Available online at www.sciencedirect.com
SCIENCE DIRECT®

Consciousness and Cognition 12 (2003) 529–543

Consciousness and Cognition

www.elsevier.com/locate/concog

Self-representation: Searching for a neural signature of self-consciousness

Albert Newen[a,*] and Kai Vogeley[b,1]

[a] *Philosophisches Seminar LFB III, Universität Bonn, Lennéstr. 39, 53113 Bonn, Germany*
[b] *Department of Psychiatry, University of Bonn, Sigmund-Freud-Str. 25, 53105 Bonn, Germany*

Received 4 March 2003

Abstract

Human self-consciousness operates at different levels of complexity and at least comprises five different levels of representational processes. These five levels are nonconceptual representation, conceptual representation, sentential representation, meta-representation, and iterative meta-representation. These different levels of representation can be operationalized by taking a first-person-perspective that is involved in representational processes on different levels of complexity. We refer to experiments that operationalize a first-person-perspective on the level of conceptual and meta-representational self-consciousness. Interestingly, these experiments show converging evidence for a recruitment of medial cortical and parietal regions during taking a first-person-perspective, even when operating on different degrees of complexity. These data lend support for the speculative hypothesis, that there exist a neural signature for human self-consciousness that is recruited independent from the degree of representational complexity to be performed.

Keywords: Self-representation; First-person-perspective; Agency; Neural correlates

1. Self-consciousness and self-representation

Always a central theme in traditional philosophy, human self-consciousness has recently become an increasingly prominent issue in cognitive neuroscience (Gallagher, 2000). Self-consciousness can be defined as the ability to become aware of one's own states, especially (but not

* Corresponding author. Fax: +49-228-735066.
E-mail addresses: newen@uni-bonn.de (A. Newen), vogeley@uni-bonn.de (K. Vogeley).
[1] Fax: +49-228-287-5025.

1053-8100/$ - see front matter
doi:10.1016/S1053-8100(03)00080-1

only) mental states (e.g., perceptions, emotions, and attitudes), as one's own states. In the case of language competent persons this is also referred to as self-reference in the sense of first-person reference or indexical reference (Newen, 1997; Perry, 1979).

According to a systematic view the complex phenomenon of self-consciousness can be characterized by three central features of our experiences (Metzinger, 2003): (1) the unity of our experiences, (2) the feeling of ownership and of agency, and (3) the perspectivity of our experiences. The unity is realized, e.g., as a sensomotoric unity but also and more important in forming a long term coherent whole of beliefs and attitudes (Vogeley, et al., 1999). Autobiographcial memory can serve as empirical indicator of this construct of a long term coherent whole of beliefs and attitudes (Fink et al., 1996; Piefke, et al., 2003). The experience of ownership (with respect to perceptions, judgements, etc.) has to be distinguished from the experience of agency (with respect to actions, thoughts, etc.) (Fink et al., 1999; Jeannerod, 1994, 2001) because in the case of involuntary action both can be different: "I may acknowledge ownership of a movement—that is, I have a sense that I am the one who is moving or is being moved—(...), but I may not have a sense of causing or controlling the movement." (Gallagher, 2000, 16). Finally the ability to take a first-person-perspective in contrast to a third-person-perspective is an essential constituent of human self-consciousness (Vogeley & Fink, 2003). These three core features have been used in traditional philosophy as arguments for the existence of a self as a nonreducible entity: According to the tradition there has to be a nonreducible self as a center of our perspective, as the bearer of the feeling of ownership and agency as well as the realizer of the unity of our experiences. According to our naturalistic view the self is identical with a human being having special characteristic capacities. So the question arises which capacities these are. The aim of the first part of the paper is to present a new answer to that question. In the modern literature you will find a lot of different kinds of selves obviously distinguished according to human capacities, e.g., Ulric Neisser distinguished the ecological self, the interpersonal self, the conceptual self, the remembered self, the private self (Neisser, 1988). Dennett introduced a narrative self. There are also discussions whether we have to distinguish an acting self, an observational self and a reflecting self (see the review of Gallagher, 2000). We would like to argue that these distinctions although sometimes helpful are all derivable from an underlying and much more systematic distinction of different forms of representation.

In this paper we will mainly concentrate on the investigation of the first-person-perspective while the first-person-perspective does not only include a visual perspective but refers to our multimodal experience and shall include also complex mental states, e.g., first-person-attitudes compared to third-person attitudes. The main function of self-consciousness is to provide integrated internal representations of the outer world and of our organism based on actual experiences, perceptions and memories providing reflected responses to the needs of our environment for the purpose of our orientation in the world. The aim of the paper is, first, to present a new conceptual framework to distinguish different kinds of self-consciousness on the basis of different forms of representation and, second, to use this framework to present the relevant empirical studies to characterize the neural correlates.

Human self-consciousness operates at least on five different levels of complexity, that comprise nonconceptual representations of bodily states, conceptual representation of objects, sentential representations of events, meta-representation of propositional attitudes (like beliefs, desires, etc.), and, as the most complex form discussed here, iterative meta-representations of propositional attitudes. However, it is in question, whether self-consciousness that is involved in cognitive operations of different complexities always has the same neurobiological foundation or, alternatively, whether it changes with different degrees of complexity. A way to study this question empirically is to study the neural correlates of self-consciousness for the different levels of complexity. Converging recruitment of neural correlates as assessed by functional imaging studies would support the hypothesis that basically the same neural mechanisms are activated, whereas differential activation patterns support the hypothesis that the neural and thus cognitive processes that are involved are substantially different. The data we present indicate that there exists a characteristic self-representation, a neural signature of self-consciousness, even when operating on different levels of cognitive complexity.

