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Self-consciousness, self-agency, and schizophrenia

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Abstract

Empirical approaches on topics such as consciousness, self-awareness, or introspective perspective, need a conceptual framework so that the emerging, still unconnected findings can be integrated and put into perspective. We introduce a model of self-consciousness derived from phenomenology, philosophy, the cognitive, and neurosciences. We will then give an overview of research data on one particular aspect of our model, self-agency, trying to link findings from cognitive psychology and neuroscience. Finally, we will expand on pathological aspects of self-agency, and in particular on psychosis in schizophrenia. We show, that a deficient self-monitoring system underlies, in part, hallucinations and formal thought (language) disorder in schizophrenia. We argue, that self-consciousness is a valid construct and can be studied with the instruments of cognitive and neuroscience.

Keywords: Consciousness; Self-consciousness; Awareness; Self–awareness; Self-monitoring; Action monitoring; Schizophrenia; Psychosis; Hallucinations; Thought disorder

1. Introduction

Questions on cognitive and neural correlates of notions such as self-awareness, self-consciousness, introspective perspective or subjective experiences have re-emerged as topics of great interest in the scientific community. This is in part due to the lack of neuroscience grasping something like a first person perspective with its methodology and an increasing unease with this situation among researchers. Employing new methods of neuroscience such as functional brain imaging, advances into thus far unexplored territory of mind–brain relationships have been made.

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These empirical approaches must however be seen against a lack of conceptual framework behind these developments regarding the structure of consciousness and self-awareness. A framework is needed though, so that the emerging, still unconnected empirical findings can be integrated and put into perspective. We therefore introduce a model of consciousness and self-consciousness, incorporating ideas from phenomenology, philosophy, and the cognitive sciences. The model described has, in part, operationalisable components, so that hypotheses derived from it can be tested empirically. It is mainly descriptive and meant as a first approximation to give cognitive and neuroscientists a conceptual framework, so that areas of interest are identified and may be explored in greater detail. After introducing our model, we shall explore one aspect of it in more detail, that is self-agency. Data and hypothesis from the cognitive sciences on self-agency will be reviewed and its neural correlates explored. This will serve as an example of how specific sub-components of our model can be tested empirically. Lastly, we will expand on pathological aspects of self-agency, i.e., psychosis in schizophrenia. The study of pathological states is particularly helpful, because tacit assumptions during the construction of explanatory models for the faculty in question may be exposed.

2. A model of consciousness and self-awareness

The scientific study on self-awareness is still in its infancy and there is not as yet a vast amount of empirical data. Therefore we need to integrate findings and concepts from different sources such as philosophy, cognitive psychology, neuroscience, and psychopathology to reach a conclusive terminology. Phenomenology may serve as a starting point. With the help of detailed phenomenological analysis, the foundations of scientific psychology (W. Wundt, W. James) and later psychiatry (K. Jaspers) were outlined in the 19th and early 20th century. In the study of self-consciousness phenomenology will serve as a definitorial base on which the sciences may built their testable hypothesis. The model we want to present (see Fig. 1) is derived from phenomenological (for further details see e.g., Henry, 1963, 1965; Merleau-Ponty, 1965) and analytical philosophy (for details see e.g., Block, Flanagan, & Güzeldere, 1997; Metzinger, 1995), cognitive psychology, psychopathology, and the neurosciences (Kircher & David, 2003a). It is tentative and meant to be largely descriptive.

We have a certain, privileged access to our own mental states that nobody else has and that cannot be accessed from the outside in its primary subjective givenness. When I taste a sip of wine, the experience of the tartness (Chianti) is something which I myself am immediately aware of. It is the subjective, prereflexive givenness of any experience that nobody else can have in my particular form. In the philosophical literature, these conscious experiences are variously called, "raw feels," "qualia" or "1st person perspective." For our purposes, we want to call them "Primary Experiences" (see Fig. 1). Every experience, the street noise from outside, the smell of perfume, the chair pressing against my back, the memory of last years party or just any vague feeling is the content of phenomenal consciousness. It is the characteristic feature of primary experiences, that they exist only through their content. We may at some point be able to fully characterize the brain state (or 3rd person perspective) that corresponds to a "raw feel," however, even the most thorough description will lack entirely the subjective experience, that only I have. The taste of wine is nothing else than molecules causing a firing pattern of taste sensors in my mouth, the

