Brain and Mind **2:** 195–211, 2001.

"Brain-Paradox" and "Embeddment" – Do We Need a "Philosophy of the Brain"?

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(Received: 29 November 2000; accepted: 27 August 2001)

Abstract. Present discussions in philosophy of mind focus on ontological and epistemic characteristics of mind and on mind-brain relations. In contrast, ontological and epistemic characteristics of the brain have rarely been thematized. Rather, philosophy seems to rely upon an implicit definition of the brain as "neuronal object" and "object of recognition": hence ontologically and epistemically distinct from the mind, characterized as "mental subject" and "subject of recognition". This leads to the "brain-paradox". This ontological and epistemic dissociation between brain and mind can be considered central for the problems of mind and mind-brain relations that have yet to be resolved in philosophy. The brain itself has not been thematized epistemically and ontologically, leading to a "brain problem". The epistemic and ontological dissociation between brain and mind presupposes an "isolated" picture of the brain, characterized by context-independence (i.e. "isolation" from body and environment). We can describe this view as an extrinsic relationship between brain, body and environment. However, based on recent empirical findings about body image and phantom sensations, we can no longer consider the brain as context-independent or "isolated" from its bodily and environmental context. Instead, the brain must be considered "embedded". Within the context of 'embeddment', brain and bodily/environmental context seem mutually to determine each other, and hence be reciprocally dependent on each other. We can describe this as an intrinsic relationship between brain, body and environment. Defining the brain as "embedded" undermines the epistemic and ontological dissociation between brain and mind and consequently resolves the "brain-paradox". This resolution sheds novel light on problems of mind and mind-brain relations by relativizing both. It is therefore concluded that philosophy should thematize ontological and epistemic characteristics of the brain, thereby taking into account the "brain problem" and developing a "philosophy of the brain". This approach not only opens a new field in philosophy but also extends the focus of empirical investigation in the neurosciences to take into account the intrinsic relationship between brain, body and environment.

Key words: brain-paradox, embeddment, mind-brain problem, philosophy of the brain

"Consciousness is a brain phenomenon, but the brain itself is a brain phenomenon"

H. Kuhlenbeck (1965)

1. Introduction: Mind-Brain Relationship and "Brain-Paradox"

1.1. BRAIN AND MIND

Neuroscientists and philosophers who assert the possibility of explaining the mind in neuroscientific terms, reflecting so-called materialistic solutions of the mind-brain relationship, are challenged by the fact that mental states themselves cannot be detected within the brain itself. For example, the subjective experience of phantom limbs cannot be found within the brain: only corresponding neuronal states but not the respective mental state of phantom experience itself can be observed there. Despite the fact that mental states cannot be detected within the brain itself, modulation of neuronal states may nevertheless alter mental states. The experience of phantom pain may be suppressed by drugs that alter the functional state of morphine receptors. Consequently mental states seem to be both dependent on and independent from neuronal states (i.e. the brain) at the same time. We will call this the "brain paradox." Philosophers who focus predominantly on the problems of mind and mind-brain relations have discussed the relationship between neuronal and mental states extensively. Neither problem has been resolved convincingly and some consider the mind-brain problem intractable and insolvable (Van Gelder, 1998). In contrast to mind and the mind-brain relationship, ontological and epistemic characteristics of the brain have rarely been thematized. One may therefore speak of a "brain problem" requiring a "philosophy of the brain".

The purpose of the present contribution consists in the following: (i) a formulation of the "brain paradox" in a strictly logical sense as an "antinomy"; (ii) an epistemic and ontological characterization of the brain as an "embedded brain," drawing upon empirical data from the case of phantom limbs; and (iii) a resolution of the "brain paradox" as an "antinomy" by applying an epistemic distinction between "embedded brain" and "isolated brain." It is hypothesized that an epistemic distinction between "isolated brain" and "embedded brain" does not allow us to assume that the mind is ontologically distinct from the brain. Defining the brain as "embedded" undermines the epistemic and ontological dissociation between brain and mind, and consequently resolves the "brain paradox." This resolution sheds new light on problems of mind and mind-brain relations by relativizing both.

1.2. "BRAIN-PARADOX" AS AN "ANTINOMY"

Despite apparent epistemic and ontological differences between brain and mind, the mind is necessarily dependent on the brain: without brain there is no mind.

Due to this dependence, the brain must somehow be reflected in the mind; but at the same time, due to the differences, the mind cannot be detected within the brain itself. The relationship between brain and mind may therefore be characterized by concomittant self-referentiality and non-self-referentiality. This is logically contradictory, since mind and brain cannot mutually refer to each other while at the same time not referring to each other. It is this contradiction between concomittant self-referentiality and non-self-referentiality that is crystallized in the "brain paradox."