2. Levels of self-consciousness

In the following we would like to propose a new theory of self-consciousness relying on the insights of developmental psychology, on the one hand, and on a linguistically inspired theory of representation, on the other. On the basis of the new theory of self-consciousness we are able to distinguish five levels of self-consciousness (Newen, 2000) and we propose that this theory offers a frame for a systematic empirical investigation of self-consciousness. Finally, two experiments concerning self-consciousness are presented and discussed as investigations of neural correlates of two out of five levels of self-consciousness.

Our theory of self-consciousness presupposes that we can only adequately conceptualize this crucial everyday phenomenon of noticing one's own mental states as one's own mental states if we distinguish the everyday mental phenomena, on the one hand, from the underlying forms of representation, on the other. From an everyday view we have self-consciousness of our perceptions, emotions, "private" thoughts, interpersonal communications, etc. which leads to the unsystematic and boundless distinctions of selves as mentioned above. On the basis of a representational theory of mind we argue that there are only a few basic representational capacities that we can use for a systematic classification of levels of self-consciousness. While explaining this new classification we are presupposing some basic understanding of consciousness with the aim of systematically investigating the special features of self-consciousness.

We will discuss only competences of human beings that are fully awake. So, we are not discussing the levels of consciousness as defined in the literature of clinical medicine on the basis of responsiveness to external stimuli.

2.1. Levels of cognitive capacities

We start our argument by introducing five different kinds of cognitive capacities according to developmental psychology: The capacity to recognize states or properties, to classify objects, to distinguish complex events, to attribute (first-order) propositional attitudes and to attribute second-order propositional attitudes to other persons.

The first cognitive capacity of recognizing (mainly bodily) states is only presupposing sensory discrimination developed already before birth. A newborn definitely consciously experiences actual sensory states: It is feeling pain, hunger, etc.

The second level is reached when babies acquired the concept of an object. The standard presupposition is that the capacity to classify objects is acquired by a baby between the 8th and 12th month of life. This characterization refers to the observations of Piaget (1936/1952). Children between 5 and 7 months do not uncover hidden objects, do not retrieve contiguous objects and do not detour around barriers: They do not reach for an object hidden under a cover or behind a screen, even if someone rattles the object or the infant were in the process of reaching for the object when it was covered (Piaget, 1936/1952). Although they can retrieve a small free-standing object, they fail to retrieve it if it is transferred on the top of a slightly larger object (Bower, 1974). Finally a toy that infants can see in a transparent box is reached from the side they see the toy (Diamond, 1981): If they see the toy through a closed side, they reach repeatedly to that side, trying no other approach to the toy (Diamond, 1993, 227). These findings are not questioned but a modern interpretation claims that not the concept of an object is acquired but that "what emerges between 5 and 12 month is, instead, the ability to *demonstrate* an understanding of these concepts, the understanding already having been present" (Diamond, 1993, 208). According to our view we need a rich bundle of competences to define the ability to distinguish stable objects, at least we can distinguish visual behavior and grasping competences. We prefer a definition that includes the grasping competences as an essential part for acquiring the concept of an object during human ontogenesis and therefore keep the traditional interpretation.

The third level we would like to mark is characterized by the ability to identify dynamic events or complex scenes like birthday parties, theater plays, football games, etc. Although at a first glance this may appear only to be a gradual step compared to the other changes it will become clear looking at the forms of representation that it marks also a relevant level of cognitive competence. One competence that is characteristic for self-consciousness at this level is demonstrated by the mirror test ("rouge test"): Without noticing it the infants receive a red spot on their forehead. With 18 month children usually learn to discover that the red spot is on their own forehead simply by looking in a mirror, i.e., they are able to discover that they are looking at their own picture in the mirror. This capacity does not only presuppose consciousness of an object but also consciousness of complex events. To learn to deal with a mirror children as well as monkeys have to discover that the image behaves in exactly the same way as they do. Roughly all other animals respond to their own images as to another individual of the same species.

The fourth step is reached between the age of 2 and 4 years. The children acquire the capacity to attribute propositional attitudes, i.e., to distinguish their own beliefs and desires from the beliefs and desires of other people. They are able to generate mental models of the minds of other persons. The characteristic test for this so-called theory of mind capacity is the false belief task (Baron-Cohen, 1995).

Finally there is the fifth cognitive level of attributing second order propositional attitudes, e.g., belief attributions like "John believes that Mary believes that the chocolate is in the kitchen." There is an analogous false belief task (for higher order beliefs) that illustrates that this cognitive capacity is normally acquired between 7 and 9 years (Perner & Wimmer, 1985). This cognitive ability may be called consciousness of iterative mental models, i.e., mental models of other people's mental models of someone's mind (see Table 1).

These kinds of cognitive capacities not only develop in succession but each capacity systematically requires the lower-level capacities although the dependencies are of different kinds. These capacities characterize *crucial* steps in the gradual process of cognitive progresses in ontogenesis.

Table 1
Levels of cognitive capacities

The capacity to	Development	Characteristic	Example
Recognize sensory states	Even before birth	Sensory discrimination	Feeling hunger
Classify objects	Between 8 and 12 months	Action-based discrimination	Seeing and grasping a ball
Categorize events or complex scenes	Between 1 and 3 years	Description-based discrimination	Birthday party as a type of event
Attribute (first-order) propositional attitudes (to construct mental models of other minds)	Between 2 and 4 years	Discrimination by attitude ascription	"John thinks that p"
Attribute second-order propositional attitudes (iterative mental models)	Between 7 and 9 years	Discrimination by second order attitude ascriptions	"Mary believes that John thinks that p"

This is argued for by (a) indicating that each cognitive capacity is correlated with essentially new possibilities to act and (b) that the related forms of representation have essentially distinct linguistic features.