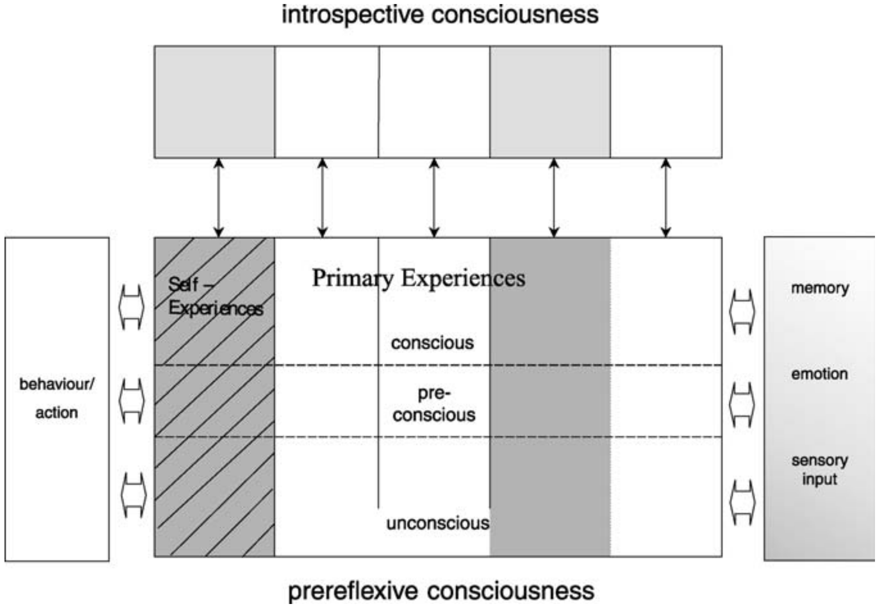

Fig. 1. A model of consciousness and self-consciousness. Mental states in "prereflexive consciousness" can be conscious, when they are attended to, preconscious, when they are not attended to or unconscious (e.g., information from the autonomous nervous system, such as heart rate or blood oxygen level) and may be sensory experiences, memories, emotions, etc. "Primary experiences" have variously been termed raw feels, qualia or 1st person perspective. Conscious and preconscious primary experiences constitute "phenomenal consciousness." The content of mental states is on a continuum of high (grey) or low (white) self-valence (e.g., perception of one's own face vs. stranger's face). There are special types of primary experiences, i.e., the feeling of unity, self-coherence, self-affectability, and self-agency, which we call self-experiences. If we reflect on primary experiences, the content enters introspective consciousness (modified from Kircher & David, 2003a).

experience of the taste only becomes real in my mind. An even better example might be pain: the feel of a pinprick is only in my mind, without the subjective feel of pain, it is not pain. It is not the firing of neurons in my spinal cord or in my brain that constitutes pain, but the awareness of a sensation in my consciousness.

These phenomenal states are something special, different from physical (chemical, neurobiological) states, because they are characterised by "transparency," "presence," and "myness" ("perspectiveness" Metzinger, 1995). "Transparency" means, that the brain constructs our reality, but the mechanism of this construction is not represented in it. The representational character of phenomenal consciousness is not accessible to consciousness. We cannot be aware of how our brain constructs primary experiences in terms of its neuro-computational mechanisms. Transparency leads to a "naïve realism," the tacit assumption that the content of phenomenal consciousness has a direct contact to the environment, and is not a mere construct, whose effects may have stronger implications for the behaviour than the "true" content. If a main part of the representational system e.g., the right parietal lobe or Wernicke's area is lesioned, the patient is unaware of the resulting deficit (hemineglect, aphasia), which leads to a lack of insight into the illness.

Conscious states are further characterised by their "presence," i.e., they are in the focus of our attention. Once we accept that phenomenological states are present, it follows, that there are other

states that are not present at the moment. There are preconscious experiences, which can enter phenomenal consciousness, once we direct our attention to them. When I focus on the tartness of the wine (primary experience A), I am usually not aware of the chair pressing against my back (primary experience B). We would argue, that there are mental phenomena, that may never enter phenomenal consciousness, but still may influence our behaviour. For example, there is now evidence from functional brain imaging studies for the unconscious processing of sensory stimuli in healthy subjects (Dehaene & Naccache, 2001; Rees, 2001). These results show, that these stimuli are processed in specific brain areas but do not enter phenomenal consciousness. Unconscious, in contrast to preconscious, states encompass all mental activity, that may not become primary experiences (e.g., sensory-motor self-monitoring, see below). We therefore define conscious, preconscious and unconscious states as "prereflexive consciousness." Conscious and preconscious states comprise "phenomenal consciousness" (see Fig. 1).

Primary experiences are characterised by a third aspect: "myness." Other authors use similar notions, such as "perspectiveness" (Metzinger, 1995) (not to confuse with "perspective taking," see below) or "ipseity," a term from phenomenology (Parnas, 2000). Experiences are always and only experiences of an "I" (see Stamenov, 2003 for linguistic implications). It is me, who realizes the taste of wine. The "I" in every primary experience is implicitly and pre-reflectively present in the field of awareness and is crucial to the whole structure. The "I" is not a 'pole' but more a field, through which all experiences pass (and it is never to be confused with a homunculus, a "mind in the mind"). This basic self does not arise from any inferential reflection or introspection, because it is not a relation, but an intrinsic property of primary experiences. When I have a perception of pain, this perception is simultaneously a tacit self-awareness, because my act of perception is given to me in the first-person-perspective, from my point of view and only in my field of awareness. This basic dimension of subjecthood is a medium in which all experience is rendered possible and takes place (Henry, 1963; Parnas, 2000; Zahavi, 2003). What is this particular functional property of "myness" that makes it the centre of consciousness? "Myness" (Ipseity) might be granted in the brain by a continuous source of internally generated input. Each and every time, when there is conscious experience (i.e., when we are awake), there is the tacit existence of internal proprioceptive input. The always ongoing flow of background cerebral activity is the centre of prereflexive consciousness. The content of this background activity is the continuous flow of "thoughts" (Dennett, 1991) and maybe even more so, a representation of a (spatial) model of our body independently of somatosensory input, the "background buzz of somatosensory input" (Kinsbourne, 1995). It is this feeling of "myness," that makes our experiences feel as a united, single being (O'Brian & Opie, 2003).

