructions about concrete and easily observed physical referents into more abstract terms suffers on grounds of parsimony.

Moreover, we demonstrated the PIC effect in a task that required participants to refer to their body as spatial reference for making sense of the task. Accordingly, we made sure that participants had to understand the spatial dimensions of the presented images before being able to judge the targets' spatial relations. Our assumption is that this is the step during media perception that creates the implicit body referencing. Because of the prior simulated or actually assumed posture taking, potentially activated by the sensory feedback during posture taking, we could observe the PIC effect.

Our findings clearly support a central role for body and posture simulation in understanding every day environment and activities (Hommel, 2009). Not only do we refer to our own body system to make sense of observed actions (Alaerts et al., 2009; Brass, Bekkering, Wohlschläger, & Prinz, 2000; Liepelt et al., 2009), motor and posture simulation are also connected to interpreting and comprehending perspective images. In short, these results suggest that posture representations are involved in understanding the perspective of the images we encounter as we browse the internet, play computer games, or even look at a friend's vacation photos. This supports the high relevance for designing media interaction (e.g., head movement) according to the presented content.

Chapter 5

General Discussion and Conclusion

This dissertation addressed the significance of body representations for visual spatial perception, with special focus on viewing conditions that involve concurrent body activation, a combination typically found in interactive media. For this purpose, (a) we developed an extensive taxonomy of the complex field of embodied spatial perception to gather a structured insight into the processes involved in such interaction. This integrated view allowed the identification of the challenging concepts involved in describing cognition as embodied or body related. Furthermore, it allows a detailed discussion and investigation of potential cognitive reasons for interactions between perception and body representation system activation. Accordingly, the taxonomy delivers an important reference for future embodied media research.

To actually run experiments in interactive media environments, we (b) developed the experimental environment Inter|act3D. It was argued that browser based environments such as Inter|act3D allow the investigation of such interactions between body and visuospatial perception independent from specific hardware or local installation directly within the interactive medium. Accordingly, any computer fulfilling the minimal requirements of running the environment could serve as a platform for embodied media cognition research.

In (c) five experiments we demonstrated that reliable embodied cognition research is actually possible within Inter|act3D. Furthermore, it was argued that image incompatible posture taking during media perception would reduce perceptual performance. This combination is highly relevant for interactive media related perception because most touch surface based environments (tablets, mobiles) involve seeing content while the recipient's head posture creates a perspective impression of the presented content. Furthermore, perspective views are frequently found in media, as in most movies and or photos.

Accordingly, we investigated the effect of different head postures on perspective visual perception. The results of all Experiments support that an observer's posture, actual and simulated, interacts with such visuo-spatial perception. We demonstrated the effect under different material and viewing conditions, showing that incompatible head postures before judging perspective views leads both to reduced judgment speed and accuracy. This result matched our hypothesis that image incompatible posture taking reduced performance.

These findings imply that the design of interactive media should stronger consider such interactions to support both speed and accuracy of media perception. The avoidance of negative interactions could become very important, for example under critical conditions such as driving and simultaneously perceiving of the content presented by a navigation system or heads up display.

5.1 Experiments - alternative body related PIC effects

We described in the taxonomy chapter that a great amount of findings is labeled by the cloudy term *embodiment*. According to the detailed findings on the connection between perception and body simulation we reviewed in the PSMC taxonomy, and due to the specific design of our experiment, we can now discuss and even exclude several alternative explanations for the appearance of such an interaction.

5.1.0.1 PBA and PIC effect

According to the taxonomy, both perception of the visual spatial environment and posture taking could involve perceptual processing that accordingly might interact in our experiments. Posture taking involves the processing of the related perceptual proprioceptive, tactile, and vestibular input, for instance, feedback from the eyes, muscle tensions and linear and rotational head tilting. Accordingly, the respective systems are prepared for perception or, due to the overlapping cognitive systems, simulation of such perception.

If perspective image processing relies on simulating the according perceptual input we may assume that the PIC effect could be generated by either the compatible or incompatible perception during posture taking. According to the deep involvement of such simulation in perception (see Taxonomy) this offers a perceptual level explanation for the measured PIC effect. However, actually investigating this would involve neuroscientific methods and measures.