Let us shortly illustrate (a): Infants that develop the capacity to classify objects acquire the competence to uncover hidden objects, to retrieve contiguous objects and to detour around barriers. When reaching the capacity to categorize events infants start to participate in cooperative games like kicking back and forth with a ball. Especially relevant for the classical notion of self-consciousness is the capacity to attribute propositional attitudes to oneself and to other people. This is the basis for social communication and the basis of constructing one's own biographical narrative. The fifth level is necessary to take into account what someone else thinks about my mental model about myself. This enables persons to act according to complex expectations of the other people. We have shortly illustrated that each kind of cognitive capacity enables the infants to make essentially new kinds of actions.

2.2. Forms of representations

The second argument (b) to defend the claim that we have characterized five essentially different cognitive capacities is relying on the fact that each cognitive capacity is typically related with a specific form of representation. A form of representation is defined by the linguistic features of the representation. To characterize the forms of representation we presuppose that we are dealing with intentional systems having representations (systems that on the basis of representations have a behavior of such a complexity that we can only explain it by ascribing beliefs, desires or other propositional attitudes) but we are not presupposing that these systems are language-competent. Only the characterization of the forms of representation is based on describing different linguistic features: Representations can be classificatory, compositional, recursive, meta-representational, and iterative meta-representational. These five forms of representations will be explained in the following.

At the first level, having the capacity to register sensory states, an intentional system is only able to classify its experiences into classes of properties or states that are present at a moment. Then the system can react according to these categories, i.e., if a frog catches a fly on the basis of noticing a black moving spot. Using linguistic terms we tend to characterize this basic capacity of categorizing by ascribing simple predicate terms. We would like to call this a *preconceptual* representation because the categories are not used to identify objects as stable in space and time.

When children acquired the capacity to classify objects they have acquired the second form of representation that is not only classificatory but also compositional. Concerning language competent systems this capacity can be explained as follows: At this level children are able to represent objects by proper names as stable in space and time. The combination of predicates "F" and proper names "a" allows a representation of simple states of affairs by composition.

The third form of representation is typical for the capacity to categorize events: If the intentional system were language competent then we would characterize the representation not only as classificatory and compositional but also as recursive: There are two kinds of linguistic recursive procedures that are involved in standard descriptions of complex events, e.g., the description of the birthday party: (i) If a system is able to form representations of simple states of affairs "Fa," "Ga," "Fb" then the recursive procedure introduced by logical operators like "and," "or," "not," etc. allows the representation of complex states of affairs describable as "Fa or Fb," "Fa and Gb," etc. (ii) A second recursive procedure that is characteristic for descriptions of complex events concerns the inner structure of simple sentences. Children learn to describe events by sentences including modifiers (i.e., adverbs or adjectives), e.g., having the capacity to classify objects a child is able to represent a ball, while being able to represent events it is able to represent *the quick running of the red ball*. If an intentional system is language competent the description of the events would involve modifiers like adverbs and adjectives. They play a recursive role because having a noun phrase the addition of an adjective leads to noun phrase again and analogously the addition of an adverb to a verb phrase produces again a verb phrase. Both recursive procedures, the recursive processes concerning the inner structure of simple sentences and the recursive processes connected with sentence operators, are characteristic for the representation of events.

The fourth form of representation is involved in the so-called consciousness of other minds. To have this capacity an infant must have a representational structure that enables it to account for propositional attitudes by representing the propositional content, the attitude and the subject of the attitude as different elements. Such a representational structure is called a meta-representation. Representations of attitudes are meta-representations of states of affairs, e.g., if a language competent intentional system makes the ascription "Mary believes that the chocolate is in the kitchen" then this should be represented as the propositional content that the chocolate is in the kitchen, the belief-relation and the subject Mary as having the belief.

The fifth form is an adequate representation of second order belief ascriptions like "Mary believes that Anne believes that the chocolate is in the living room." The iteration of meta-representational structures constitutes a new level of representation. The different levels of representation are summarized in Table 2.

An intentional system can use its representations to represent the external world as well as its own states. If a representation is used to represent one's own states, the system constructs a self-model (Metzinger, 2003). We would like to call this a type of self-acquaintance or self-consciousness. Since there are different forms of representation we can distinguish different types of self-consciousness as well.

Table 2
Forms of representation

	The cognitive features	If a system were language competent then the formal structure of the representations would be characterized by
Nonconceptual representation	Classificatory: Distinguishing properties	The use of general terms "F," "G"
Conceptual representation	Classificatory and compositional: Distinguishing things and classify them as part of state of affairs	The use of general term "F," singular terms (names) "a" and their composition "Fa"
Sentential representation	Classificatory, compositional, and recursive: Distinguishing states of affairs and classify them as part of complex states of affairs	The additional use of modifiers within sentences and logical operators to construct complex sentences by recursive composition;
Meta-representation	Classificatory, compositional, recursive, and meta-representational: Distinguishing states of affairs and propositional attitudes	The additional use of a structure distinguishing the propositional content, the attitude, and the subject of an attitude
Iterative meta-representation	Classificatory, compositional, recursive, meta-representational, and iterative meta-representational: Distinguishing first and second order propositional attitudes	The additional use of a structure distinguishing the propositional content, the attitude and the subject of an attitude on a second order level

2.3. The relevant types of self-acquaintance and self-consciousness

Relying on the five different forms of representation that are extracted by looking at cognitive capacities we are now in a position to characterize five kinds of self-consciousness.

