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NEW IDEAS

The Mind as an Emerging Configuration of the Personal Brain

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This essay examines the relationship between metabolic brain processes and psycho-physiological activities or mental activity. It is argued that metabolic brain processes, including those involved in the production of energy, proteins and other molecules are restorative and conditional, rather than directly involved in mental activities. This stance suggests that life-time acquired learning and memory is precipitated as a permanent and personal configuration of the brain, that is in principle accessible to neurophysiological examination. Current neuroscience largely ignores implicitly or explicitly the search for new emergent configurations of the brain.

Keywords: philosophy of mind, functional MRI, brain metabolism, first person perspective.

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INTRODUCTION

From both philosophical and neurobiological points of view a major issue is whether brain physiology encompasses the mind or not. Might we consider the mind as a property of the brain or, alternatively, is the mind beyond the scope of neurobiology? This essay is an attempt to convince the reader that mental function, including those attributed to cultural, environmental or societal influences can in principle be understood in the context of brain physiology. For brevity, mental and psychological activity, being higher brain activities, is opposed to brain activity directly related to sensory perception and locomotion. The present essay is an extension of my previous work (Korf and Grambergen 2007; Korf 2010).

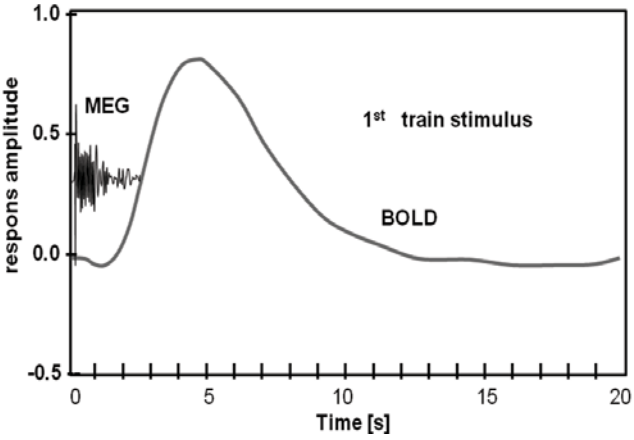
I discuss two neurobiological studies: the former is about visual activation of the brain and the latter is an example at the neuronal level. This is to illustrate the temporal relationship between brain metabolism and electrophysiological activity. It appears that brain metabolism is a prerequisite for higher activities and that brain metabolism is detached from psychological or mental activity. The conclusion led us to propose an emerging neurobiological configuration containing our life-time acquired memories and that making us the person we are.

NEUROBIOLOGICAL EXAMPLES

In current neuroscience functional brain imaging techniques, such as functional MRI (fMRI), have a major position in psychological and clinical research and practice. The underlying assumption of fMRI is that the psychological or mental tasks require energy. Differences of regional blood flow (rCBF) between two experimental conditions (e.g. rest and task performance) are assumed to reflect the involvement of particular brain regions in executing the tests. Images of blood-oxygen-level dependence (BOLD), the fMRI contrast of blood deoxyhemoglobin, are acquired with spatial and temporal resolution of 1-4 millimeters and 1-4 seconds respectively. The local response to energy utilization is an increase of blood flow, after a delay of 0.5-2 seconds and peaking over 4-6 seconds, before returning to baseline metabolism. In contrast, increases of cerebral electrophysiological activity following exposure to challenges (visual and auditory stimuli or executing psychological tasks) are observed in far shorter time intervals, in the order of 50 milliseconds or less (De Zwart et al. 2009). This report shows delayed and non-linear relationships between the BOLD signals and the electrophysiological responses that precede the increase of blood flow.

Figure 1 shows an example with experimental details. The speed of neuronal activity in a mental task can also be illustrated with a linguistic study: meaningful from nonsense words are already distinguished within 50 milliseconds (details in VanTurennout et al. 1989). These experiments support the idea that brain metabolism is a delayed response to the neuronal processing of psycho-physiological stimuli and tasks.

Figure 1
Relationship between physiological activation studies and brain energy metabolism: effect of trains of visual stimuli on subsequent increase of brain regional blood flow, as assessed with functional MRI (fMRI). The direct physiological effects of the stimuli are shown as magnetic electro-encephalographs (MEG).
Redrawn from De Zwart et al. 2009



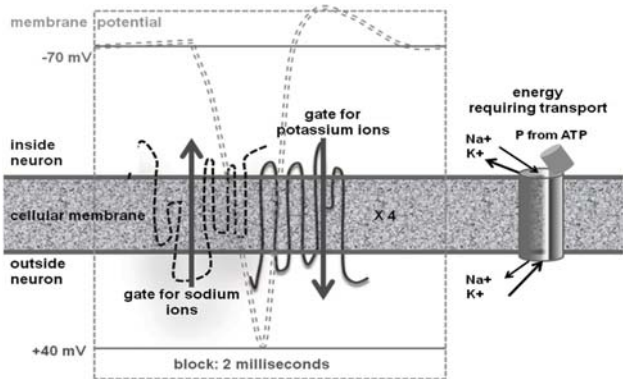
The latter idea is also supported by examining the timing of neuronal activity and energy use at the molecular scale. The human brain consumes approximately 25% of the energy of the whole body at physical rest, and approximately 70% of the brain energy supports and maintains neurotransmission processes and the generation of nerve action potentials (Attwell and Iadecola 2002; Korf and Gramsbergen 2007; Mangia et al. 2009). I describe schematically the sequence of some molecular processes during an action potential. Due to protein conformations, the sodium and potassium channels are opened and closed, thus allowing the entrance and egress of sodium and potassium ions, respectively. The signal to open the channels happens within 0.1 millisecond (or less), whereas the cycle of opening and closing of the channels lasts less than 2 milliseconds (Figure 2), the rest-potential being restored after 5 milliseconds. After a number of action potentials the intracellular levels of sodium ions increased concomitant of decreasing potassium ions. Opening and closing of the channels require very little energy, whereas restoration of the original trans-membrane ion gradients consumes far more energy. Energy consumption follows neural activity to prepare the neuron for future activity.