An initial presentation of the "brain paradox" – though not in a strictly logical sense – can be traced back to Schopenhauer, who first considered the brain to be both "subject of recognition" and "object of recognition." The brain recognizes other brains while at the same time it is recognized by other brains: "Aber sofern das Gehirn erkennt, wird es selbst nicht erkannt; sondern ist das Erkennende, das Subjekt aller Erkenntnis .... Was hingegen erkennt, was jene Vorstellung hat, ist das Gehirn, welches jedoch sich selbst nicht erkennt, sondern nur als Intellekt; d.h. als Erkennendes, also nur subjektiv, sich seiner bewußt wird" (Schopenhauer, 1977, p. 302). Kuhlenbeck, relying on Schopenhauer, formulates the same point in Englisch: "...our phenomenal world of consciousness is a brain phenomenon, but the brain itself, as we know it, is a phenomenon of consciousness; or, in shorter form: consciousness is a brain phenomenon, but the brain itself is a brain phenomenon" (Kuhlenbeck, 1965, p. 595). According to Kuhlenbeck (1960, p. 181; 1972, p. 376) the "brain paradox" is the logical proof of the theoretical insolvability of the mind-brain problem. Due to the fact that the world appears only as a "brain phenomenon" for us, we remain principally unable to recognize the world itself as an "absolute world" independent from ourselves and thus from the brain itself. Relying on initial versions by Schopenhauer and Kuhlenbeck we now want to reformulate the "brain paradox" in a strictly logical sense, as an "antinomy."

The brain (as a subject) recognizes all subjects as brains.

A psychiatrist (PS) and a philosopher (PH) meet on a conference on consciousness. The psychiatrist, who works in functional brain imaging, investigates the ability of the brain to recognize one's own and other persons. The philosopher is a specialist on the problem of self-recognition and self-consciousness. Both discuss epistemic implications of functional brain imaging for recognition of one's own and other persons and brains.

PS: I recognize you as a brain.
PH: Sounds interesting. What about other persons?
PS: I recognize all persons as brains.
PH: Who gives you that ability?
PS: My brain. My brain recognizes all persons as brains.
PH: Who are you?

PS: A person, of course.
PH: How do you recognize yourself?
PS: As a person, of course.
PH: Who recognizes yourself as a person?
PS: My brain.
PH: If your brain recognizes yourself not as a brain but as a person then your assumption, "My brain recognizes all persons as brains" must be wrong.

How should the psychiatrist answer?

The brain apparently references its own brain via the mind, whereas others brains are referenced as brains. Such a double reference leads apparently to irreducible "self-contradiction by accepted ways of reasoning" (Quine, 1976, p. 5). The sentence constituting the "brain paradox" as an antimony is true if and only if it is false: as is, for example, the famous antinomy of Epimenides (himself a Cretan), "All Cretans are liars." If the brain recognizes itself as the "subject of recognition" it cannot recognize any other brain as the "subject of recognition" but only as "objects of recognition." If the brain recognizes all other brains as "subjects of recognition" it cannot recognize itself as the "subject of recognition" but only as an "object of recognition." Consequently, the sentence is true if and only if it is false: It is either true for one's own brain and false for others' brains, or false for one's own brain and true for others' brains.

In summary the "brain paradox" as an "antinomy" points out the double role of the brain recognizing itself as a mind, i.e., "subject of recognition," and being recognized as a brain, i.e. "object of recognition." This status is contradictory since due to the epistemic and ontological differences one and the same organ (i.e., the brain) cannot be both mind and brain at the same time.

2. "Embodiment" and "Embeddment" of the Brain: Neuronal Organisation in Phantom Sensations

2.1. BODY IMAGE

We are well able to identify movements and specific parts of our own and others bodies and we are able to perceive the body as a whole, i.e., its "general body structure" (Melzack, 1989). This "general body structure" must somehow be encoded by the brain since otherwise we would be unable to recognize and observe either our own or others' bodies. Consequently the "general body structure," which we recognize and observe, must somehow be generated and constructed by the brain itself. This is sometimes called the "body schema" or "body image" and can be defined as follows: "The final result, a mental construct that comprises the sense impressions, perceptions and ideas about the dynamic organisation of one's own body and its relation to that of other bodies, is variously termed body schema, body image and corporeal awareness" (Berlucchi and Aglioti, 1997, p. 560).

How does the brain construct the body (image) to which it is related? According to Melzack (1992) construction of the body image in the brain relies upon a large neural network in which somatosensory cortex, posterior parietal lobe and insular cortex play crucial and different roles. The somatosensory cortex is apparently responsible for constructing the general shape of the body, relying on tactile and propioceptive stimuli. The posterior parietal cortex (comprised of superior parietal cortex, intraparietal sulcus, and adjacent rostral and inferior parietal lobule), especially the right hemisphere, seems to provide the linkage between the tactile-propioceptive body shape as constructed in somatosensory cortex and spatial coordinates. This linkage generates a spatial schema of the body, i.e., the body image. Finally the insular cortex provides the linkage with those parts of the limbic system (hypothalamus, etc.) involved in emotional and visceral functions. Consequently generation of body image is closely related to visceral and emotional functions of that particular individual person.

Lesion studies support the existence of this neural network generating and constructing the body image. Lesions in somatosensory cortex induce deficits in the tactile and propioceptive spheres, leading to severe alterations in body image with an inability to delineate the shape of one's own body from the environment (see Berlucchi and Aglioti, 1997; Metzinger, 1997). Lesions in parietal cortex do not affect one's ability to delineate the shape of the body but rather the ability to recognize the shape of the body in a correct way. These alterations in awareness of the body may be reflected in either positive or negative symptoms (Berlucchi and Agliotti, 1997). Negative symptoms include denial or non-recognition, i.e., anosognosia of motor and/or sensory deficits (see below for further explication), personal neglect in the form of hemisomatoagnosia (neglect of one side of one's own body), feelings of non-belonging and denial of ownership of a body part, and hatred of hemiparetic limbs, i.e., misoplegia. Patients exclude and expunge the neglected or disowned body parts from the body image and justify the parts' material existence with confabulatory explanations. Positive symptoms include supernumary limbs, where patients report the existence of an additional limb, e.g., of a third "ghost arm" (Hari *et al*., 1998). Interestingly, one patient with a right parietal cortical lesion reporting such a "ghost arm" showed suppression of somatosensory evoked potentials (i.e. SEP) only in secondary somatosensory cortex (SII), an area close to the insula, but not in primary somatosensory cortex (SI). This case supports further the assumption of a differential role of primary and secondary somatosensory cortex in generation of the body image. The right parietal cortex seems especially to be related with the image of one's own body, whereas the left parietal cortex may be related to body image in general i.e. the one from one's own and others' bodies. Finally, lesions or electrical stimulation in the insular can cause somatic hallucination, illusions of changes in body positions and feelings of being outside one's own body (Berlucchi and Aglioti, 1997). These symptoms indicate the particular importance of this area in generating the body image.