An intentional system that is only relying on nonconceptual representations is able to represent its own bodily states. This is the basic form of consciousness of one's own states that we call *phenomenal self-acquaintance*. If the consciousness of one's own mental states is based on conceptual representations this will be called *conceptual self-consciousness*. This is the first level that deserves the classification as self-consciousness (in contrast to self-acquaintance) because the intentional system is able to classify objects, i.e., it is representing itself as an object with varying properties that is different from other objects with varying properties in the world. On the basis of such a conceptual representation an infant also starts to produce joint attention with its mother (or father) concerning an object. The other types of self-consciousness are just characterized in an analogous way. The most important level is *meta-representational self-consciousness*. This is the first level which enables an infant to construct a mental model of itself and of other people. It is the basis for the first autobiographical self-knowledge that finally reaches a new quality if the infant furthermore acquired the capacity to construct iterative meta-representations. Then the autobiography of the girl Susan starts to be influenced by thoughts like "Mary hopes that I believe that school is an important factor." If Susan is able to construct a mental model about Mary's mental model about her, she can start to act in such a way that she supports the construction of

Table 3
Levels of self-consciousness

Forms of representation	Types of self-consciousness (or self-acquaintance)	Paradigms for empiricial investigations of neural correlates
Nonconceptual representation	Phenomenal self-acquaintance	
Conceptual representation	Conceptual self-consciousness	First-person versus third-person perspective in spatial cognition
Sentential representation	Sentential self-consciousness	
Meta-representation	Meta-representational self-consciousness	First-person-attitude-ascription versus third-person-attitudes
Iterative meta-representation	Iterative meta-representational self-consciousness	

such a mental model as she prefers it to be. This level is called *iterative meta-representational self-consciousness* (see Table 3).

The great advantage of this conceptual frame is that the complex everyday phenomenon of self-consciousness is now characterized by five clearly distinguishable competences that allow us to develop paradigms to investigate the neural correlates of each kind of self-consciousness. It can be also easily shown that the "selves" distinguished in the introduction are derivable from these levels, e.g., the "private self" as described by Neisser or the "narrative self" as described by Dennett are special forms of meta-representional self-consciousness.

3. Self-representation and first-person-perspective

First-person-perspective (1PP) taking as one essential prerequisite is not sufficient but necessary for human self-consciousness and can thus be taken as empirical indicator for self-consciousness. To assign 1PP is to center one's own multimodal experiential space upon one's own body, thus operating in an egocentric reference frame (Vogeley & Fink, 2003). In the following we refer to experiments that operationalize 1PP on the conceptual and meta-representational level according to the classification of different representational levels above. Representing and integrating such mental states into one common framework requires the ability to take 1PP and can be considered as a basic constituent of a "minimal self" (Gallagher, 2000) which enables us to experience the subjective multimodal experiential space centered upon our own body (Vogeley & Fink, 2003). In language, the correct assignment and involvement of 1PP is reflected by the use of first-person pronouns ("I," "my," etc). 1PP is furthermore a key constituent in any of our relations to our environment, e.g., spatial cognition, action in the environment and all forms of social interaction.

3.1. Conceptual representation: First-person-perspective in space

First-person-perspective in the context of spatial cognition refers to the experience of the centeredness of the subjective multidimensional and multimodal experiential space upon one's own body and can thus be opposed to the third-person-perspective (3PP), in which mental states, e.g., resulting from spatial perception or judgement, can be ascribed to someone else. During spatial cognition, we operate in a reference frame as "a means of representing the locations of entities in space" (Klatzky, 1998). In an egocentric reference frame, constituted by subject-to-object relations, locations are represented related to a personal agent and his physical configuration. Egocentric reference frames can be further subdifferentiated, as they may be defined with respect to the midline of the visual field, the head, the trunk, or the longitudinal axis of the limb involved in the execution of a certain action (Behrmann, 1999). In contrast, an allocentric reference frame, sometimes also referred to as "exocentric" or "geocentric," is constituted by object-to-object relations (best described in a Cartesian coordinate system). It refers to a framework that is independent from the agent's position (Aguirre & D'Esposito, 1999; Klatzky, 1998).

The cognitive operations when perceiving a visual scene from one's own perspective (1PP) differ from taking a view of the same scene from another person's viewpoint, although both tasks are centered on the body of the agent, however, the self or the other. To separate these two levels of descriptions clearly, the perspective-related terms 1PP and 3PP indicate the phenomenal level, whereas the terms egocentric and allocentric reference frames refer to the cognitive or neural level as conceptualized by the onlooking (scientific) observer. The crucial difference between 1PP and 3PP is that 3PP necessitates a translocation of the egocentric viewpoint.

A number of studies have focused on the issue of perspective taking in space. Taking 1PP appears to rely at least in part on temporo-parietal processing as assessed in navigational tasks. For example, Maguire et al. (1998) demonstrated that a right inferior parietal region was activated whenever egocentric calculations (i.e., computing body turns toward the target) were necessary in addition to the processing of allocentric spatial information (mediated via the hippocampus). Subtracting a static condition from "ego-movement" conditions including trail-following or way-finding also involved bilateral medial parietal cortex (Maguire et al., 1998). These findings have been corroborated by other studies which also showed that the key regions for spatial navigation comprise medial parietal and right inferior parietal cortex, posterior cingulate cortex and the hippocampus (Maguire et al., 1999).