There are very particular types of primary experiences that I would like to call "primary self-experiences" (see Fig. 1). Primary self-experiences are not different from any other type of primary experiences in the way they are transparent, present and perspective and differ from them only in their content. Basically they comprise of: (1) self-agency, the sense of the authorship of ones actions; (2) self-coherence; the sense of being a physical whole with boundaries; (3) self-affectivity; experiencing affect correlated with other experiences of self; (4) self-history (autobiographical memory) a sense of enduring over time. How does the pervasive feeling of selfhood, the sum of the experience of all primary self-experiences (the self-construct) arise? Because primary self-experiences, not different from other primary experiences, have transparency and myness as integral properties. The representational structure is not represented in the generation of these

self-experiences. In the same way, that we think we are in direct contact to the world, although it is a mere construct in our brain, we feel in direct contact with ourselves. We do not at all realize that it is just a construct that can be overthrown, for example in depersonalisation or delusions of alien control. Of course, not all of these phenomenologically defined primary self-experiences can be tested scientifically. We therefore need operationalisable concepts. We suggest, that a being who experiences phenomenal self-consciousness should, at least, have the following abilities: (1) autobiographical memory (Fink et al., 1996; Kircher et al., 2002), (2) recognition of the own face (Kircher et al., 2001b), (3) perspective taking (emotional, cognitive, and spatial); this is closely related to the concept of "Theory of Mind" (Fletcher et al., 1995; Stuss, Gallup, & Alexander, 2001; Vogeley et al., 2001); (4) self-agency (see below). This may not be an exhaustive list, but can serve as examples of scientifically testable abilities that correlate with phenomenal self-experiences. Below we want to further explore the concept of self-agency as an example.

So far we described the first level of consciousness, i.e., prereflexive self-consciousness. At a second level, we can reflect about the content of phenomenal consciousness, it is a reflective awareness of primary experiences. Versions of this "introspective consciousness" (see Fig. 1) can be found in the works of Locke (1959), James (1950), Armstrong (1980), Churchland (1995), William Lycan Lycan (1997), and others. It may also be called "higher order thought," "perception of the mental," "second person perspective," "second-order thoughts" and may be conceptualised as a perception-like, higher order representation of our own mental states. For example I can reflect about the pain of a pinprick, or the blueness of the sky.

For a coherent self-structure across time, an unimpaired memory system is necessary (Markowitsch, 2003). We would claim, that all mental states, be they memories, feelings, sensory perceptions etc, can be processed on a self vs. non-self continuum, depending on the self-valence of its content (indicated by the grey scale in Fig. 1). For example the autobiographical content of being in love has a high self-valence, whereas the event of a stone thrown into the Atlantic by someone has a low self-valence. This means, the content of prereflexive consciousness and introspective consciousness is processed on a self vs. non-self dimension.

3. Action monitoring

We now want to focus on one particular aspect of primary self-experiences, namely self-agency. This faculty will serve as an example, how aspects of the model outlined above can be explored through empirical research. Self-agency has tentatively been defined as the feeling of being the author of one's actions (see above). When we move our arm, we know that it is us, who moves the arm and not an external force. However, in certain conditions, such as delusions of control in schizophrenia, this tacit implication becomes disentangled (see below). How do we know, that it is us, and not someone else, who moves the arm in the absence of visual control?

A number of theories suggest that one might be unable to monitor one's movements independently of their consequences. These include the two systems theory of visual processing (Bridgeman, 2000; Milner & Goodale, 1995), the common coding theory of perception and action (Prinz, 1997), and the internal model approach to motor control (Blakemore & Frith, 2003; Blakemore, Wolpert, & Frith, 2002). The two systems theory of visual perception suggests that there are two separate streams of processing in the visual system, one for the conscious

identification of objects (what path) and one for online movement control (how path, Milner & Goodale, 1995). Studies demonstrating that information not consciously detected is still available for online movement control (Bridgeman, Lewis, Heit, & Nagle, 1979; Goodale, Pelisson, & Prablanc, 1986; Prablanc & Martin, 1992) suggest that one is not aware of many aspects (how path) of one's movements. The what path and the how path do not only process different types of information, e.g., colour vs. movement, but also largely differ in their processing speeds (Castiello, Paulignan, & Jeannerod, 1991).

Another model that focuses on the relationship between movements and their intended consequences is the ideomotor approach to voluntary action (Greenwald, 1970; James, 1890; Knuf, Aschersleben, & Prinz, 2001). A modified version of this approach, the common coding theory, assumes that performing voluntary actions involves a representation that codes distal events (Decety & Grezes, 1999; Knoblich & Flach, 2001a) and in particular, events that can be generated using one's own action repertoire (Knoblich & Prinz, 2001; Rizzolatti, Fogassi, & Gallese, 2001). As soon as the activation of these event codes exceeds a certain threshold, a movement is carried out and the respective events are perceived. The involved processes are not under voluntary control which is suggestive of oneself only being aware of a movement's intended consequences. People assess whether they have realised an intention by a comparison of the intended with the observed event (Jeannerod, 1999). This would imply that one is only aware of one's own movements, when they are specified in the action plan or when large deviations between intention and perception occur.

A third approach suggesting that one is not aware of many aspects of one's own movements is the internal model theory of motor control (Frith, Blakemore, & Wolpert, 2000; Wolpert & Kawato, 1998). According to this theory there are two functionally different components in the motor system, inverse and forward circuits. It is assumed that inverse models provide the motor commands necessary to achieve a desired consequence of an action, specified by higher-level goals (e.g., event representations as postulated by the common coding theory). One is fully aware of the desired consequences of an action, but unaware of the motor programs per se. Forward models predict the sensory consequences of each motor program to be executed, an idea first put forward in von Holst and Mittelstaedts (von Holst & Mittelstaedt, 1950) efference copy model. It is claimed that, whenever a motor program is issued, an efference copy is produced in parallel. A prediction of the sensory consequences expected after the execution of the program is based on this efference copy. The internal model theory of motor control has been successfully applied to explain a whole variety of disorders related to the awareness of actions (for an overview see Kircher & David, 2003b).