Activity in the neural network generating the body image cannot be primarily related to single and separate stimuli independently from their respective context. Instead, activity in this neural network seems to be primarily organized in relation to and dependent upon the respective context, as reflected, for example, in the crucial role of tactile and propioceptive stimuli and thus of somatosensory cortex for body image. Therefore construction of the body image is not primarily related to the absolute position of every single and separate limb independently from the respective context, reflecting purely "mechanical markers." Rather, it is related to the relative position of a limb to other limbs and the respective environmental context, reflecting angles and trajectories as "bio-mechanical markers" (see also Jahanshahi and Frith, 1998; Deecke, 1996; Jeannerod, 1997; Wolpert *et al.*, 1996). Therefore neural activity may not be organised according to the stimuli itself, but rather in orientation to relations between stimuli and context (see also Thelen and Smith, 1994, pp. 132–138).

2.2. PHANTOM SENSATIONS AND CORTICAL PLASTICITY

The most interesting disturbance of the body image is the phantom limb where "people who have lost an arm or leg often perceive the limb as though it is still there" (Melzack, 1992, p. 90). Several philosophers, including Descartes and Merleau-Ponty, recognized the possibility of phantom limbs. Due to new imaging techniques, this phenomenon has recently invoked interest among neuroscientists as well. In the following, we will describe briefly the phenomenon of phantoms and the pathophysiological mechanisms potentially underlying them.

Some authors (Ribbers *et al.*, 1989, p. 137; Heinzel, 1998) distinguish between "phantoms," "phantom sensation," and "phantom pain." "Phantom" refers to the "awareness of non-existent or deafferentiated part of the body with a specific shape, a specific weight, or a specific kinetic". "Phantom sensation" refers to all painless sensations of the phantom which can be used synonoumsly with "phantom experiences." "Phantom pain" refers to all painful sensation of the phantom. Phantom sensations can occur after amputation of the legs and almost all other parts of the body (breast, rectum, penis, etc.) and are characterized by kinaesthetic sensations, kinetic sensations such as feelings of movements, and exteroceptive sensations such as feelings of external pressure, tactile stimuli, or alterations of temperature (Jensen, 1984, p. 409; Davis, 1993). The central characteristic of phantom sensations is the subjective experience of a feeling of certainty despite objective counterevidence. This feeling of subjective certainty leads to the conviction of reality of the phantom: "The most extraordinary feature of phantoms is their reality to the amputee. Their vivid sensory qualities and precise location in space – especially the first – make the limbs so lifelike that a patient may try to step off a bed onto a phantom foot or lift a cup with a phantom hand. The phantom, in fact, may seem more substantial than an actual limb, particularly if it hurts' (Melzack, 1992, p. 90). Thereby the subjective feeling of a phantom is stronger than insight into the objective reality of the loss of that particular limb. This feature is demonstrated impressively in the following case reports.

> A sailor accidentally cut off his right index finger. For forty years afterwards he was plagued by an intrusive phantom of the finger rigidly extended, as it was when cut off. Whenever he moved his hand towards his face – for example to scratch his nose – he was afraid that his phantom finger would poke out his eye out. He knew this to be impossible, but the feeling was irresistible (Sacks, 1985, pp. 63–64).

Another patient (P), without any cognitive deficits, reported a phantom arm in a talk with an interviewer (I):

I: How many arms do people usually have?
P: Two
I: And if someone lost an arm, they would have?
P: Just the one.
I: How many arms do you have?
P: Three.
I: How did that happen?
P: I had one amputated.
I: If you have two arms and one was amputated, how many arms would you have?
P: Two ... or three. I know it's a nonsense (Halligan *et al.*, 1993, pp. 159–166):

Another characteristics of phantom sensations consists in the fact that they can be influenced and modulated by a variety of internal and external stimuli. For example physical stimuli such as temperature and weather may modulate the feeling of the phantom limb. This feature is demonstrated nicely in the following case report: "Thus before a spell of frost his toes felt crushed as if by a tight show. (...) Again, before rain he had the sensation as if his foot and toes were incompletely immersed in water which was being gently whirled around. (...) All these abnormal sensations were more obtrusive in the winter and so accurate that he had gained a local reputation as a weather prophet" (Riddoch, 1941, p. 199). In addition to physical stimuli, psychological functions may modulate phantom sensations as well. Strong concentration ("... when his mind was fully occupied he was unaware of his phantom," Riddoch, 1941, p. 198) or intense emotions ("emotions such as anger or excitement makes the patient forget the phantom," Henderson and Smyth, 1948, p. 98) may modulate the phantom sensation.