A simple spatial cognitive task to be solved from 1PP and 3PP was employed in one of our own studies. We systematically varied 1PP and 3PP in a simple 3D-visuospatial task in which we presented a virtual scene consisting of an avatar surrounded by red objects. Subjects were asked to assess the number of red balls as seen from either their own (1PP) or the avatar's perspective (3PP). Both conditions are based on egocentric operations, as the objects have to be located in relation to an agent in both conditions, either the test person or the avatar. In case of 3PP, however, additional use of allocentric operations is necessary to generate egocentric coordinates for the agent. A fMRI study on 11 subjects demonstrated differentially increased neural activity during 1PP (as opposed to 3PP) in the left medial prefrontal cortex and the posterior cingulate cortex bilaterally. In contrast, 3PP was associated with differentially increased neural activity in the region of the superior parietal lobe bilaterally. The data clearly demonstrate a differential brain activation during both tasks with medial prefrontal cortex activations during 1PP (Vogeley, et al., in press).

The relevance of the parietal cortex for spatial cognition can also be derived from studies on patients with right parietal lesions leading to extinction or spatial neglect (Behrmann, 1999; Marshall & Fink, 2001). For example, Farrell and Robertson (2000) studied neglect patients with right posterior cortical lesions employing a task in which the patients had to point to targets previously seen after a body rotation in the absence of vision. The patients systematically underestimated the angle of rotation which was interpreted as an impairment in accurate tracking of changes in egocentric spatial relationships (Farrell & Robertson, 2000). Other clinical syndromes related to lesions of right superior parietal cortex are deficits in representing the relative location of objects or other persons with respect to one's own body, also referred to as "egocentric disorientation" (Aguirre & D'Esposito, 1999; Farrell & Robertson, 2000).

3.2. Meta-representation: First-person-perspective in social interaction

Closely related to the ability to assign and maintain a self-perspective is the meta-representational capacity to attribute beliefs, desires or other attitudes to others, often referred to as "theory of mind" (Premack & Woodruff, 1978) or "mindreading" (Baron-Cohen, 1995). This is an essential social skill which can be assessed in paradigms in which mental states of another person are to be modeled. A number of functional imaging studies using PET and fMRI have previously successfully delineated brain regions involved in "reading other minds" (Fletcher et al., 1995; Gallagher et al., 2000). These studies have repeatedly demonstrated increased neural activity associated with TOM conditions in the anterior cingulate cortex. We were able to replicate these findings and to demonstrate additional differential brain activation when the test persons themselves were involved as an agent in the particular story. The capacity for taking 1PP in such TOM contexts showed differential activation in the right temporo-parietal junction and the medial aspects of the superior parietal lobe, i.e., the precuneus (Vogeley et al., 2001). Neural activations common to 1PP in TOM and 3PP in TOM was observed in the anterior cingulate cortex. Similar activation patterns were also found in two other studies involving self-referential processing. Anterior cingulate activations were found during judgments about trait adjectives that were related to oneself as opposed to others (Kelley et al., 2002) and during a study in which volunteers were asked to think intensely on how they would describe the personality traits and physical appearance of themselves as opposed to others (Kjaer, Nowak, & Lou, 2002).

Ruby and Decety (2003) studied perspective taking by asking subjects to respond to a list of health-related questions, either from one's own or someone else's perspective. During 1PP the postcentral gyrus was activated, whereas 3PP relevant activations comprised the anterior medial prefrontal cortex, the left superior temporal sulcus and temporal pole and the right inferior parietal lobe. The results of this particular study are somewhat different from the studies reported above as the right inferior parietal lobule is activated during 3PP but not during 1PP. This could be reconceptualized with the hypothesis that the right temporo-parietal region is crucial for the successful differentiation between 1PP and 3PP.

However, the fact, that differential brain loci in different brain lobes are activated associated with the attribution of 1PP relative to "mind-reading" (reviewed in Gallagher & Frith, 2003) of or ascription of trait adjectives to others, suggests that these components are implemented in different brain modules and thus constitute distinct psychological processes.

3.3. First-person-perspective in action

Integrating mental states into one combined framework representing the integrity of our own mind also requires the ability to refer to our "body in the brain." It has been hypothesized, that 1PP creates a literally spatial model of one's own body, upon which the experiential space is centered (Berlucchi & Aglioti, 1997). This conjecture is in good accordance with reports on increased neural activity of right inferior parietal cortex involving visuo-spatial attention not only in navigation tasks (Maguire et al., 1998) but also the assessment of the subjective mid-sagittal plane (Galati, et al., 2001; Vallar et al., 1999). Similarly in this respect, Iacoboni et al. (1999) performed a study on motor imitation in which he contrasted an imitation task relative to two different observation tasks of specific finger movements. Brain activated regions comprised the left frontal operculum, the right parietal region and the right parietal operculum.

Another important source of information of bodily states is obviously the reference to a gravitational vertical as upright orientation as primary reference. Andersen, Shenoy, Snyder, Bradley, and Crowell (1999) reviewed evidence for the fact that vestibular information is used by the posterior parietal cortex for the perception of self-motion. A significant interaction of line bisection judgments and galvanic vestibular stimulation generating a distortion of the egocentric frame of reference was observed to be associated with increased neural activity in right inferior parietal cortex (Fink et al., in press). All these studies provide strong evidence for the crucial involvement of the predominantly right parietal cortex in the computation of egocentric reference frames.