5.1.0.2 SBA and PIC effect

Besides the pure perceptual level, the taxonomy delivered support that both representation of the visual spatial environment and posture taking concurrently access the structural body representation. On the one hand, posture taking changes the current state of the structural body representation according to the taken posture because the limbs' spatial relations change during posture taking. On the other hand, the representation of the spatial environment refers to the current structural body as frame of reference to represent the relation between self and observed spatial environment. Thus, we may assume that both processes (posture taking, space representation) interact under concurrent conditions. Accordingly, we may expect a PIC effect after concurrent involvement of the body as frame of reference in spatial tasks and spatial images (e.g., perspective images).

Besides the concurrent access to the body as frame of reference, we also described several cognitive side-effects that typically accompany such body referencing (e.g., after thinking of the own hand) that could themselves create a PIC effect: (a) concurrent bias of spatial attention according to primed body elements and (b) biased sensibility in relation to the currently attended body elements (e.g., heightened sensitivity on and around the hand after thinking of the hand).

Accordingly, thinking of the head could facilitate identification of objects around the head, heighten attention for specific spatial areas in relation to the head (e.g., upper areas), and anticipate specifically featured objects that conceptually match the concept head (e.g., a hat). However, the actual design of the experiments and, above all, of the target objects eliminates these alternatives.

1. Only targets on unpredictable, random spatial positions around the image center were presented. Accordingly, no posture related preference for any distinct spatial areas would systematically support or hinder judgments.

2. Only targets without vertical semantics (e.g., shoe=below, lamp=above) were presented. Accordingly, the anticipation of specific features according to the posture should not have interact with target judgments. Furthermore, the chosen targets looked the same (rotation invariant) independent from the viewing angle (sphere). Thus, no sensory feature anticipation or suppression for specific spatial locations should be able to create a PIC effect.

3. The images were only presented while participants hardly saw their own body (Experiment 1-4), or not saw their own body at all (Experiment 5). The intention behind omitting any presentation of the participants' own or others' bodies in the material was to avoid any explicit cue that could suggest using the body as frame of reference during image perception. Accordingly,

their own or others' visual body could not explicitly be involved in coding the scene.

The carefully chosen and presented targets eliminate conflicts between spatial attention and incompatible target location and feature anticipation as an explanation for the PIC effect. Furthermore, neither the posture manipulation (take a head posture) nor the image material explicitly suggests referencing to the body for interpreting the environment. This makes it implausible that the observed effect could be based on spatial reference frames related cognitive effects such as target-self relation preparation, spatial attention bias, or specific spatial feature anticipation.

5.1.0.3 MBA and PIC effect

Beyond the structural analysis based explanation for the PIC effect, the taxonomy indicates that concurrent motor activity might be a reason for the observed PIC effect. Both perception of the visual spatial environment and posture taking could involve concurrent activation of bodily movement related cognition. This means that the simulated movement while processing the image of a chair could interact with an incongruent standing up posture taking. Accordingly, the PIC effect could be explained by: (a) concurrent (cortical) motor activity in the movement related neuronal networks; (b) concurrent forward prediction of typical internal and external sensory effects typically experienced during motor execution; (c) concurrent attention bias towards different movement target areas (e.g., tilting the head up involves attending upwards); and (d) concurrent attention guidance and anticipation towards expected target features (e.g., tilting the head down makes the observer expect features of objects typically found in that area, e.g., foot or carpet).

Besides this general motor simulation based connection, the design eliminated the major cognitive side-effects we identified for movement activation, attention shifting towards future target locations, and specific target features. The chosen design significantly reduced the consequences of such anticipation by using simple targets (sphere) that do not offer specific visual features typically associated with vertical head related actions. This leaves the motor activity based explanations.

Naturally, posture taking involves specific motor activity. Accordingly, the cortical motor activity caused by posture taking could create interactions with subsequent actual or simulated motor activities. To start with, we only have one actually executed movement after posture taking (head tilting) in our experiments: the participants' manual responses. We have no indication to assume that the horizontal hand responses (left-right choice) in our experiments interacted with vertical (up/down) head movements. The same is true for a potential effect of simulated head tilting during processing of the perspective images. Thus, we may exclude interactions between actual and simulated posture taking with the response action as an explanation for the PIC effect.