How can we account for phantom phenomena? Melzack (1992) assumes, on the basis of the body image introduced above, that there is a neural network or so-called "neuromatrix" – including the somatosensory system, reticular afferents to the limbic system, and cortical regions – that is important for self-recognition and recognition of external objects and entities. This "neuromatrix" is largely prewired by genetics and generates a continuous pattern of activity, the "neurosignature", that can be modified by new sensory inputs. Consequently, Melzack distinguishes between a genetically determined and thus unchangeable part within the neuromatrix, the "phylomatrix", and an experience-dependent part, the "ontomatrix" (Melzack, 1989, p. 10). In the anatomical regions of the neuromatrix, neural processing is generated in parallel cycles. Melzack calls this "cyclical processing" and claims that it provides feelings and action in relation to the body image. Phantom phenomena may then be caused primarily by the persisting activity of those components within the "neuromatrix" that have been deprived of their normal inputs because of the loos of a body part, and by the brain's interpreting this activity as originating from the lost part.

How does this alteration in the brain's interpretation of activity take place: that is, what are the corresponding physiological mechanisms? Recent research shows that the existence of phantoms is closely related to cortical plasticity, reflecting reorganisational processes in somatosensory cortex (Ramachandran, 1993, 1995, 1996). If, for example, the right hand is amputated, the left hand has to take over all the functions of the right. The cortical area for the left hand is enlarged by these additional demands. Similar observations have been made in musicians, whose fingers that are trained and involved in playing their respective instruments showed much larger areas of representation in somatosensory cortex than their other fingers (Elbert *et al.*, 1995). Phantom sensations may thus be accounted for by cortical reorganisation: Representational areas for still existing limbs overlap with those for the amputated limbs, so that neuronal impulses derived from the former are related to the latter. There is confusion in recognising the origin of neuronal impulses (Flor *et al.*, 1995; Knecht *et al.*, 1996, 1998).

What are the mechanisms of cortical reorganisation? Partial deafferentiation, reflecting disruption of neuronal linkages in amputation, may occur in a staged fashion (Berlucchi and Aglioti, 1997; Davis, 1993). First it may involve the immediate expression of latent inputs, second the formation of new synapses, and third the stabilization or elimination of synapses in accordance with their functional usefulness. Thereby afferences, being functionally inactive before amputation, may be reactivated during partial deafferentiation: probably providing new functional linkages that had not been functionally relevant before the deafferentiation. Demasking of previously subthreshold synapses by means of, for example, loss of GABAergic-mediated local inhibition, as well as modulating synaptic efficiacy by means of, for example, new forms of activity-dependent modulation mediated by NMDA-receptors, may play crucial roles in cortical reorganisation (Davis, 1993; Knecht and Ringelstein, 1999). Cortical reorganisation may be modulated by several factors including age, training and a variety of different neurochemical agents (see Knecht and Ringelstein, 1999 for an overview). It remains unclear whether the phantom pain itself may be considered either as the consequence of cortical reorganisation or rather as the cause for induction of reorganisational processes. The latter assumption is supported by reversal of cortical reorganisation in subjects with regional anesthesia for their phantom pains (Birbaumer *et al.*, 1997) or myoelectric prosthesis (Lotze *et al.*, 1999) It is therefore suggested that phantom pain and pain in general may alter the synaptic threshold for activation in somatosensory cortical areas, leading consequently to cortical reorganisational processes.

Finally, it is important to note that these processes of cortical reorganisation can only be induced by a functionally meaningful context: as reflected in behaviourally, i.e., functionally relevant stimuli. Meaningless stimuli, for example a passive highly repetitive sensory stimulation without behavioral relevance for the respective individual person, do not lead to cortical reorganisation (Knecht and Ringelstein, 1999). Consequently, as already supported by the enlarged cortical representational areas in musicians and phantom patients (see above), the criterion for induction of cortical reorganisation (of the body image) does not consist primarily in any kind of change irrespective of its behavioral relevance, but rather in the meaning of alterations and stimuli as reflected in functional, i.e., behavioral usefulness for the respective individual person: "The meaning of a stimuli for the behaving organism's attention and intentions seems to be crucial for the overall dynamics of the organisation of sensory cortical maps, so that foreign inputs that become expressed in a deafferentiated portion of the somatosensory cortex should be maintained only if they can command attention and be useful for motor control" (Berlucchi and Aglioti, 1997, p. 563).

3. "Philosophy of the Brain": "Embeddment"

3.1. DEFINING "EMBEDDED BRAIN" AND "ISOLATED BRAIN"

The empirical examples just discussed demonstrate the following: (i) a close, i.e., intrinsic relationship between brain and body, as reflected in generation of body image by the brain; (ii) a close, i.e., intrinsic relationship between brain/body and environment, as reflected in context-dependence of neuronal organisation. Point (ii) is supported by the necessity of context-dependence. We demonstrated that neuronal organisation in terms of spatial markers is necessarily dependent on the respective bodily context, so that neuronal organisation relied on "bio-mechanical markers" rather than on "mechanical markers" (see above). Furthermore, cortical reorganisation was not determined primarily by stimuli themselves but rather by their functional relevance, i.e., by meaning of the stimuli in relation to the respective environmental context (see above). In both cases neuronal organisation remained necessarily dependent upon the respective bodily and environmental context. It is this necessary dependence between brain, body and environment that characterizes an intrinsic relationship. Such an intrinsic relationship has to be distinguished from an extrinsic relationship where brain, body and environment are only contingently related to each other, showing neither reciprocal dependence nor mutual determination.