A highly relevant study in this respect was performed by Ruby and Decety (2001) who studied perspective taking in a motor imagery task. Subjects had to imagine that either themselves or the experimenter manipulates an object. During 1PP simulation of action, only regions in the left hemisphere were activated, including the inferior parietal lobe, precentral gyrus, superior frontal gyrus, occipito-temporal junction, and anterior insula. During 3PP simulation of action, the right hemisphere was activated, namely the inferior parietal cortex, precuneus, posterior cingulate and frontopolar cortex.

The relevance of right parietal cortex for correct assignment of 1PP can also be inferred from neuropsychological studies of brain damaged patients who are unaware of or even deny some of the very deficits that impair their performance in every day life. This condition is called "anosognosia" (Babinski, 1914) and is commonly found in association with personal and peripersonal neglect. The latter neurological deficits also cast light on the neural mechanisms of 1PP in space (Behrmann, 1999; Marshall & Fink, 2001). Taken together, functional imaging data suggest that the area of the temporo-parietal junction is involved in computing an egocentric reference frame.

To understand how an individual successfully behaves in its environmental context, it needs a conceptualization of the "self" in the context of its environment. This relation, constituted by the relation of the subject itself with the surrounding objects was conceptualized as the "core self" by Damasio (1999). It is postulated to be a transient relation, which needs re-instantiation from moment to moment, which in turn constantly refers to the so-called "proto self," the latter remains unconscious and represents bodily states. Medial cortical regions are hypothetically recruited if such a state of "core self" is instantiated (Damasio, 1999), a prediction which is in accord with medial cortical activation sites, that comprise anterior medial prefrontal, medial parietal, and posterior cingulate cortex (Damasio, 1999).

Empirical evidence for the recruitment of medial cortical activation sites during experiences of self-reference is provided by the concept of a so-called "default mode of the brain" put forward recently (Gusnard, Akbudak, Shulman, & Raichle, 2001; Raichle et al., 2001). According to this hypothesis, resting states, stimulus-independent thoughts and the like, which are experienced as a "state of self" correlate with "the default mode of the brain" characterized by certain cortical activation patterns, predominantly in the anterior and posterior cingulate and medial parietal cortex. If a cognitive activity requires a higher demand, neural activation is "shifted" towards the recruited neuronal network; medial frontal and parietal regions in turn then tend to decrease their activity (Raichle et al., 2001). According to the speculative interpretation of Gusnard et al. (2001), this is not only a noisy signal, but might reflect a "continuous simulation of behavior" or "an inner rehearsal as well as an optimization of cognitive and behavioral serial programs for the individual's future," in short: A state of the "multifaceted self" (p. 4263). What appears as "state of self" on the phenomenal level, appears as "default brain state" on the neuronal level. Similarly, Andreasen et al. (1995) described a posterior cingulate deactivation during situations in which subjects were not engaged in a focused cognitive task, attributing this deactivation to spontaneous, probably purely associative mentation processes. This ongoing purely associative mentation would then be suspended when the subject becomes engaged in an experimental task requiring specific cognitive activities. In the same sense, Burgess et al. argue that the precuneus supports the inspection of internal images (Burgess, et al., 2001).

4. A common neural signature for self-representation

These experiments show converging evidence for a recruitment of medial cortical regions and inferior parietal and temporoparietal cortices bilaterally during taking a first-person-perspective, even when operating on different degrees of complexity. The data reviewed here lend support for the speculative hypothesis that there exist a neural signature for self-involvement, that is recruited during cognitive processes that require self-ascription or reference to 1PP. Notably, this recruitment is independent from the degree of representational complexity of the cognitive processes to be performed. 1PP taking as one essential prerequisite is not sufficient, but necessary for human self-consciousness. The brain regions involved in assigning 1PP comprise medial prefrontal, medial parietal, and inferior parietal and temporoparietal cortex bilaterally. These findings complement recent neurobiological theories of self-consciousness which focus on the relation between the subject and his/her environment by supplying a neural basis for its key components.

With respect to the neural correlates of subjective experiences we focus on the theoretical model proposed by Damasio (1999), who differentiates between first-order- and second-order-representations of body states also called "proto-self" and "core self." The core self contributes to this model with re-mapping of bodily states that reflect experience-dependent changes in body states. Taking 1PP thus re-instantiates a transient relationship of oneself in relation to objects in the outer world in its specific spatial and temporal context, which is a key constituent of the core self. The view that these activations might constitute part of the neural basis of the core self is also supported by studies suggesting executive functions for the anterior cingulate cortex and evaluative functions for the posterior cingulate cortex (Vogt, Finch, & Olson, 1992). The theoretical framework of the core self as a constituent of human self-consciousness also seems to apply for self-related cognitive processes referring to visuospatial or social cognition.

Our data are also in good accordance with studies on the neural correlates of emotional experiences related to the core self: Self-generated emotions during recall of emotionally salient personal life episodes are associated with increased activity in the anterior and posterior cingulate cortex bilaterally (Damasio et al., 2000). A similar result during emotional experience is reported in a PET study by Critchley, et al., (2001).

5. Conclusion

In conclusion, building up relationships between oneself and objects in the outer world constitutes an important basis for self-consciousness. The specific subjective perspectivalness in the first-person-account is realized by the integration of both the subject and the world model as the two main constituents of the internal representation framework in our nervous system. It has been postulated that these basic properties are integrated in a so-called "self-model" as an episodically active complex neural activation pattern in the human brain, possibly based on an innate and "hard-wired" model (Melzack, Israel, Lacroix, & Schultz, 1997; Metzinger, 1995, 2003). This self-model could then plausibly serve as a continuous source of a specific kind of milieu information on the own body and organism, which is activated whenever conscious experiences including properties of ownership, perspectivity and unity occur. As such, 1PP is constitutive and a necessary pre-requisite for human self-consciousness. Evidence from cognitive neuroscience imply medial cortical structures (comprising anterior medial prefrontal, medial parietal, and posterior cingulate cortex) and inferior parietal and temporoparietal cortex as the basic neural mechanisms involved in 1PP.