Thus, the observed PIC effect could appear due to the either compatible or incompatible motor activity involved in the simulated head posture taking used for comprehending the perspective image. In the chosen design this remains an explanation for the PIC effect.

To sum, the chosen design eliminates the cognitive consequences of movement involvement (target related attention shift and feature anticipation) as an explanation for the observed PIC effect. However, a more general involvement of motor simulation while processing perspective images still remains an explanation.

5.1.0.4 CBA and PIC effect

According to our taxonomy, both perception of the visual spatial environment and posture taking can create concurrent assumptions about the assumed spatial location an observer localizes at during perception. Accordingly, we have to check the involvement of incompatible implicit and explicit self-relocation (e.g., showing people in action or tools in space).

In the conducted experiments, neither the posture instruction nor the visual material contained any cues that have been reported to suggest explicit or implicit covered self-relocalization. Accordingly, neither the visual material contained any visual humans in space or non-egocentric body elements, nor did the presented elements refer to any spatial movement related semantic (e.g., chair for sitting down, bottle for drinking). Furthermore, the images show the target scene from a clearly egocentric point of view. Thus, interactions on the CBA level are improbable.

5.1.1 Conclusion

To summarize, we discussed several major explanations for the observed interaction between head posture taking and perspective image perception. The chosen design leaves several potential explanations for the measured PIC effect: concurrent perceptual processing of somatic percepts, concurrent structural representation of the body in space, and perception related motor activation. Since the taxonomy supports that these levels strongly overlap, studies interested in identifying their respective contribution will require a specialized study design.

The way our experiments were designed allowed a firs time demonstration of the interaction between head postures and image perception. By eliminating a broad range of typical cognitive side-effects that could create the observed PIC effect without any actual connection to the body itself (e.g., attention biases and target feature anticipation), the experiments support an actually body related PIC effect.

5.2 Generalizability of Results

The conclusions drawn from the experiments' results must necessarily be tempered with regard to the conditions in which we demonstrated the interactions between body and perception.

An important observation is that we conducted all experiments within Inter|act and on a normally sized screen. Thus, we may assume that the observed effect occurs under the most typical visual conditions. Due to the increasing significance of mobile devices with small screens, it remains an interesting question whether the effect would be as explicit on small devises as on normal sized devices, where the presented material covers a larger area of the visual field. Some findings indicate that visual embodiment effects could be sensitive to screen size (e.g., Abrams et al., 2008)

Another consideration covers the choice of our participants. As in most studies, our participants were paid and aware that they were participating in a study. Furthermore, the mean age was below 30 and contained more participants with academic background than typically found in the population of media consumers. This bias is frequently found in cognitive studies, and we see no indication that the observed interaction between perception and body control could be specific to this group. However, it might be conceivable that the high level of familiarity with media in this comparably young group and the potentially higher level of concentration of academics might have influenced the general size of the effect.

Furthermore, we have to ask to what extent the effect generalized to other gestures, such as hand posture related perception or other head related or even full body postures. The present studies were conducted to examine the influence of head postures on perspective perception. According to our interpretation that these findings refer to the involvement of the body as frame of reference, we may expect similar results for other head related postures (e.g., left/right tilt). Moreover, the dynamic switching between bodily frames of references we identified in our taxonomy might even indicate that according effects could be found for interactions with full postures (e.g., sitting vs. standing). The existing literature that supports interactions between hand postures and hand related visual perception additionally indicates that visual perception is also influenced by more specific postures as hand gestures.

To conclude the discussion on generalizability of the results, it should be pointed out that we developed our experiments to demonstrate the dependency between head posture related cognition and perspective visual perception and nothing else. With regard to these goals, the results are valuable for both theory (cognitive dependency between seemingly independent processes) and for practical considerations for developing and designing comprehensive interactive media (how media content and interaction should be attuned to each other). However, it also implies the great amount of possible, equally relevant research that remains to be conducted.