An intrinsic relationship between brain, body and environment defines "embeddment." Embeddment must be distinguished from "isolation," which denotes a purely extrinsic relationship between brain, body and environment. "Embeddment" can be defined in three distinct senses. First, "embeddment" may refer to "embodiment": an intrinsic integration of the brain within the body (making the celebrated "brain in a vat" impossible). Second, "embeddment" in a narrow sense may refer to "embeddment" as intrinsic integration of brain and body within the environment (making an "objective body," as distinguished from a "lived body" impossible). Third, "embeddment" may refer to "embeddment" in a wider sense, including both above mentioned senses of "embeddment," i.e. "embodiment" and "embeddment" in a narrow sense (making "isolation" between brain, body and environment impossible). It is the latter sense of "embeddment" (as distinguished from "isolation") which is referred to as "embeddment" in the following.

The nature of exact relation between brain and body should first be described in more detail. Some authors regard the brain as a control system for the body, a "controller for an embodied activity" (Clark, 1997, p. XII), implying only unilateral dependence between brain and body. The body becomes controlled and determined by the brain but not vice versa. One could no longer speak of "embeddment" in the third sense defined above. Rejecting such unilateral dependence, Shoemaker speaks of "biological embodiment," pointing out the relevant and constitutive role of the body for dynamic brain organisation itself (see Shoemaker, 1984, pp. 117–119). In addition to the more general notion of "biological embodiment," Shoemaker assumes "volitional embodiment" and "sensory embodiment," denoting brain-body relationships in more specific senses (Shoemaker, 1984, p. 117). In "volitional embodiment" the brain and body are reciprocally dependent on each other. Realization of movements, as related to the body, depends on volition, as related to the brain. Generation of volition depends also on predispositional structures and possibilities of the body, implying that the relationship between brain and body can be characterized by "co-constitution and co-occurrence" with respect to volitions. "Sensory embodiment" describes reciprocal adaptation between sensory functions and environmental events. Brain, body and environment "mesh" to each other (Shoemaker, 1984, pp. 125–126), as is reflected in context-dependence of neuronal organisation (see above).

Next, the ontological relationship between brain, body and world shall be described in a more differentiated way. Lakoff and Johnson (1999, p. 36) distinguish between "neural embeddment" and "phenomenal embeddment." The latter describes interactions between brain/body and world, whereas the former characterizes neural mechanisms that give rise to "phenomenal embeddment." Principles of dynamic brain organisation reflect neural organisation, i.e., the "neural embeddment" necessary for realizing interaction between brain/body and world that reflects "phenomenal embeddment." "Neural embeddment" is thus a necessary though not sufficient condition for the latter.

In addition to distinct forms of embeddment ("neural" and "phenomenal"), distinct kinds of ontological relations between brain/body and world may be distinguished. Borrett *et al.* (2000, pp. 262–263) distinguishes between "analytic" and "phenomenological embeddment." "Analytic embeddment" denotes only a contingent relation between brain/body and environment, whereas "phenomenological embeddment" describes a necessary relation between brain/body and world reflecting mutual determination and reciprocal dependence between both.

The "embedded brain" can also be defined by a relationship of "co-constitution and co-occurrence," with mutual determination and reciprocal dependence between brain, body and environment reflecting "phenomenological embeddment". In contrast, the "isolated brain" shows only "interaction and modulation" but no "co-constitution and co-occurrence" between brain, body and environment, reflecting only "analytic embeddment." The brain defined as an "isolated brain" may interact with body and environment, which in turn may modulate brain function. However the basic structure of neuronal organisation of the "isolated brain" remains independent from and undetermined by body and environment.

As we demonstrated above, there is strong empirical support for assuming that the human brain is an "embedded brain." The case of phantom sensations showed that realization and implementation of dynamic brain organisation seems to be dependent on and determined by the respective bodily and environmental context. Furthermore, if "phenomenological embeddment" is replaced by "analytic embeddment," the brain no longer functions in its 'normal' way: as illustrated by such neuropsychological disturbances as anosognosia and the like (see above).

Finally, the epistemic relationship between brain, body and world shall be described with respect to the definitions of "isolated brain" and "embedded brain." In addition to "phenomenological embeddment" one may speak of "epistemic embeddment," describing reciprocal dependence between brain, body and environment with respect to epistemic abilities. The body remains dependent on the brain since the brain provides predispositional epistemic structures for the possibility of active epistemic exploration of the environment as performed by the body. Conversely, the predispositional epistemic structures of the brain depend on the body since the body provides the referent, i.e., the "spatial center" (see above) necessary for development of the former. The problem of potential dependence of predispositional epistemic brain structures on the body has been discussed in philosophy by means of the example of a "brain in the vat." A "brain in the vat" is a "disembodied brain" and thus an "isolated brain" with which any kind of "modulation and interaction" (see above) with body and environment is impossible. If a "brain in the vat" would show similar epistemic abilities and inabilities as our actual brain, distinguishing between "epistemic embeddment" and "epistemic isolation" would be superfluous. However, due to the lack of a similar body and environment, a "brain in the vat" would have different epistemic abilities with distinct mental states: "Applying this to the case of the brain in the vat, if there were brains in the vat, receiving their sensory inputs from computers, their words could not have the same referents as ours have and their mental states could not have the same contents ours have" (Shoemaker, 1984, p. 57). Consequently, the case of "brains in the vat" underlines the importance of distinguishing between "embedded brain" and "isolated brain" in epistemic respects and implies the necessity of assuming "epistemic embeddment."

