Functional brain imaging and the body-mind problem: The royal way or a blind end?

Boris KOTCHOUBEY
University of Tübingen, Dept. Medical Psychology and Behavioral Neurobiology, Gartenstrasse 29, 72074 Tübingen, Germany; boris.kotchoubey@uni-tuebingen.de

Abstract

The modern brain-mind studies are being conducted within two essentially different approaches. In one of them, mind and behavior represent a set of independent variables, and brain activity represents a set of dependent variables. In the opposite approach the brain activity represents a set of independent variables, and subjective and behavioural measures constitute dependent variables. If we study the neurophysiological basis of mind and consciousness and rely upon the former approach exclusively, this can lead us to absurd conclusions. The modern functional neuroimaging (FNI) also belongs to the former approach as it follows the same experimental logic, in which the pattern of neural activation is the dependent variable, and the experimental task is the independent variable. Thus what is true for that approach in general is also true for FNI. The belief that the high precision of FNI allows the researcher to overcome these limitations is an illusion, as the problems of logical nature cannot be solved by improving precision of measurements. Only a combination of the two approaches may permit correct conclusions regarding brain mechanisms of mental activity. In contrast, FNI alone can be useful in elucidating psychological problems and in exploring important issues in psychological (behavioral) theories. Hence, psychologists, rather than neurophysiologists, should be the main beneficiaries of FNI.

1. There are two approaches in the experimental study of the body-mind problem, which will thereafter be called the **Ψ-approach** and the **Φ-approach**, respectively[1]. Within the Ψ-approach, the experimenter varies psychological variables such as stimuli, tasks, or individual differences among participants (e.g., their personality), while physiological reactions are recorded as dependent variables. Examples are: effects of emotional experience on autonomic and facial muscular responses; or effects of cognitive tasks on late components (e.g., P300 or N400) of event-related brain potentials. Within the Φ-approach, in contrast, independent variables are results of immediate intervention in bodily functions, whereas changes in behavior (in the broad sense, including subjective experience understood as a kind of covert behavior) are recorded as dependent variables. Examples are: changes in memory processes due to sleep deprivation; variation of motor and cognitive behavior as function of transcranial magnetic stimulation of the brain; pharmacological effects on moods and emotions. The difference between the approaches is summarized in Table I.

2. The study of the neurophysiological basis of mental processes was usually regarded as a prerogative of the Φ-approach, whereas Ψ-approach did not claim to make a considerable contribution to this issue. This approach has, however, other aims, for example:

2.1. Objectivation of psychological data. In numerous cases it is impossible to conclude from observed behavior and self-reports to mental states of an individual. Some people have reasons to conceal their thoughts and feelings (the problem of lie detection); others are unable to express their needs and intentions (severe paralysis, global aphasia, and similar conditions). Even though objective physiological correlates of mental processes do not have a higher epistemological status as compared with subjective reports, the former have a higher technical value because they are measured in physical units (e.g., volts, seconds).

2.2. Testing psychological theories. Many theories of mind and behavior postulate certain entities which cannot be immediately observed but are useful for explanation of observed data. Physiological measures help to operationalise such entities. Thus in experiments in which subjects should respond with either the right or the left hand, **action planning** can be operationalised as the selective excitation of the corresponding (i.e., contralateral) hand motor area. Using this in-

[1] Meaning „psychical“ and „physical“ (bodily), respectively. Needless to say, Ψ should not be confused with parapsychological phenomena.

dex, it was possible to test and finally to reject the sequential model (Sternberg 1966, 1969) that stated that motor preparation strictly follows the processing of stimulus information. Rather, if stimulus processing and response preparation can be regarded as separate processing stages, they must largely overlap in time (De Jong et al 1988; Osman et al 1992). Another example is the long-lasting discussion in the psycholinguistics, whether a heard or read word is first perceived free of context, then integrated into the context of the sentence and the conversation; or whether the context determines word perception from the very beginning. Only by means of the analysis of brain physiological data the controversy could be solved for the second alternative (Van Petten 1995).

Table I

	Independent variables	Dependent variables
Ψ-approach	Psychological: stimuli, tasks, psychological (state or trait) characteristics of subjects	Physiological: autonomic, muscular responses, changes in the brain function
Φ-approach	Physiological: e.g., sleep deprivation, lesion or irritation of some brain area or in a neurotransmitter system	Psychological: changes in overt (observed) or in covert behavior, including subjective reports (introspection)

2.3. Physiological methods of therapy and rehabilitation. On the basis of the Ψ-approach, techniques of psychophysiological interventions have been developed, the most striking of which being the so-called brain-computer interface, i.e., the software which allows users (e.g., completely paralysed patients) to control computer without any motor action, just by means of their brain activity (review by Kübler et al 2001).

This very incomplete list indicates how many aspects of the relationship between brain and mind can be of importance. The question, how the neural activity of particular brain structures causes mental activity, is only one possible question, but not the only possible (and not necessarily the central) one.