5.3 Future research

The general idea of this dissertation was the development of both theoretical, technical, and experimental requirements for future embodied media perception research. In our experiments we identified the interaction between head posture taking and spatial media perception. The taxonomy of embodied perception identified a great amount of further potential sources of conflicts between content perception and body representation activation. Accordingly, besides our investigation of interactions between vertical spatial judgments and posture taking, other experiments could address horizontal space, distance judgments, and general quality judgments and their sensitivity to head, hand, and full body postures. Due to the great amount of hand gestures found in media, this would be of great practical value.

Inter|act3D offers a broad range of tools to investigate such interactions within applied media. Thus, the influence of simulated and actual perceptual states (PBA), visual bodies and postures (SBA), movements (MBA), and alternative locations (CBA) could be investigated in detail. For instance, Inter|act3D allows presenting movies while executing manual gestures on touch screens to investigate effects of gesture on movie comprehension. Moreover, it can be used to embed (via augmented reality module) controllable virtual elements (e.g., stick, sword) into the observed environment to investigate if the effects described for actual tool usage on spatial perception (see SBA) would also appear for virtual tools. Furthermore, Inter|act3D allows countless combinations of self and remote body observation (e.g., via camera or others on images or in movies), body control (e.g., movements as driving, walking around, manual gestures, head tilting, posture taking), and body related content perception (e.g., spatial images, tools identification).

In general, this dissertation has unlocked the major potentials of body-based media perception. The general power of our experimental environment and the potential interactions suggested by the perceptual body dependencies described in our taxonomy support that we only covered a tiny part of the potential of investigating embodied media perception. Accordingly, both the developmental environments and the taxonomy could receive further refinements, so more detailed predictions and experiments could be conducted. For example, the coverage of gesture specific interactions and development of the respective modules could allow a broad range of experiments on interactions between gestures and media perception.

Hopefully, our broad investigation of this connection, from both theoretical, technical, and experimental points of view, contributes to a thorough investigation of these cognitive processes for both creating more advanced interactive media techniques and to gain insight into the cognitive processes creating our perception of media content and media environments.

5.4 Summary

Today's media increasingly emphasizes the fluent collaboration between body and medium. Thus, surfaces become tangible, GUIs allow multi-touch gestures, deliver haptic feedback, or embed elements into our natural spatial environment. In some cases they even extend or integrate into the body by becoming wearable or implanted. Accordingly, the typical media recipients will not, as in the past, consume content statically as during television or reading a book, they will perceive media content while they move and according to their moving body while they walk with their smartphone, look around while using augmented reality glasses or use gestures on top of their tablets.

This relation between body and perception, however, can create a broad range of incompatibilities because the body is not only involved in body control but also during processing of a broad range of media content. To investigate the effects of such incompatibilities, three elements become necessary: a conceptual and deep understanding of the cognitive connection between body and media perception, the development of experimental environments to investigate their mutual dependency within different media, and experiments that explicitly focus on the relation between body related cognition and media perception.

Accordingly, within this dissertation, we develop these central theoretical and practical tools necessary for investigating the interactions between body related cognition and media related cognition within a broad range of media platforms by: (a) reviewing and structuring the current state of research and its challenges in the field of spatial content perception; (b) developing the experimental environment *Inter|act3D* that allows platform and media independent investigation of this connection; and (c) investigating a central dependency between media perception and body representations; the effect of body posture on visual media perception.

The first part of this dissertation presents a theoretical based taxonomy and discussion of the elements frequently found to classify observed effects as *embodied*. We discuss these findings according to four frequently found, seemingly distinguishable body levels leading to the four levels of the PSMC taxonomy, namely the references to bodily percepts (PBA), spatial-structural body (SBA), body movement (MBA), and body in space (CBA). After identifying challenges of referring to these intuitive body levels, we accumulate the neural and behavioral evidence for each level and discuss its validity and reported cognitive consequences for mediated spatial perception. Accordingly, the taxonomy provides a more detailed and integrated understanding of the connection between body and space related media perception. Especially discrepancies between assumed involvement of the body and its actual involvement during perception indicates the importance for offering a detailed overview on this highly complex mutual connection.