In summary, the brain can be defined ontologically as an "embodied brain" characterized by integration of the brain within the body, and as an "embedded brain" determined by intrinsic adaptation between brain and environment. The "embodied brain" can be characterized by "biological embodiment," "volitional embodiment," and "sensory embodiment." Ontologically, the "embedded brain" can be characterized by "co-constitution and co-occurrence." There is mutual determination and reciprocal dependence between brain, body and environment, reflecting "phenomenological embeddment" as opposed to "analytic embeddment." Epistemically, the "embedded brain" can be characterized by reciprocal dependence between epistemic brain structures and bodily reference, reflecting "epistemic embeddment" contrasted with a "brain in the vat" and "epistemic isolation."

3.2. ONTOLOGICAL AND EPISTEMIC IMPLICATIONS OF "EMBEDDMENT"

Characterizing the brain as "neuronal object" and "object of recognition" presupposes its "isolation" from the environment (in the sense of "isolated brain" defined above). If the brain is not "isolated" from the environment, then it could not be distinguished from the "mental subject," i.e., the mind, in ontological respects. "Embeddment" as defined by an intrinsic relationship between brain, body and environment (see above) neither allows for dissociation between "neuronal object" and "mental subject" nor between "object of recognition" and "subject of recognition." Instead, ontological and epistemic dissociations between brain and mind are replaced by distinct forms of so-called "selective-adaptive couplings" between brain, body and environment, reflecting their intrinsic relationship.

Second, it remains true that mental states cannot be detected within the brain itself, but only for the "isolated brain." In contrast, mental states may be found within relationship between brain, body and environment and may therefore be related with the "embedded brain". For example, subjective experience of the phantom limb itself cannot be found within the "isolated brain," where neuronal states are considered in isolation from their respective bodily and environmental context. Instead, we demonstrated that organisation and reorganisation of neuronal states in cerebral cortex relies predominantly on functional relevance, i.e., on meaning in relation to the respective environmental context (see above). The limb experienced as a phantom still has a particular functional relevance, i.e., a meaning for the subject within its environmental context. Consequently, organisation of individual neuronal states can only be accounted for by considering their relation to bodily and environmental context. Though the phantom limb cannot be found within the "isolated brain," it may nevertheless be located in the intrinsic relationship between brain, body and environment, and thus in the "embedded brain."

Third, the distinction between "isolated" and "embedded brain" cannot be considered primarily as an ontological difference. Rather, both definitions can be distinguished in an epistemic respect from which no ontological differences follow. "Isolated brain" and "embedded brain" describe distinct forms of "selective-adaptive coupling" between brain, body and environment, reflecting different kinds of epistemic abilities. The definition of "isolated brain" reflects the epistemic ability of abstraction since such an account detaches the brain from its own necessary conditions, i.e., the body and the environment. The definition of "embedded brain" reflects the epistemic ability of "concretion" since such an account relies on drawing relationships between brain, body and environment.

Fourth, since both "isolated brain" and "embedded brain" reflect distinct kinds of epistemic abilities (see above), recognition of both may dissociate from each other. We are well able to recognize directly an "isolated brain" since we can abstract neuronal states from their own necessary conditions, i.e., the bodily-environmental context. However we as humans remain apparently unable to recognize directly the relationship between brain, body and environment, and thus the brain as an "embedded brain." Instead, we can recognize the brain as an "embedded brain" only indirectly, by inference from empirical data (see above). The reason for this epistemic inability remains unclear. One potential suggestion may be the asymmetry between consciousness and unconsciousness with respect to epistemic abilities and brain processing. Our epistemic abilities are necessarily tied to consciousness even though most brain processing extends far beyond its conscious function. It is the unconscious function of brain processing which apparently remains hidden for us and to which we have no direct epistemic access. However, the unconscious function of brain processing may reflect an intrinsic relationship between brain, body and environment, and thus the "embedded brain". If the unconscious function of brain processing remains hidden for us, then the "embedded brain" itself cannot be recognized directly. Instead, the brain can be recognized directly only by abstraction, as necessarily tied to consciousness, implying that the brain itself appears as an "isolated brain." Due to an asymmetric relation between unconsciousness and consciousness, we may remain unable to recognise directly the foundation of our own epistemic abilities. We may falsely relate our epistemic abilities with consciousness and the "isolated brain," thereby neglecting unconsciousness and the "embedded brain" as necessary conditions (see also our initial quotation by Kuhlenbeck on the front page).

4. Conclusion: "Brain-Paradox" Revisited

4.1. RESOLUTION OF "ANTINOMY"

The brain, as an "embedded brain," recognizes all "embedded brains" as "isolated brains."

The distinction between one's own and others' brains, going along with the ontological and epistemic dissociations between "subject" and "object of recognition," can no longer be presupposed within the framework of "embeddment." The principal difference between one's own and others' brains is resolved since both one's own and others' brains can be recognized directly only as "isolated brains." Therefore, the ontological and epistemic distinctions between "subject" and "object of recognition" can no longer be maintained with respect to the brain.