The theories and results reviewed suggest that awareness of several aspects of one's own movements is limited. However, a question that has received less attention is whether one can overcome these limitations for relatively unconstrained movements, and when one is explicitly attending to changes in the mapping between one's movements and their consequences. We think that addressing this question is important, because the lack of awareness observed in prior studies could be due to either the necessity to act very fast, or to the lack of an instruction to closely attend to possible perturbations. In order to address whether awareness of voluntary movements is also limited when one is explicitly asked to monitor them, we developed a new task (Knoblich & Kircher, submitted). Participants were asked to continuously draw circles on a writing pad. A moving dot reproduced the movement of the pen tip on the writing pad onto a computer monitor,

without leaving a trace. The only external constraint was to complete a full circle in a given time (an acoustic signal indicated when participants were expected to reach the 12 o'clock position). In each trial, three circles were drawn under a 1:1 mapping. While drawing the fourth circle, the mapping between the movement and its visual consequences was changed, so that the dot movement on the screen was accelerated, relative to the movement of the pen tip on the writing pad. This resulted in an increase of the radius of the circular dot movement on the screen, if drawing on the writing pad was continued similarly as before. Alternatively, if the mapping change was compensated for by drawing circles with a smaller radius, the circle observed on the screen remained the same. Participants were instructed to immediately lift the pen from the writing pad, when they detected a mapping change. They were instructed to keep on drawing circles, until a trial ended, when they perceived no change. The main results were as follows: (1) Participants accurately compensated for substantial mapping changes in order to produce the same visual outcomes, without consciously detecting these changes; (2) The absolute amount of compensation did not influence conscious detection, indicating that it was not based on proprioceptive information per se; and (3) Conscious detection of a mapping change did not correlate with drawing velocity, indicating that it is influenced by the way visual and motor systems are coupled. These results demonstrate that movements cannot be monitored independently of their visual consequences. Further, automatic compensation is in part involuntarily. With this experiment we could demonstrate an empirical example of how the domain "self-agency" within "unconscious self-experiences" in our model outlined above can be explored in great detail.

The low sensitivity for detecting external influences might be thought to reflect a vulnerability that could be seen as an evolutionary disadvantage. However the use of tools is made possible by these flexible mappings between movements and their proprioceptive and visual consequences (Decety & Grezes, 1999; Prinz, 1992). A flexible system allows the anticipation of intended consequences without having to take into account detailed visuo-motor mappings. Consequently however, a detachment of action planning and control from the proprioceptive input increases the danger of system failures. These can lead to incorrect attribution of events to self and other, as it is the case in schizophrenia (Kircher & David, 2003b).

4. Brain systems involved in action monitoring

We now want to briefly summarize results from functional imaging studies, that provide evidence for self-monitoring mechanisms on a neurophysiological level. Efference copy mechanisms may play an important role in distinguishing one's own from another person's action. For example a self-produced tactile stimulus is perceived as less ticklish than the same stimulus generated externally. In an fMRI study brain activation was compared when subjects experienced a tactile stimulus that was either self-produced or externally produced. The neural activity of the somatosensory cortex was higher when the stimulus was externally produced compared to the condition when it was self-produced (Blakemore, Wolpert, & Frith, 1998). Further the cerebellum may be involved in predicting the specific sensory consequences of movements (Blakemore, Frith, & Wolpert, 2001).

Similar to the tactile domain, in the visual system the simultaneousness of producing a movement and at the same time perceiving its consequences is likely to play an important role for

perceiving it as self-generated. Therefore, we investigated whether different temporal delays (0–200 ms) between carrying out a simple repetitive movement and perceiving the respective visual feedback would change the pattern of activation in brain areas related to motor control and movement perception in an fMRI study (Leube et al., in press). In addition, we were interested in the brain areas involved during explicit judgments of simultaneity between movements and their visual consequences. If visuomotor integration is achieved by some sort of predictive mechanism like the forward model the pattern of results should be similar to the pattern observed for tactile information, although it is likely that different brain areas are involved.

In our study, healthy subjects, while functional Magnetic Resonance Imaging (fMRI) data was acquired, opened and closed their hand in a 0.5 Hz rhythm while being filmed by a fMRI compatible video camera. During short trials subjects had visual feedback of their movements (projected on a screen with a video beamer) which was temporally delayed between a range of 0 and 200 ms (using a computer). Subjects had to detect if a delay was present or not.

The activation of the superior temporal sulcus, was positively correlated with the extent of the temporal delay between a self-generated movement and the corresponding visual feedback. Conversely the activation of the putamen was negatively correlated with the extent of the temporal delay between a movement and its visual feedback. This is exactly the relationship one would expect between a motor area (putamen) generating error signals that, in turn, modulate the activation of perceptual areas (superior temporal sulcus). Perceptual areas known to be involved in movement processing, as the superior temporal sulcus show an increase in activation with increasing temporal delay. The reason is that simultaneously carrying out the observed movement should attenuate movement perception. Areas involved in motor control, as the basal ganglia show a decrease in activation with increasing delay. This result supports the interpretation that the mechanism picking up the temporal delay is based on a feedforward mechanism connecting perceptual and motor areas.