3. The situation has changed with the advent of brain imaging techniques. Their advantage as compared with the classical methods used within the Ψ-approach (the EEG, autonomic and hormonal responses) is twofold. First, they have a higher spatial resolution. Second, they provide measures of the activity of any deliberate (deep) brain region. (The EEG, for comparison, only indicates the activity of superficial cortical layers.) This woke up the hope that the windows into the working human brain are opened. What is needed, is to formulate adequate psychological tasks and to record the magnetoencepalography, positron emission tomography (PET), or functional magnetic resonance imaging (fMRI) while subjects are performing these tasks. A long series of such experiments, testing one kind of behavior after another, would finally yield the comprehensive picture of the relationship between brain and mind.

4. This optimistic view ignores the fact that methodological advantages do not compensate for disadvantages of the logics of a scientific study. More exact watches can measure time with higher precision, but they cannot measure anything but time. The logical basis of the Ψ-approach remains the same regardless of the precision of the measurements: subjects' task is an independent variable, and brain physiological signals varying as a function of that task are regarded as "neuronal basis" of those mental processes which are necessary to perform this task. Notwithstanding the improvement in instrumental precision, such a conclusion is logically impossible.

5. Sarter, Bernston, and Cacioppo (1996) illustrated this point by means of the following parable. Let's assume that we wonder whether the temperature in our room (a behavioral function) depends on the work of the heating device (the "underlying mechanism"). For simplicity, we take two experimental conditions: it's either warm or cold in the room. We record whether the lamp (LED) on the heating lights on in each of these conditions. This is the typical Ψ-approach, and a typical design of a brain imaging experiment. The following four cases (see Table II) can occur, three of which, albeit quite natural, would lead us to very strange conclusions: that heating is fully irrelevant for room temperature (e.g., in cases 3 and 4), or even that the heater decreases (!) room temperature. This example concerns an extremely simple system including only two factors (i.e., heating and sunshine), one feedback loop (in the heating device), and one intermediate variable (i.e., LED). Nevertheless, within the Ψ-approach we are completely unable to disentangle the resulting interactions and to separate causes from effects even in this simple case (see Sarter et al 1996, for details). How can we hope to succeed using this approach for the analysis of the human brain with its millions of feedback loops and intermediate variables?

Table II

	Case I	**Case II**	**Case III**	**Case IV**
Experimental condition: **warm**	Light ON	Light OFF	Light OFF	Light OFF
Control condition: **cold**	Light OFF	Light ON	Light OFF	Light OFF
CONCLUSION	The heater increases the temperature	The heater decreases the temperature!		Heating is irrelevant for the room temperature!
Real cause of the observed results		The reference value is set at a low level, thus heating switches off automatically	Measurement in summer: the heating is completely off, the room temperature varies as function of sunshine	The LED on the heater is broken (though the heater works well)

6. The use of brain imaging (generally, of the Ψ-approach) for the study of brain mechanisms underlying mind and behavior is based on the implicit acceptance of the philosophical principle of **strong token identity**. According to that principle, there is exact one-to-one correspondence between the states of brain and the states of mind; in other words, for each individual mental state there is one, and only one, individual brain state, and these two states are, in fact, the same. Don't worry about the question what does it mean to say that a mental state and a brain state are "the same". More important for the present discussion is that the strong token identity is a purely **ontological** thesis without any epistemological value. Individual mental states are unique, they repeat never, as my headache just now is different from my headache one minute ago, not to speak about your headache. Accordingly, absolutely unique are the corresponding brain states. But absolutely unique states cannot be objects of scientific investigation. Each experiment must presume repeated events. An empirical study based on the principle of the uniqueness and non-repeatability is a contradictio in objecto. This is the problem which arises when a philosophy is implicitly assumed, rather than explicitly acknowledged: philosophical adherents of the principle of token identity know very well that this principle cannot be used for experimental inquiry (e.g., Davidson 1995; Kim 1996).

7. Obviously, if the strong token identity works, there would be no difference at all between the Ψ- and Φ-approaches. It would not matter whether we start with physiology and proceed to psychology, or vice versa. Like in mathematics, different correct approaches would lead to exactly the same result. But, as stated above, this identity between unique and mental and neural events is the thing we can only believe, but we can never know.

8. A completely different version of the philosophical theory of psychophysiological identity is called **type identity**. From this view, not single neural and mental events correspond to each other but broad types of events. This time it is not my headache now, but pain in general, which should be compared with the corresponding brain states. However, as the heating case nicely shows, this correspondence cannot be one-to-one, but only one-to-many and many-to-one. Room temperature can rise from 16°C to 20°C because the heating in the room is on, or because the door to the other, well-heated room is open, or because of sun radiation. For this reason, even if we ever are able to record and analyse the activity of each single neuron during a memory task, this activity will not constitute a "neural basis of memory". We only can correctly understand the relation between the heating and the room temperature if we directly manipulate the design and function of the heating device and record the consequences of these manipulations, that is, if we use the opposite, Φ-approach.