However, this distinction is a necessary condition for the possibility of the "brain paradox" as an "antinomy" (see above). If such a distinction can no longer be maintained, the "brain paradox" as an "antinomy" becomes impossible and must be considered resolved.

4.2. PROBLEMS OF MIND AND MIND-BRAIN RELATIONS

First, if both one's own and others' brains can be recognized only as "isolated brains," we may ask how a characterization of the brain as an "embedded brain" can arise. The impossibility of recognizing the brain directly as an "embedded brain" does not exclude the possibility of indirect recognition. As demonstrated above, the "embedded brain" may be inferred indirectly from empirical data, including both subjective experience with functional relevance (i.e., with meaning) and neuronal states as measured in isolation from the respective bodily-environmental context.

Second, distinguishing "isolated brain" and "embedded brain" should not be equated with an ontological dissociation between "neuronal object" and "mental subject." Within the framework of an "embedded ontology," ontological and epistemic distinctions between "mental subject" and "neuronal object" are undermined by relativization. These distinctions are replaced by various modes of "selective-adaptive coupling" between brain, body and environment that reflect different relationships (e.g., "intrinsic" or "extrinsic," as described above). "Isolated" and "embedded brain" themselves reflect different relationships between brain, body and environment. Instead of presupposing distinct ontological entities, as for example brain and mind, "embedded ontology" focuses rather on different kinds of relationship between brain, body and environment (Northoff, 2001). Consequently, ontological and epistemic dissociations between "neuronal object" and "mental subject" are superfluous within an "embedded ontology."

Third, the epistemic dissociation between "subject" and "object of recognition" is replaced by the distinction between "isolated" and "embedded brain." The former dissociation is mutually exclusive epistemically, generating the logical contradiction of the "brain paradox." By contrast, "isolated" and "embedded brain" do not mutually exclude each other on epistemic grounds. The "isolated brain" can be considered as the only epistemic way the "embedded brain" can recognize itself directly (see above): i.e., the "isolated brain" may be considered as the "epistemic version" of the "embedded brain".

Fourth, the epistemic impossibility of recognizing the "embedded brain" directly (see above) does not imply the existence of a mind ontologically distinct from the brain. Distinguishing between "isolated" and "embedded brain" is primarily epistemic, without any ontological implications with respect to mind. If no such ontological distinction can be maintained, the problems of mind and mind-brain relations are undermined by relativization. The problems of mind focusing on its ontological attributes are transformed into the search for different relationships between brain, body and environment (see above). The problem of mind-brain relations as an ontological problem is resolved and transformed into an epistemic problem investigating the relationship between "isolated" and "embedded brains" with respect to epistemic abilities and inabilities (Northoff, 2001).

Fifth, relativization of problems of mind and mind-brain relations within the context of "embeddment" opens new thematic horizons for both philosophy and neuroscience. Philosophers should thematize ontological and epistemic characteristics of the brain, thereby taking into account the "brain problem" and developing a "philosophy of the brain." These activities lead potentially to new forms of epistemology and ontology (Northoff, 2001). This approach also extends the focus of empirical investigation in the neurosciences to take into account the intrinsic relationship between brain, body and environment.

Acknowledgements

I thank Alexander Heinzel for helpful comments on the manuscript. I also thank three anonymous reviewers and the editor for their thoughtful comments that very much helped me to clarify both my concepts and their presentation. The work was supported financially by grants from the German Research Foundation (No 304/1-1, 4-1).

References

Berlucchi, G. and Aglioti, S., 1997: The body in the brain: Neural bases of corporeal awareness, *Trends in Neurosciences* **20**(2), 560–504.

Birbaumer, N., Lutzenberger, W., Larbig, W., Unertl, K., Töpfner, S., Grodd, W., Taub, E. and Flor, H., 1997: Effects of regional anesthesia on phantom limb pain are mirroed in changes in cortical reorganization, *J of Neuroscience* **17**(14), 5503–5508.

Clark, A., 1997: *Being There: Putting Brain, Body, and World Together*, MIT Press, Cambridge, MA.

Clark, A., 1999: An embodied cognitive science, *Trends in Cognitive Science* **3**(9), 345–351.

Davis, R., 1993: Phantom sensation, phantom pain, and stump pain, *Arch Phys Med Rehabil* **74**, 79–91.

Deecke, L., 1996: Motor initation and imagination, *Cognitive Brain Research* **13**, 1–7.

Elbert, T., Pantev, C., Wienbruch, S., Rockstroh, B. and Taub, E., 1995: Increased cortical representation of fingers of the left hand in string players, *Science* **270**, 305–307.

Flor, H., Elbert, T., Knecht, S., Wienbruch, C., Pantec, C., Birbaumer, N., Larbig, W. and Taub, N., 1995: Phantom limb pain as a perceptual correlate of massive cortical reorganisation in upper extremity amputees, *Nature* **375**, 482–484.

Hari, R., Hänninen R., Mäkinen, T., Jousmäki, V., Forss, N., Seppä, M. and Salonen, O., 1998: Three hands: Fragmentation of human bodily awareness, *Neuroscience Letters* **240**, 131–134.

Heinzel, A., 1998: Phantomerlebnisse und Qualia. Philosophische Magisterarbeit an der Universität Düsseldorf.

Henderson, W.R. and Smyth, G.E., 1948: Phantom limbs, *J of Neurology, Neurosurgery, and Psychiatry* **2**, 88–112.

Jahanshahi, M. and Frith, C., 1998: Willed acton and its impairments, *Cognitive Neuropsychology* **15**, 483–533.