The different levels of representation can be operationalized by taking 1PP that is involved in representational processes on different levels of complexity. Interestingly, empirical studies show converging evidence for a recruitment of medial cortical regions during taking 1PP, even when operating on different degrees of complexity. These data lend support for the speculative hypothesis, that there exist a neural signature for self-involvement, that is recruited independent from the degree of representational complexity to be performed. The thesis will be tested in the future by developing new paradigms for the other levels of self-consciousness.

References

Aguirre, G. K., & D'Esposito, M. D. (1999). Topographical disorientation: A synthesis and taxonomy. *Brain, 122*, 1613–1628.

Andersen, R. A., Shenoy, K. V., Snyder, L. H., Bradley, D. C., & Crowell, J. A. (1999). The contributions of vestibular signals to the representations of space in posterior parietal cortex. *Annales of New York Academy Sciences, 871*, 282–292.

Andreasen, N. C., O'Leary, D. S., Cizadlo, T., Arndt, S., Rezai, K., Watkins, G. L., Ponto, L. L., & Hichwa, R. D. (1995). II. PET studies of memory: Novel versus practiced free recall of word lists. *Neuroimage, 2*, 296–305.

Babinski, J. (1914). Contribution a l'etude de troubles mentaux dans l'hemiplegie organique cerebrale (Anosognosie). *Revista de Neurologia, 27*, 845–848.

Baron-Cohen, S. (1995). *Mindblindness*. Cambridge, MA: MIT Press.

Behrmann, M. (1999). Spatial reference frames and hemispatial neglect. In M. Gazzaniga (Ed.), *The new cognitive neurosciences* (pp. 651–666). Cambridge, MA: MIT Press.

Berlucchi, G., & Aglioti, S. (1997). The body in the brain: Neural bases of corporeal awareness. *Trends in Neuroscience, 20*, 560–564.

Bower, T. G. R. (1974). *Development in Infancy*. San Francisco: Freeman.

Burgess, N., Maguire, E. A., Spiers, H. J., & O'Keefe, J. (2001). A temporoparietal and prefrontal network for retrieving the spatial context of lifelike events. *Neuroimage, 14*, 439–453.

Critchley, H. D., Mathias, C. J., & Dolan, R. J. (2001). Neuroanatomical basis for first-and second-order representations of bodily states. *Nature Neuroscience, 4*, 207–212.

Damasio, A. R. (1999). *The feeling of what happens: Body and emotion in the making of consciousness*. New York: Harcourt Brace.

Damasio, A. R., Grabowski, T. J., Bechara, A., Damasio, H., Ponto, L. L., Parvizi, J., & Hichwa, R. D. (2000). Subcortical and cortical brain activity during the feeling of self-generated emotions. *Nature Neuroscience, 3*, 1049–1056.

Diamond, A. (1981). Retrieval of an object from an open box: The development of visual-tactile control of reaching in the first year of life, *Society of Research in Child Development Abstracts, 3/78*.

Diamond, A. (1993). Neuropsychological insights into the meaning of object concept development. In M. H. Johnson (Ed.), *Brain development and cognition, a reader* (pp. 208–247). Oxford: Blackwell.

Farrell, M. J., & Robertson, I. H. (2000). The automatic updating of egocentric spatial relationships and its impairment due to right posterior cortical lesions. *Neuropsychologia, 38*, 585–595.

Fink G. R. et al. (in press). Compensation for distorted egocentric representation of space implicates right inferior parietal cortex. *Cortex*.

Fink, G. R., Markowitsch, H. J., Reinkemeier, M., Bruckbauer, T., Kessler, J., & Heiss, W. D. (1996). Cerebral representation of one's own past: Neural networks involved in autobiographical memory. *Journal of Neuroscience, 16*, 4275–4282.

Fink, G. R., Marshall, J. C., Halligan, P. W., Frith, C. D., Driver, J., Frackowiak, R. S., & Dolan, R. J. (1999). The neural consequences of conflict between intention and the senses. *Brain, 122*, 497–512.

Fletcher, P., Happé, F., Frith, U., Baker, S. C., Dolan, R. J., Frackowiak, R. S. J., & Frith, C. D. (1995). Other minds in the brain: A functional imaging study of "theory of mind" in story comprehension. *Cognition, 57*, 109–128.

Galati, G., Committeri, G., Sanes, J. N., & Pizzamiglio, L. (2001). Spatial coding of visual and somatic sensory information in body-centred coordinates. *European Journal of Neuroscience, 14*, 737–746.

Gallagher, I. (2000). Philosophical conceptions of the self: Implications for cognitive science. *Trends in Cognitive Sciences, 4*, 14–21.

Gallagher, H. L., & Frith, C. D. (2003). Functional imaging of 'theory of mind'. *Trends in Cognitive Sciences, 7*, 77–83.

Gallagher, H. L., Happé, F., Brunswick, N., Fletcher, P. C., Frith, U., & Frith, C. D. (2000). Reading the mind in cartoons and stories: An fMRI study of 'theory of mind' in verbal and nonverbal tasks. *Neuropsychologia, 38*, 11–21.