9. The impossibility to realise the thesis of type identity using the Ψ-approach is simply due to the fact that mental "types" are not "natural kind terms". This means that there is no such "thing" as attention or memory. The task of comparison between a long list of mental states, on the one hand, and the parallel list of brain states, on the other hand – this task cannot be performed, not because the mental states exist independently of brain states but because mental states are not things at all and thus cannot be compared with other things. Mental concepts are not given by God; they emerge in experience, be it everyday experience (concepts of lay psychology) or scientific investigation (concepts of scientific psychology). Memory cannot be localised within the brain – not because memory exists beyond and without the brain and body as a kind of "mental substance", but because memory is not something existing independently of our experimental study, which we simply take in this study and match it against, e.g., activation in the hippocampus. Rather, memory is a **construct** useful to explain the results of our experience and our studies. It becomes reality within this

experiential and experimental context. The same can be shown to hold for any other mental processes and states.

10. According to an old legend, the annoyed Macedonian prince Alexander asked his teacher Aristotle to show him, instead of effortful mathematical exercises, a different, easier way to the summits of the art of geometry. "Unfortunately, there is no royal way in science," answered Aristotle. The point of his answer is clear from the fact that in the antique time, "royal ways" was the name for most important, broad and secure roads, a synonym for the modern "highways". The idea that now we only need to apply brain imaging techniques to compare mental processes, one after another, with the respective brain activations, is the idea of a highway to the final solution of the mind-body problem. As shown above, this idea as unrealistic as a specific royal was to the knowledge of geometry. For, on the one hand, the one-to-one-token psychophysiological identity breaks down on its epistemological emptiness; on the other hand type psychophysiological identity meets the problem of the non-existence of natural mental types.

11. But exactly this issue, i.e., the a posteriori nature of mental and behavioral typology, opens the best perspective for application of brain imaging. Its analytical power, substantially exceeding that of traditional psychophysiological methods, allows to clarify many conceptual problems and distinctions in psychology.

12. Selected examples of this power are:

12.1. <u>Indication of differences</u>. Behavioral theory of learning distinguish between explicit and implicit learning processes. Imaging revealed the most convincing evidence to support this distinction. The same sequences of movements (Grafton et al. 1995) or sensory events (McIntosh et al. 1999) activate completely different brain areas depending of whether these sequences are learnt ex- or implicitly.

12.2. <u>Indication of similarities</u>. Imaging studies of the last decade demonstrated an astonishing similarity between the neural correlates of performed, prepared, imagined, and perceived movements (e.g., Lotze et al. 1999; Jeannerod 2001). Even watching tools with which particular movements are performed, can activate the same structures that are active during real performance (Chao and Martin 2000).

12.3. <u>Movement and learning</u>. For more that 100 years is the thesis discussed that implicit learning must include motor components; in other words, we cannot implicitly learn any stimulus material, but only a sequence of (overt or covert) movements related to those stimuli. Schubotz and von Cramon (2002) demonstrated that the content of implicitly learnt events is closely related to particular components of the movement-related brain system. If, for instance, subjects learned a sequence of events which differed according to their size, neural activity increased in the areas related to hand movements; if they learned a sequence of events differing in their pitch, the activation in speech motor areas increased.

12.4. <u>Inhibition of return</u>. When two visual stimuli are presented shortly after each other, and the second stimulus should be responded to with button press (a simple reaction time task), this very plain situation results, nevertheless, in several complex effects. If the interval between the stimuli is very short (e.g., 0.2 s), the response to the second stimulus is faster when both have been presented at the same place of a screen (e.g., in the left upper corner) than if they have been located differently. With a little longer intervals, however (e.g., 0.4 s), the phenomenon of inhibition of return appears: the response to the second stimulus presented at the same place as the first one is slower that if the two have been presented in different locations! A study using fMRI indicated that only those brain structures selectively increased their activity during inhibition of return which exert inhibitory control of eye movements (Lepsien and Pollman, 2002). A possible explanation is that the first stimulus elicits an involuntary microssaccade (small, very fast eye movement) in its direction. These saccades are not allowed: the standard instruction in those experiments requires gaze fixation on the point always located in the centre of the visual field. To suppress the saccade, the brain inhibits attention to everything which might happen in this provoking location. If the second stimulus appears at the same place, its processing is thus hampered.

13. **Conclusion.** The methodology of functional brain imaging is neither the royal way to a (never-to-be-found) simple experimental solution of the mind-body problem, nor a blind end. Its (unfortunately) quite usual application to "precisely localise" a mental function in the brain and "to study the underlying brain mechanisms" of that function is mostly nonsense, being based on the confused neurologists' ideas of brain-mind identity. At the very best, imaging techniques can be used for this sake as an accessory means whose result would need additional support from studies using intervention techniques (i.e., the Φ-approach). However, brain imaging is a powerful tool for analysis of mental and behavioral processes and phenomena. Its main beneficiaries should, therefore, be psychologists, rather than neurophysiologists or radiologists.

Thus making a round, we return to the conclusion first drawn by Russian neuropsychologists four decades ago (Bassin, Bernstein, and Latash 1966/1999), that the most interesting issue in the study of the brain is not **where** a function is localised, but rather, **what** is localised there.

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