In contrast to previous studies in which the cerebellum was shown to provide an error signal for the attenuation of the somatosensory consequences of movements (Blakemore et al., 2001), its function in our study seemed to be restricted to provide fine-grained temporal information under conditions of uncertainty. This supports the notion that the basal ganglia process temporal information on a larger and that the cerebellum on a more fine-grained time scale (Ivry, 1996). Another brain region, the parietal lobe, has been strongly implicated in the processing of (self) agency since imitation studies (Decety, Chaminade, Grezes, & Meltzoff, 2002) and studies with mental imagery (Ruby & Decety, 2001) showed that the right parietal cortex is specifically activated when another person imitates an action the subject has performed earlier or when one is asked to mentally imagine somebody else performing an action. Additionally to features of temporal resolution in the putamen/posterior STS (Leube et al., in press) and perspective taking in the parietal lobe (Ruby & Decety, 2001) a gross mismatch between intention of a movement and it's visual feedback is detected in the frontal lobes (right DLPFC) (Fink et al., 1999). The latter study implies executive processes in the conscious detection of a mismatch between a movement and its visual consequences. From these functional imaging studies on the neural implementation of mechanisms defining agency it can be concluded that several task-dependent functional mechanisms of this faculty are realised in different parts of the brain. This fact explains perhaps why the feeling of being oneself can be disturbed (schizophrenia, depersonalisation, etc.) but never completely erased.

5. Self-monitoring in schizophrenia

Finally, we want to explore "self-agency" (as part of "phenomenal primary self-experiences" in our model) in a pathological state. We think it is of particular relevance to test hypothesis generated from experiments in animals or healthy subjects in patients. This could reveal tacit assumptions of a model, which consequently would have to be adjusted. Schizophrenia is a complex disorder with a broad variety of very diverse symptoms (see textbooks of Psychiatry for details). In the following, we do not want to explore schizophrenia as a whole. Nor is it intended to offer a complete synthesis across the levels of phenomenal self-consciousness and the cognitive psychology of schizophrenia.[1] Rather we want to focus on a particular set of symptoms within the schizophrenia spectrum, i.e., psychosis in schizophrenia. This symptom cluster overlaps with but is not identical to the construct of positive symptoms. Psychosis in schizophrenia consists of bizarre delusions, and in particular delusions of control. In the continental psychopathological tradition, the latter symptoms are subsumed under a separate entity, Ego-disturbances (Jaspers, 1913, 1963), and comprise made thoughts, actions and feelings. The patients experiences volitions as being inserted into his mind or made from a third, outside party. These experiences are then explained in a delusional manner. Further, psychosis is characterised by auditory hallucinations, in particular conversing or imperative voices and formal thought disorder (loosening of associations, neologisms, and thought incoherence).

Frith (1987), Feinberg (1978), and Malenka, Angel, Hampton, and Berger (1982) proposed that psychosis is due to deficits in self-monitoring. Self-monitoring systems enable one to distinguish the products of self-generated actions or thoughts from those of other-generated actions or thoughts. Above, we claimed that self-monitoring in healthy subjects might be based on a central process that determines deviations between the predicted and observed consequences of physical or mental actions. When predicted and observed consequences match, the observed consequences are experienced as self-generated. Frith and colleagues (Blakemore & Frith, 2003; Frith et al., 2000) further assume that the future consequences of actions are predicted on the basis of an efference copy of each motor program that is issued (Jeannerod, 1994). Others have postulated that self-monitoring is normally based on a more direct comparison between the intention underlying an action and its observed outcome (Jeannerod, 1999; Jeannerod et al., 2003). Self-monitoring does not only occur in the sensory motor domain but plays a major role in the production of language as well. During the normal generation of coherent language feedback loops on different levels of the production process detect self-generated errors (phonological, semantic, syntactic, and pragmatic) that are then corrected (Levelt, 1983, 1989). Detection of self-generated errors may be disrupted in schizophrenic patients with formal thought disorder (Kircher & David, 2003a; Kircher et al., 2001a).

Similarly, patients with Ego-disturbances and hallucinations cannot correctly compare the expected and observed consequences of an action and therefore have problems to identify their actions and thoughts as the cause for events they perceive. Empirical evidence for this claim was provided in several studies. One study has demonstrated that tactile sensations following

[1] For descriptions of the phenomenology of prepsychotic states in schizophrenia see (Parnas, 2003) or (Moller & Husby, 2000).

self-generated movements are attenuated in healthy subjects, but not in patients with paranoid-hallucinatory syndrome (Blakemore, Smith, Steel, Johnstone, & Frith, 2000). Further experiments have demonstrated that schizophrenic patients with paranoid-hallucinatory syndrome who carried out simple joystick movements could not correct movement errors in the absence of visual feedback, although there were no clinical indications of a disorder of the motor system (Frith & Done, 1989; Malenka et al., 1982; Mlakar, Jensterle, & Frith, 1994; Stirling, Hellewell, & Quraishi, 1998). Patients with paranoid-hallucinatory syndrome and passivity phenomena (ego-disturbances) are also less sensitive to angular deviations between their actual hand movements and the visual consequences of these movements (Daprati et al., 1997; Franck et al., 2001). This might be due to an overactivation of parietal cortex regions in schizophrenic patients with passivity phenomena (Spence et al., 1997). The parietal cortex has only recently been implicated in the detection of angular deviation between own and foreign movements (Farrer et al., 2003).