Jeannerod, M., 1997: *The cognitive Neuroscience of Action*, Basil Blackwell, Oxford.

Jensen, T.S., Borge, K., Nielsen, J. and Rasmussen, P., 1984: Non-painful phantom limb phenomena in amputee: Incidence, clinical characteristics and tmeporal course, *Acta Neurologica Scand* **70**, 407–414.

Knecht, S., Hennigsen, H., Elbert, T., Flor, H., Höhling, C., Pantev, C. and Taub, E., 1996: Reorganisation and perceptual changes after amputation, *Brain* **119**, 1213–1219.

Knecht, S., Hennigsen, H., Höhling, C., Elbert, T., Flor, H., Pantev, C. and Taub, E., 1998: Plasticity of plasticity? Changes in the pattern of perceptual correlates or reorganisation after amputation, *Brain* **121**, 717–724.

Knecht, S. and Ringelstein, E.B., 1999: Neuronale plastizität des soamtosensorischen Systems, *Der Nervenarzt* **70**, 889–898.

Kuhlenbeck, H., 1960: Schopenhauers Bedeutung für die Neurologie, *Nervenarzt* **32**, 177–182.

Kuhlenbeck, H., 1965: The concept of consciousness in neurological epistemology, in J. Smythies (ed.), *Brain and Mind*, Routledge Publisher, London, pp. 137–161.

Kuhlenbeck, H., 1972: Schopenhauers Satz "Die Welt ist meine Vorstellung" und das Traumerlebnis, in E. Buchev, E. Payne and K. Kurth (eds), *Von der Aktualität Schopenhauers*, Kramer Publisher, Frankfurt/M.

Kuhlenbeck, H., 1982: The human brain and its universe. Bd. 1: The world of natural sciences and its phenomenology. Bd. 2: The brain and its mind. Basel.

Lakoff, G. and Johnson, M., 1999: *Philosophy in the Flesh*, California University Press.

Lotze, M., Grodd, W., Birbaumer, N., Erb, M., Huse, E. and Flor, H., 1999: Does the use of a yoelectric prothesis prevent cortical reorganisation and phantom limb pain? *Nature neuroscience* **2**(6), 501–502.

Melzack, R., 1989: Phantom limbs, the self and the brain, *Can Psychology* **30**, 1–16.

Melzack, R., 1992: Phantom limbs, *Scientifc American*, 90–96.

Metzinger, T., 1997: Ich-Störungen als pathologische Formen mentaler Selbstmodellierung, in G. Northoff (HG), pp. 169–191.

Northoff, G., 1997: *Neuropsychiatrie und Neurophilosophie*, Schöningh Publisher, Paderborn.

Northoff, G., 2000: Are Q-memories delusions? A neurophilosophical approach, *Philosophical Psychology* **63**, 199–235.

Northoff, G., 2000: *Das Gehirn: Eine neurophilosophische Bestandsaufnahme*, Mentis Publisher, Paderborn.

Northoff, G., 2001: Philosophy of the brain. Hypothesis of "embedment", in revision.

Northoff, G., Richter, A, Gessner, M., Witzel, T., Schlagenhauf, F., Koetter, R., Bogerts, B. and Heinze, H.J., 2000: Functional dissociation between medial orbitofrontal and lateral prefrontal cortex during emotional processing: A combined fMRI-MEG study, *Cerebral Cortex* **10**, 98–110.

Quine, W., 1976: *The Ways of Paradox*. Harvard University Press, Cambridge, MA.

Ramachandran, V.S., 1990: What neurological syndrome can tell us about human nature, *Cold Spring Habrour Sympsoia on Biology*, Vol LXI, Cold Spring Habrour Laboratory Press.

Ramachandran, V.S., 1993: Behavioral and MEG correlates of neural plasticity in the adult human brain, *Proc. Natl. Acad. Scie.* **90**, 10413–10420.

Ramachandran, V.S., Rogers-Ramachandran, D. and Cobb, S., 1995: Touching the phantom limb, *Nature* **377**, 489–490.

Ramachandran, V.S. and Rogers-Ramachandran, D., 1996: Synesthesia in phantom limbs induced with mirrors, *Proc Royal Society of London* **262**, 377–386.

Ramachandran, V.S. and Blakeslee, S., 1998: *Phantoms in the Brain*, New York.

Ribbers, G., Mulder, T. and Rijken, R., 1989: The phantom phenomenon: A critical review, *Int J of Rehabilitation Res.* **12**(2), 175–186.

Riddoch, G., 1949: Phantom limbs and body shape, *Brain* **64**, 197–222.

Sacks, O., 1985: *The Man Who Mistook His Wife for a Hat*. Inc. New York.

Schopenhauer, A., 1977: *Die Welt als Wille und Vorstellung*, Diogenes Publisher, Zuerich.

Shoemaker, S., 1984: *Identity, Cause and Mind: Philosophical Essays*, Cambridge.

Thelen, E. and Smith, L., 1994: *A Dynamic Systems Approach to the Development of Cognition and Action*, MIT Press, Cambridge, MA.

Van Gelder, T., 1998: The dynamical hypothesis in cognitive science, *Behavioral and Brain Science* **21**, 615–665.

Wolpert, M., Goodbody, S.J. and Husain, M., 1998: Maintaining internal representations: The role of the human superior parietal lobe, *Nature Neuroscience* **1**(6), 529–533.