Apparently, protein conformations (presumably in the sub-nanosecond range) are key processes in the initiation and execution of neuronal and consequently mental (i.e. psychological, and possibly psychopathological) activity. Fast neuronal activity is unrelated to brain metabolism and escapes detection with fMRI.

IMPLICATIONS

The emphasis thus far is on energy metabolism, but similar reasoning applies to any other metabolic process. For instance, gene transcription, protein synthesis or neurotransmitter formation and degradation do not directly cause functional brain activity. Instead, these processes provide the conditions enabling the brain to react fast and precise and to acquire and store information. If, as argued, brain metabolism is conditional, what could be a general process explaining mental functions? I distinguish two alternatives: the first one explaining short-term processes (i.e. short-term memory) and the second accounting for long-term information (including long-term memory). Short-term memories, that are memories stored for only a couple of hours, are highly vulnerable to transient inter-

Figure 2
Relationship between physiological activation studies and brain energy metabolism: subsequent alterations of protein configurations during the development of an action potential of a typical brain neuron. Left proteins are the sodium and potassium channels, right is the energy requiring pump that restores the sodium/potassium ion gradient over the neuronal outer membrane following several action potentials. Gray broken line: course of the membrane potential.
Composed from Jensen et al. 2011, Yu and Catterall 2003, Kühlbrandt 2004 and Wikipedia



ruptions of normal and ongoing brain activity, such as metabolism, cerebral blood flow, epileptic insults (in psychiatric practice convulsive therapy), accidents and severe hypothermia. Patients have loose or no memories of the period preceding the transient interruption, whereas long-term memory remains largely intact. In the uninterrupted functioning brain at least a part of the short-term memories turns to be stored permanently, thereby becoming resistant to interruptions. For instance after a coma of several weeks or even months, the awakened patient may still realize who he is, recognize his family and remember most of his school knowledge as before, in addition to the loss of several memories and capabilities depending on the extent and location of possible brain damage. All this together suggests that long-term memories become part of the "hardware" of the brain and of the person, a feature that is remarkable in view of the continuous turnover of all brain and body molecules during life.

These considerations should not be misunderstood as to propose that the brain is the "hardware" and that the metabolism is the "software" (of a computer). Major differences are: the "hardware" -the brain- is only partly pre-programmed and fixed in space and time largely by gene related processes, but it is continuously modified, thereby becoming highly personal during life. Moreover, although being based on general and universal principles, brain physiology is also personal and does only apply to the personal brain. The combined metabolic/physiological processes and the pseudo-stabile hardware of the brain together create some kind of a personal universe, containing (all) personal information acquired during life. Memories acquired during life are not stored in a strictly temporal order: we do not remember childhood experiences after retrograde inspection by starting with the more recent memories. Rather, the proposed personal universe contains memories that are retrieved by association, not necessarily by sequential storage. In this respect personal memorizing is more like current computer search machines showing up all (often unrelated) items, containing (some) similar terms, but most often unrelated to the time when these items were firstly stored in the network, unless programmed this way.

The current concept is very close to the analysis of J.R. Searle, concluding that some conceptualization of mind corresponds to a concomitant structure of the brain. Such a correspondence does not happen through a strict correlation, i.e. that particular brain structures produce some particular "parts" of the mind, but rather that the mind is an emerging property of the brain (Searle 1992; Vicari 2008). Although being materialistic, such an emerging configuration cannot be deduced or predicted from its building blocks. Such emerging brain configurations have causative power over the underlying elements. For instance, structures of the human brain, such as the cerebral cortex or the prefrontal cortex, have at least some power over such processes as the release of hormones from lower and evolutionary older regions such as the hypothalamus and pituitary gland. Applied to psychiatry: major life-events have long been recognized as contributing to the development of depression. Hence, depression has often been primarily attributed to a poor regulation of the stress-hormone hydrocortisone (cortisol) at the level of the pituitary gland. But there is an important difference between stress and a life-event: stress aims primarily the organism to survive, whereas a major life-event is the consequence of a personal cognitive perception, e.g. the death of a beloved partner.

CONCLUDING REMARKS

The present conceptualization proposes that every mental function can in principle be understood as brain physiology. The proposal has 3 major features:

First, it aims at incorporating current neurobiological knowledge of the brain, thus acknowledging ontogenesis and evolution as guiding principles;

Second, it hypothesises brain configurations emerging from brain elements with properties irreducible or unpredictable from the underlying elements. These presumed higher structures have causative power over the constitutive elements;

Third, because of the first and second features, it takes first-person experiences into account and avoids dualistic mind/brain concepts.

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