In an own study we determined whether there is a failure of self-monitoring in schizophrenia patients with paranoid-hallucinatory syndrome or formal thought disorder (Knoblich, Stottmeister, & Kircher, submitted). We used the same task as described before (see part 'Action monitoring') that required subjects to continuously monitor the relationship between a hand movement and its visual consequences. Three groups of schizophrenic patients, either with prominent paranoid-hallucinatory syndrome, with formal thought disorder or without these symptoms and a healthy control group were assessed with this task. The results from this study showed that patients with either paranoid-hallucinatory syndrome or formal thought disorder were selectively impaired in their ability to detect a mismatch between a self-generated movement and its consequences but not impaired in their ability to automatically compensate for the gain change. Patients without these symptoms were much less impaired. This result supports the assumption that self-monitoring is mainly impaired in patients with psychosis, but hardly in non-psychotic patients. It has been proposed that psychotic patients cannot correctly predict the sensory consequences of motor programs specifying the actual movement (Blakemore & Frith, 2003; Frith et al., 2000). However, this would imply that the ability to automatically compensate for gain changes is also somewhat impaired in these patients. This was not the case. All patients compensated for the gain change similar to healthy controls. Patients with formal thought disorder were most severely impaired in detecting a mismatch between self-generated movements and their visual consequences. This result shows that impaired self-monitoring (Levelt, 1989) is, in part, underlying formal thought disorder. Our results expand findings from another study (Fourneret, Franck, Slachevsky, & Jeannerod, 2001) which suggests that the experience of alien control cannot be directly related to an underlying cognitive deficit in the conscious monitoring of their own actions. Other studies led to the notion of an impaired working memory/executive function deficit in schizophrenia as one of the contributing factors of an action monitoring deficit (Posada, Franck, Georgieff, & Jeannerod, 2003).

Taken together, the results show that an impaired self-monitoring ability characterizes patients with a variety of core symptoms of schizophrenia. Given the diversity of these symptoms it seems unlikely that a single self-concept or self-system is disturbed. Rather, it might be useful to think of specific sub-systems that underlie these different symptoms. These systems are connected to a complex self-model that is the result of an interaction of multiple systems that embody intentionality and result in the experience to be a self (Kircher & David, 2003a; O'Brian & Opie, 2003). One functional principle that may underlie some these systems is that they generate expectations

about what the perceived physical and mental consequences of intentions, actions, and thoughts will be. Paranoid-hallucinatory symptoms and formal thought disorder in schizophrenia could then be conceptualised as impairments of generating reliable predictions in different sub-systems of the self-model.

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References

Armstrong, D. (1980). *The nature of mind and other essays*. Ithaca: Cornell University Press.

Blakemore, S. J., & Frith, C. D. (2003). Disorders of self-monitoring and the symptoms of schizophrenia. In T. Kircher & A. David (Eds.), *The self in neuroscience and psychiatry*. Cambridge, UK: Cambridge University Press.

Blakemore, S. J., Frith, C. D., & Wolpert, D. M. (2001). The cerebellum is involved in predicting the sensory consequences of action. *Neuroreport, 12*, 1879–1884.

Blakemore, S. J., Smith, J., Steel, R., Johnstone, C. E., & Frith, C. D. (2000). The perception of self-produced sensory stimuli in patients with auditory hallucinations and passivity experiences: Evidence for a breakdown in self-monitoring. *Psychological Medicine, 30*, 1131–1139.

Blakemore, S. J., Wolpert, D. M., & Frith, C. D. (1998). Central cancellation of self-produced tickle sensation. *Nature Neuroscience, 1*, 635–640.

Blakemore, S. J., Wolpert, D. M., & Frith, C. D. (2002). Abnormalities in the awareness of action. *Trends in Cognitive Sciences, 6*, 237–242.

Block, N., Flanagan, O., & Güzeldere, G. (1997). *The nature of consciousness*. Cambridge, MA: MIT Press.

Bridgeman, B. (2000). Interactions between vision for perception and vision for behavior. In Y. Rossetti & A. Revonsuo (Eds.), *Beyond dissociation: Interaction between dissociated implicit and explicit processing* (pp. 17–40). Amsterdam: John Benjamins.

Bridgeman, B., Lewis, S., Heit, G., & Nagle, M. (1979). Relation between cognitive and motor-oriented systems of visual position perception. *Journal of Experimental Psychology: Human Perception and Performance, 5*, 692–700.

Castiello, U., Paulignan, Y., & Jeannerod, M. (1991). Temporal dissociation of motor responses and subjective awareness. A study in normal subjects. *Brain, 114*, 2639–2655.

Churchland, P. (1995). *The engine of reason, the seat of the soul: A philosophical journey into the brain*. Cambridge, MA: MIT Press.

Daprati, E., Franck, N., Georgieff, N., Proust, J., Pacherie, E., Dalery, J., & Jeannerod, M. (1997). Looking for the agent: An investigation into consciousness of action and self-consciousness in schizophrenic patients. *Cognition, 65*, 71–86.

Decety, J., Chaminade, T., Grezes, J., & Meltzoff, A. N. (2002). A PET exploration of the neural mechanisms involved in reciprocal imitation. *Neuroimage, 15*, 265–272.

Decety, J., & Grezes, J. (1999). Neural mechanisms subserving the perception of human actions. *Trends in Cognitive Sciences, 3*, 172–178.