The second part of this dissertation covers the experimental aspects of investigating the connection between body and media perception. Such research requires an experimental environment that is not limited to specialized platforms, hardware or media content. Accordingly, we developed Inter|act3D, an experimental environment and developmental framework that integrates a broad range of media content, hardware, platforms, and net services. The high level of independence allows the investigation of interactions between body and media perception within the versatile and inhomogeneous field of interactive media. Our experiments give an example of the possible research within this environment. We designed and conducted five experiments to show that the investigation of body representation dependent media perception is possible within Inter|act3D. We deliver support that perspective spatial image perception actually interacts with both simulated and actual posture taking, and call this interaction the posture-image compatibility (PIC) effect.

In the Pretest and Experiment 1, we test visual material, posture instructions, and the generally the browser based experimental environment Inter|act3D. Experiment 2 demonstrates for the first time a significant interaction between media induced action (posture) and media perception of perspective spatial image material, the PIC effect. Experiment 3 examines and replicates the PIC effect under more demanding, web typical conditions, as additional distraction and concurrent activities. Experiment 4 verifies that the observed effect is independent from specific image ambiguity frequently found in perspective views. Finally, Experiment 5 demonstrates that the PIC effect generalizes independent from the external spatial and visual input during posture taking.

The presented Experiments support by our newly developed experimental environment that a simple movement (head posture taking) is sufficient to influence the perception of one of the most common media types (visual perspective views). This finding is on the one hand highly relevant for the design of interactive media, because more and more media rely on the simultaneous execution of posture taking during spatial content perception (navigation system, touchscreens), and on the other hand for basic cognitive research by supporting the specific connection between cognitive head posture body on perspective visual comprehension. Taken together, the overview by the embodiment taxonomy, the experimental freedom given by the experimental environment Inter|act3D, and the significant results from the experiments deliver important theoretical and technical support for applied media oriented embodied cognition research and researchers.

5.5 Zusammenfassung

Die Entwicklung heutiger Medien betont zunehmend eine fliessende Zusammenarbeit zwischen Körper und Medium. Dementsprechend werden virtuelle Oberflächen berührbar, sie erlauben Gesten mit mehreren Fingern, liefern spürbares Feedback, oder betten virtuelle Elemente in unsere natürliche Umgebung ein. In einigen Fällen werden Medien sogar in unseren Körper eingebettet und sind tragbar oder implantiert.

Der zukünftige Mediennutzer wird Medieninhalte nicht mehr, wie in der Vergangenheit beim Fernsehen oder Bücherlesen, statisch konsumieren. Nutzer werden angebotene Medieninhalte wahrnehmen während sie sich bewegen und in Bezug zu ihrem sich bewegenden Körper, etwa beim Herumlaufen mit ihrem Smartphone, beim Betrachten der Umgebung durch eine Augmented Reality Brille oder durch freie Gesten und Bewegungen im Raum.

Diese enge Beziehung zwischen Körper und Medienwahrnehmung kann durchaus konflikthaft sein, denn auch die Verarbeitung von Inhalten verwendet kognitive Systeme der Körpersteuerung und Wahrnehmung. Die Untersuchung solcher Inkompatibilitäten erfordert daher drei Ebenen, die noch ungenügend entwickelt sind: Ein integriertes theoretisches Verständnis der zugrundeliegenden kognitiven Verbindung von Körper und Medienperzeption, die Programmierung einer Versuchsumgebung, die die Untersuchung dieser Verbindung innerhalb verschiedener Medienplattformen erlaubt, und eine grosse Anzahl an Experimenten, die explizit die Beziehung von körperbezogener Kognition und Medienperzeption adressieren.

Entsprechend dieser Anforderungen entwickeln wir mit dieser Dissertation die zentralen theoretischen und praktischen Werkzeuge, die notwendig sind für die Untersuchung dieser Wechselwirkungen innerhalb eines breiten Spektrums interaktiver Medienplattformen: Das umfasst: (a) Einen Überblick und Strukturierung des aktuellen Forschungsstandes und dessen Herausforderungen im Feld körperbezogener räumlicher Inhaltswahrnehmung, (b) Die Entwicklung der Experimentalumgebung *Inter|act3D* zur Untersuchung dieser Verbindung auf unterschiedlichen Plattformen und mit unterschiedlichen Medieninhalten und (c) Die experimentelle Untersuchung einer zentralen Abhängigkeit zwischen Medienperzeption und Körperrezeption am Beispiel des Einflusses von Körperhaltung auf perspektivisch-visuelle Medienperzeption.