Gusnard, D. A., Akbudak, E., Shulman, G. L., & Raichle, M. E. (2001). Medial prefrontal cortex and self-referential mental activity: Relation to a default mode of brain function. *Proceedings of National Academy of Sciences USA, 98*, 4259–4264.

Iacoboni, M., Woods, R. P., Brass, M., Bekkering, H., Mazziotta, J. C., & Rizzolatti, G. (1999). Cortical mechanisms of human imitation. *Science, 286*, 2526–2528.

Jeannerod, M. (1994). The representing brain: Neural correlates of motor intention and imagery. *Behavioral and Brain Sciences, 17*, 187–245.

Jeannerod, M. (2001). Neural simulation of action: A unifying mechanism for motor cognition. *Neuroimage, 14*, S103–S109.

Kelley, W. M., Macrae, C. N., Wyland, C. L., Caglar, S., Inati, S., & Heatherton, T. F. (2002). Finding the self? An ecent-related fMRI study. *Journal of Cognitive Neuroscience, 14*, 785–794.

Kjaer, T. W., Nowak, M., & Lou, H. C. (2002). Reflective self-awareness and conscious states: PET evidence for a common midline parietofrontal core. *Neuroimage, 17*, 1080–1086.

Klatzky, R. L. (1998). Allocentric and egocentric spatial representations: Definitions, distinctions, and interconnections. In C. Freksa & C. Habel (Eds.), *Spatial Cognition. An interdisciplinary approach to representing and processing spatial knowledge* (pp. 1–17). Heidelberg: Springer.

Maguire, E. A. et al. (1998). Knowing where and getting there: A human navigation network. *Science, 280*, 921–924.

Maguire, E. A. et al. (1999). Human spatial navigation: Cognitive maps, sexual dimorphism, and neural substrates. *Current Opinion in Neurobiology, 9*, 171–177.

Marshall, J. C., & Fink, G. R. (2001). Spatial cognition: Where we were and where we are. *Neuroimage, 14*, S2–S7.

Melzack, R., Israel, R., Lacroix, R., & Schultz, G. (1997). Phantom limbs in people with congenital limb deficiency or amputation in early childhood. *Brain, 120*, 1603–1620.

Metzinger, T. (1995). Faster than thought. Holism, homogeneity and temporal coding. In T. Metzinger (Ed.), *Conscious experience*. Thorverton: Imprint Academic.

Metzinger, T. (2003). *Being no one*. Cambridge, MA: MIT Press.

Neisser, U. (1988). Five kinds of self-knowledge. *Philosophical Psychology, 1*, 35–59.

Newen, A. (1997). The logic of indexical thoughts and the metaphysics of the "self". In W. Künne, A. Newen, & M. Anduschus (Eds.), *Direct reference, indexicality and propositional attitudes* (pp. 105–131). Stanford: CSLI publications.

Newen, A. (2000). Selbst und Selbstbewusstsein aus philosophischer und kognitionswissenschaftlicher Perspektive. In A. Newen & K. Vogeley (Eds.), *Selbst und Gehirn* (pp. 19–56). Paderborn: Mentis.

Perner, J., & Wimmer, H. (1985). "John thinks that Mary thinks that:" Attribution of second-order beliefs by 5- to 10-year-old children. *Journal of Experimental Psychology, 39*, 437–471.

Perry, J. (1979). The problem of the essential indexical. *Nous, 13*, 3–21.

Piaget, J. (1936). La naissance de l'intelligence chez l'enfant (Das Erwachen der Intelligenz beim Kinde, übers. ins Deutsche München: dtv-Verlag 1992).

Piefke, M., Weiss, P. H., Zilles, K., Markowitsch, H. J., & Fink, G. R. (2003). Differential remoteness and emotional tone modulate the neural correlates of autobiographical memory. *Brain, 126*, 650–668.

Premack, D., & Woodruff, D. (1978). Does the chimpanzee have a "theory of mind"? *Behavioral and Brain Sciences, 4*, 515–526.

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of National Academy of Sciences USA, 98*, 676–682.

Ruby, P., & Decety, J. (2003). What you believe versus what you think they believe: A neuroimaging study of conceptual perspective-taking. *European Journal of Neuroscience, 17*, 2475–2480.

Vallar, G., Lobel, E., Galati, G., Berthoz, A., Pizzamiglio, L., & Le Bihan, D. (1999). A fronto-parietal system for computing the egocentric spatial frame of reference in humans. *Experimental Brain Research, 124*, 281–286.

Vogeley, K., Bussfeld, P., Newen, A., Herrmann, S., Happe, F., Falkai, P., Maier, W., Shah, N. J., Fink, G. R., & Zilles, K. (2001). Mind reading: Neural mechanisms of theory of mind and self-perspective. *Neuroimage, 14*, 170–181.

Vogeley, K., & Fink, G. (2003). Neural correlates of first-person-perspective. *Trends in Cognitive Science, 7*, 38–42.

Vogeley, K., Kurthen, M., Falkai, P., & Maier, W. (1999). The prefrontal cortex generates the basic constituents of the self. *Consciousness and Cognition, 8*, 343–363.

Vogeley, K., May, M., Falkai, P., Zilles, K., Fink, & G. R. (in press). Neural correlates of first-person-perspective as one constituent of human self-consciousness. Journal of Cognitive Neuroscience.

Vogt, B. A., Finch, D. M., & Olson, C. R. (1992). Functional heterogeneity in cingulate cortex: The anterior executive and posterior evaluative regions. *Cerebral Cortex, 2*, 435–443.

Further Reading

Evans, G. (1982). *The varieties of reference, hg. v. J. McDowell*. Oxford: Oxford University Press.