Dehaene, S., & Naccache, L. (2001). Towards a cognitive neuroscience of consciousness: Basic evidence and a workspace framework. *Cognition, 79*, 1–37.

Dennett, D. (1991). *Consciousness explained*. Boston, Toronto, London: Little Brown and Company.

Farrer, C., Franck, N., Georgieff, N., Frith, C. D., Decety, J., & Jeannerod, M. (2003). Modulating the experience of agency: A positron emission tomography study. *Neuroimage, 18*, 324–333.

Feinberg, I. (1978). Efference copy and corollary discharge: Implications for thinking and its disorders. *Schizophrenia Bulletin, 4*, 636–640.

Fink, G. R., Markowitsch, H. J., Reinkemeier, M., Bruckbauer, T., Kessler, J., & Heiss, W.-D. (1996). Cerebral representations of ones own past: Neural networks 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. C., Happe, F., Frith, U., Baker, S. C., Dolan, R. J., Frackowiak, R. S., & Frith, C. D. (1995). Other minds in the brain: A functional imaging study of "theory of mind" in story comprehension. *Cognition, 57*, 109–128.

Fourneret, P., Franck, N., Slachevsky, A., & Jeannerod, M. (2001). Self-monitoring in schizophrenia revisited. *Neuroreport, 12*, 1203–1208.

Franck, N., Farrer, C., Georgieff, N., Marie Cardine, M., Dalery, J., d'Amato, T., & Jeannerod, M. (2001). Defective recognition of one's own actions in patients with schizophrenia. *American Journal of Psychiatry, 158*, 454–459.

Frith, C. D. (1987). The positive and negative symptoms of schizophrenia reflect impairments in the perception and initiation of action. *Psychological Medicine, 17*, 631–648.

Frith, C. D., Blakemore, S. J., & Wolpert, D. M. (2000). Abnormalities in the awareness and control of action. *Philosophical Transactions of the Royal Society of London B Biological Sciences, 355*, 1771–1788.

Frith, C. D., & Done, D. J. (1989). Experiences of alien control in schizophrenia reflect a disorder in the central monitoring of action. *Psychological Medicine, 19*, 359–363.

Goodale, M. A., Pelisson, D., & Prablanc, C. (1986). Large adjustments in visually guided reaching do not depend on vision of the hand or perception of target displacement. *Nature, 320*, 748–750.

Greenwald, A. G. (1970). Sensory feedback mechanisms in performance control: With special reference to the ideo-motor mechanism. *Psychological Reviews, 77*, 73–99.

Henry, M. (1963). *L'essence de la manifestation*. Paris: PUF.

Henry, M. (1965). *Philosophie et phénoménologie du corps*. Paris: PFU.

Ivry, R. B. (1996). The representation of temporal information in perception and motor control. *Current Opinion in Neurobiology, 6*, 851–857.

James, W. (1890). Principles of psychology. In *Encyclopedia Britannica*. Chicago.

James, W. (1950). *Principles of psychology* (Vol. I). New York: Dover Publications.

Jaspers, K. (1913). *Allgemeine psychopathologie*. Berlin: Springer.

Jaspers, K. (1963). *General psychopathology*. Manchester: Manchester University Press.

Jeannerod, M. (1994). The representing brain—neural correlates of motor intention and imaginery. *Behavioural and Brain Sciences, 17*, 187–202.

Jeannerod, M. (1999). The 25th Bartlett Lecture: To act or not to act: Perspectives on the representation of actions. *Quarterly Journal of Experimental Psychology A Human Experimental Psychology*, 1–29.

Jeannerod, M., Farrer, M., Franck, N., Fourneret, P., Posada, A., Daprati, E., & Georgieff, N. (2003). Action recognition in normal and schizophrenic subjects. In T. Kircher & A. David (Eds.), *The self in neuroscience and psychiatry*. Cambridge, UK: Cambridge University Press.

Kinsbourne, M. (1995). Awareness of one's own body: An attentional theory of its nature, development and brain basis. In J. L. Bermudez, A. Marcel, & N. Eilan (Eds.), *The body and the self*. Cambridge, MA: MIT Press.

Kircher, T. T. J., Brammer, M. J., Bullmore, E., Simmons, A., Bartels, M., & David, A. S. (2002). The neural correlates of intentional and incidental self processing. *Neuropsychologia, 40*, 683–692.

Kircher, T. T. J., & David, A. S. (2003a). Self consciousness: An integrative approach from philosophy, psychopathology and the neurosciences. In T. Kircher & A. David (Eds.), *The self in neuroscience and psychiatry*. Cambridge, UK: Cambridge University Press.

Kircher, T. T. J., & David, A. S. (2003b). *The self in neuroscience and psychiatry*. Cambridge, UK: Cambridge University Press.

Kircher, T. T. J., Liddle, P. F., Brammer, M. J., Williams, S. C. R., Murray, R. M., & McGuire, P. K. (2001a). Neural correlates of formal thought disorder in schizophrenia. *Archives of General Psychiatry, 58*, 769–774.

Kircher, T. T. J., Senior, C., Phillips, M. L., Rabe-Hesketh, S., Benson, P. J., Bullmore, E. T., Brammer, M., Simmons, A., Bartels, M., & David, A. S. (2001b). Recognising one's own face. *Cognition, 78*, B1–B15.

Knoblich, G., & Flach, R. (2001a). Predicting the effects of actions: Interactions of perception and action. *Psychological Sciences, 12*, 467–472.

Knoblich, G. & Kircher, T. (submitted). Deceiving oneself about control: Sensitivity for mapping changes between movements and their consequences.