Daraus ergibt sich im ersten Teil dieser Dissertation eine theoriebasierte Taxonomie und Diskussion der Elemente, die häufig genannt werden, um einen beobachteten Effekt als *embodied* zu klassifizieren. Wir diskutieren diese Funde entlang vier häufig gebrauchter, scheinbar trennbarer Ebenen, die sich entsprechend in unserer PSMC Taxonomie finden, der Bezug auf (a) körperliche Perzepte (PBA), (b) räumlich-struktureller Körper (SBA), (c) Körperbewegung (MBA), und (d) räumliche Verortung des Körpers (CBA).

Nachdem wir potentielle Herausforderungen der Anwendung solcher intuitiver Körperkonzepte diskutieren präsentieren wir neuronale und verhaltensbasierte Belege für und gegen jede der konzeptuellen Ebenen inklusive bekannter kognitiver Auswirklungen auf räumliche Medienperzeption. Entsprechend liefert diese Taxonomie ein detaillierteres und integriertes Verständnis der Verbindung von körper- und raumbezogener Medienverarbeitung. Vor allem die dadurch sichtbare Diskrepanz zwischen intuitiv angenommener und tatsächlicher Beteiligung des Körpers während der Wahrnehmung unterstütz die Wichtigkeit einer derart detaillierten Betrachtung der hochkomplexen Verbindung von Körper und Wahrnehmung.

Der zweite Teil dieser Dissertation deckt die experimentellen Aspekte der Untersuchung von Wechselwirkungen zwischen Körper und Medienverarbeitung ab. Diese Forschung erfordert eine Experimentalumgebung, die nicht auf spezialisierte Plattformen, Hardware oder Medieninhalte begrenzt ist. Dementsprechend haben wir Inter|act3D entwickelt, eine Experimentalumgebung und ein Programmier-Framework, dass es erlaubt ein breite Spektrum an Medieninhalten, Hardware, Plattformen und Netzdiensten zu integrieren. Dieser hohe Grad an Integration erlaubt die Untersuchung der Wechselwirkungen zwischen Medienverarbeitung und Körperverarbeitung innerhalb des vielfältigen und inhomogenen Feldes interaktiver Medien.

Die von uns durchgeführten Experimente geben ein Beispiel der Möglichkeiten dieser Umgebung. In fünf Experimenten zeigen wir mittels Inter|act3D beispielhaft die Abhängigkeit zwischen Medienperzeption und Körperrepräsentation. Wir liefern Belege, dass die Wahrnehmung räumlich-perspektivischer Bilder in Wechselwirkung sowohl zu vorgestellter als auch tatsächlicher Körperhaltung steht und bezeichnen diese Wechselwirkung als den posture-image compatibility (PIC) Effekt.

Im Vortest und in Experiment 1 testen wir unser visuelles Material, die Haltungsinstruktionen und allgemein unsere browserbasierten Experimentalumgebung Inter|act3D. Experiment 2 zeigt zum ersten Mal eine signifikante Interaktion zwischen medieninduzierter Haltungseinnahme und Medienverarbeitung von räumlich-perspektivischem Bildmaterial, den PIC Effekt. In Experiment 3 testen und replizieren wir den PIC Effekt in einer web-typischeren, ablenkungsreicheren Umgebung. Experiment 4 zeigt zusätzlich, dass der beobachtete Effekt unabhängig ist von der Mehrdeutigkeit des Bildmaterials, eine Eigenschaft, die oft in perspektivischen Ansichten vorhanden ist. Abschliessend demonstrieren wir in Experiment 5, dass der PIC Effekt auch unabhängig von externen räumlichen oder visuellen Stimuli während der Haltungsänderung auftritt.