Knoblich, G., & Prinz, W. (2001). Recognition of self-generated actions from kinematic displays of drawing. *Journal of Experimental Psychology: Human Perception and Performance, 27*, 456–465.

Knoblich, G., Stottmeister, F., & Kircher, T. T. J. (submitted). Self-monitoring in Schizophrenia.

Knuf, L., Aschersleben, G., & Prinz, W. (2001). An analysis of ideomotor action. *Journal of Experimental Psychology: General, 130*, 779–798.

Leube, D., Knoblich, G., Erb, M., Grodd, W., Bartels, M., & Kircher, T. T. J. (in press). The neural correlates of perceiving one's own movements. Neuroimage.

Levelt, W. J. (1983). Monitoring and self-repair in speech. *Cognition, 14*, 41–104.

Levelt, W. J. M. (1989). *Speaking from intention to articulation*. Cambridge, MA: MIT Press.

Locke, J. (1959). *An essay concerning human understanding* (Vol. I). New York: Dover Publications.

Lycan, W. G. (1997). *Consciousness and experience*. Cambridge, MA: MIT Press.

Malenka, R. C., Angel, R. W., Hampton, B., & Berger, P. A. (1982). Impaired central error-correcting behavior in schizophrenia. *Archives of General Psychiatry, 39*, 101–107.

Markowitsch, H. J. (2003). Autonoëtic consciousness. In T. Kircher & A. David (Eds.), *The self in neuroscience and psychiatry*. Cambridge, UK: Cambridge University Press.

Merleau-Ponty, M. (1965). *Phänomenologie der Wahrnehmung (Phénoménologie de la Perception, Gallimard, Paris, 1945)*. Berlin: Walter de Gruyter.

Metzinger, T. (Ed.). (1995). *Conscious experience*. Paderborn: Schöningh-Verlag.

Milner, A. D., & Goodale, M. A. (1995). *The visual brain in action*. New York: Oxford University Press.

Mlakar, J., Jensterle, J., & Frith, C. D. (1994). Central monitoring deficiency and schizophrenic symptoms. *Psychological Medicine, 24*, 557–564.

Moller, P., & Husby, R. (2000). The initial prodrome in schizophrenia: Searching for naturalistic core dimensions of experience and behavior. *Schizophrenia Bulletin, 26*, 217–232.

O'Brian, G., & Opie, J. (2003). The multiplicity of consciousness and the emergence of the self. In T. Kircher & A. David (Eds.), *The self in neuroscience and psychiatry*. Cambridge, UK: Cambridge University Press.

Parnas, J. (2000). The self and intentionality in the pre-psychotic stages of schizophrenia: A phenomenological study. In D. Zahavi (Ed.), *Exploring the self* (pp. 115–147). Amsterdam, Philadelphia: John Benjamin.

Parnas, J. (2003). Anomalous self-experience in early schizophrenia: The clinical manifestations. In T. Kircher & A. David (Eds.), *The self in neuroscience and psychiatry*. Cambridge, UK: Cambridge University Press.

Posada, A., Franck, N., Georgieff, N., & Jeannerod, M. (2003). Anticipating incoming events: An impaired cognitive process in schizophrenia. *Cognition, 81*, 209–226.

Prablanc, C., & Martin, O. (1992). Automatic control during hand reaching at undetected two-dimensional target displacements. *Journal of Neurophysiology, 67*, 455–469.

Prinz, W. (1992). Why don't we perceive our brain states? *European Journal of Cognitive Psychology, 4*, 1–20.

Prinz, W. (1997). Perception and action planning. *European Journal of Cognitive Psychology, 9*, 129–154.

Rees, G. (2001). Neuroimaging of visual awareness in patients and normal subjects. *Current Opinion in Neurobiology, 11*, 150–156.

Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Reviews Neuroscience, 2*, 661–670.

Ruby, P., & Decety, J. (2001). Effect of subjective perspective taking during simulation of action: A PET investigation of agency. *Nature Neuroscience, 4*, 546–550.

Spence, S. A., Brooks, D. J., Hirsch, S. R., Liddle, P. F., Meehan, J., & Grasby, P. M. (1997). A PET study of voluntary movement in schizophrenic patients experiencing passivity phenomena (delusions of alien control). *Brain, 120*, 1997–2011.

Stamenov, M. (2003). Language and self-consciousness: Modes of self-presentation in language structure. In T. Kircher & A. David (Eds.), *The self in neuroscience and psychiatry*. Cambridge, UK: Cambridge University Press.

Stirling, J. D., Hellewell, J. S., & Quraishi, N. (1998). Self-monitoring dysfunction and the schizophrenic symptoms of alien control. *Psychological Medicine, 28*, 675–683.

Stuss, D. T., Gallup, G. G., Jr., & Alexander, M. P. (2001). The frontal lobes are necessary for 'theory of mind'. *Brain, 124*, 279–286.

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.

von Holst, E., & Mittelstaedt, H. (1950). Das Reafferenzprinzip (Wechselwirkungen zwischen Zentralnervensystem und Peripherie). *Naturwissenschaften, 37*, 464–476.

Wolpert, D. M., & Kawato, M. (1998). Multiple paired forward and inverse models for motor control. *Neural Networks, 11*, 1317–1329.

Zahavi, D. (2003). Phenomenology of self. In T. Kircher & A. David (Eds.), *The self in neuroscience and psychiatry*. Cambridge, UK: Cambridge University Press.