Die vorgestellten Experimente belegen mittels der von uns entwickelten Experimentalumgebung, dass eine einfache Bewegung (Kopfdrehung) schon Einfluss auf die Wahrnehmung einer der häufigsten Formen visueller Darstellung hat, auf perspektivisch visuelle Ansichten. Dieser Beleg hat zum einen Bedeutung für die anwendungsorientierte Kognitionsforschung und damit für die Gestaltung interaktiver Medien, die immer mehr auf Bewegungen während der Medienwahrnehmung beruhen (Navigationssysteme, Touchscreens). Auf der anderen Seite hat dieser Fund Bedeutung für die grundlagenorientierte Kognitionsforschung, indem wir zum ersten Mal einen Effekt von Kopfbewegungen auf Bildverstehen liefern und damit eine Überlappung dieser Systeme.

Zusammenfassend bieten die übersichtliche Taxonomie, die Untersuchungsmöglicheiten in unserer Versuchsumgebung und die signifikanten Ergebnisse der Experimente wichtige bisher fehlende technische und theoretische Werkzeuge für die Untersuchung der Wechselwirkungen zwischen aktivem Körper und visueller Wahrnehmung sowohl im Feld angewandter Medien-Forschung als auch medienorientierter embodied cognition Forschung.

Kapitel 6

Appendix

6.1 Dates of experiments

Data-recording of the Experiments we reported was finished on the dates listed in the following table.

Experiment #	Date	Internal name	Publish name
Pilot	finished 20.08.2010	Prestudy	no
Experiment 1	finished 20.09.2010	Lab 1	no
Experiment 2	finished 29.10.2010	Lab 2	paper 1
Experiment 3	12. and 20.10.2010	Mensa study	no
Experiment 4	finished 01.05.2011	Schelling	paper 2
Experiment 5	finished 10.06.2011	HMD	paper 3

Table 6.1. Dates and names of experiments

6.2 List of variables in recorded datasets

In each dataset several data were recorded:

Dataentry ID	Function	Comment
ExpName	Name of Experiment	Set in sourceCode (global) or Interact GUI (for current session)
UserID	Automatically increasing unique participant number	Loaded from and increased by every call of Interact
StepName	Study step name	Used if experiment consists of several parts (e.g., Questionnaire, 3DTask, Mathtest) "
StepNum	Trial Number (1. . . .n)	
ArrMode	Current spatial arrangement of yellow and red target spheres	Left=yellow is left from red, Equal=yellow straight in front of behind red, Right=yellow is right from red
PressedKey	KeyCode of pressed key on keyboard	Used to distinguish several key combinations as input method
Choice	The choice the participant made (yes/no)	Used to calculate judgment accuracy
AnswAcc	The accuracy of the participant's choice (true/false)	
ReadingTime	Time used for reading the posture instruction until pressing 'next'	Duration between instruction appearance and key (space) press
RTChoice	Time between appearance of 3DTask image and choice	Duration between image appearance and key (left/right) press
PostureDirection	Direction of imagined or physical posture	Factor in analyses (down, straight, up)
PostureManipulation	Posture taking method	Factor in analyses (physical vs. imagined)
ViewMode	Kind of image used in 3D Task	Factor in analyses (floor view vs. ceiling view)
PosRed / PosBlue / Pos Yellow	Index between 0..24 3D target object positions (50 possible positions (25 in ceiling and 25 in floor condition)	In all conditions: 0"=in 2D most left and in 3D furthest away; "24"=in 2D most right and in 3D closest. Hence in ceiling condition 0=down,left and in floor image up,left
ConditionNum	Number of condition (1..12)	Condition=combination of posture direction, manipulation and view mode
Layout	Number of layout used in 3D Task	A Layout is a combination of PositionArrays for the objects, objects and backgroundimage
TrialType	Part the trial belongs to	Is the recorded trial part oft training trials (=true) or of real study (=false)
Timestamp (Date, time, time_ms)	Day/Month/year; time; ms	Recorded time in milliseconds relative to system time when event was triggered (e.g., key press)
CorrectAnswer	Expected answer	Calculated from choice and Answ Acc
RowIndex2DYellow	2D Row on 2D screen of red sphere	5 possible rows, 1= lowest, 5 = highest; used to decide if yellow is below red
RowIndex2DRed	2D Row of yellow sphere	

Table 6.2. Recorded data in Experiment dataset

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