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LOCALIZATION IN COGNITIVE NEUROSCIENCE: OPTIMISM (BECHTEL) VERSUS SKEPTICISM (UTTAL)

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Abstract*: In the last years, there is a strong dispute regarding localization of particular neural areas through neuroimaging (using fMRI, PET, etc.) that are correlated with specific mental states in cognitive neuroscience. Many researchers (Becthel, for instance) working in cognitive neuroscience are quite optimistic regarding the results of their works. However, other people (Uttal, for instance - their number has increased in the last years) inquire about the status of the empirical results offered by neuroimaging tools and such correlations. It seems that a new framework of thinking is necessary for solving the actual problems of cognitive neuroscience.*

Keywords: *cognitive neuroscience, neuroimaging, localization, integration, correlation.*

1. INTRODUCTION

There is a strong dispute among philosophers/scientists from the cognitive neuroscience regarding the use of fMRI, PET, etc. in *localizing* the brain activities that are correlated with certain mental states/functions. There is an optimistic group claiming that the mind can be explained through the localization of certain neural areas (the philosopher Bechtel as leader and the majority of researchers who work in cognitive neuroscience using fMRI, PET, MEG, EEG, etc.) and a pessimistic group (Uttal, as leader, Piccinini, Hardcastle and Stewart, Prinz, and many others). The outcomes of this dispute are quite important for the future research in cognitive neuroscience for the following years. Regarding the usefulness of the brain imaging (mainly, fMRI and PET) in explaining the mind (through localization), I will investigate, in the first two sections of this paper, Bechtel's optimism in relationship with Uttal's skepticism and, in the next section, the "complexity" of the brain and the emergence of the mind. In the final section, I suggest that maybe a new paradigm of thinking is necessary for people working in cognitive neuroscience.[2]

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[2] In the footnotes, I include certain ideas of various researchers that are strong related with the topics analyzed in this paper. These quite large and numerous

2. BECHTEL'S OPTIMISM

Bechtel tries to explain the human mind introducing a new concept: "mental mechanisms".[1]

> A mechanism is a structure performing a function in virtue of its components parts, component operations, and their organization. The orchestrated functioning of the mechanism is responsible for one or more phenomena. (Bechtel and Abrahamsen 2005; Bechtel 2006) (Bechtel 2009, p. 6; 2008 p. 13)

The notion of mechanism is related to localizations in the brain, i.e. the "correlation" between some mental mechanisms and neuronal areas. Even if he knows that seeing a simple object (vision as a mental function) requires the localization of more than 30 neuronal areas in the brain, Bechtel is convinced that the localization (and the "decomposition") of mental states in the brain will be successful in the future even if he mentions that even for perceiving a simple object, there are correlated more than 30 neuronal areas. Nevertheless, being optimistic for localization (and decomposition), Bechtel pleads for the *heuristic theory of identity*. (Bechtel 2008, for details see …) Interestingly, lately Bechtel attempts to adapt his theory to the latest researches in brain imaging. He considers that the notions of "localization" and "brain areas" need to be re-conceptualized. (Bechtel 2011) His new alternative is a combination of mechanisms with the dynamical system approach, i.e. the dynamical mechanisms. Bechtel (2008) already tried to combine reductionism with emergence. Mechanistic reductionism is Janus-faced. "As William Wimsatt (1976a) proposes, it is possible to be both a reductionist and an emergentist." (Bechtel 2008, p. 129) Moreover, Bechtel wants to preserve not only decomposition, but also the autonomy of a system introducing Bernard's notion of "internal environment" (Bernard's expression in Bechtel 2009, p. 12 or Bechtel 2008) or Cannon's "homeostasis" and its extended notion, Varela's "autopoiesis".

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footnotes help me to illustrate better the actual crisis already present but still unnoticed in cognitive neuroscience.

[1] I will emphasize some changes in Bechtel's approach that appeared in the last two years. For a detailed investigation of Bechtel's mechanisms in cognitive neuroscience (mainly, his work from 2008), see...

> Autonomous systems are mechanistic (dynamical) systems defined as a unity by their organization. We shall say that autonomous systems are organizationally closed. That is, their organization is characterized by processes such that (1) the processes has related as a network, so that they recursively depend on each other in the generation and realization of the processes themselves, and (2) they constitute the system as a unity recognizable in the space (domain) in which the processes exist (p. 55). (Bechtel 2008, p. 217)[1]

In 2009, Bechtel adds that

> In fact, living systems has typically highly integrated despite the differentiation of operations between different organs and cell types. The mind/brain seems to be no different on this score – it consists of component processing areas that perform different computations which has nonetheless highly integrated with each other. Such a mechanism does not typically include encapsulated modules, and one is not likely to find them in the mind/brain. (Bechtel 2009)

Bechtel continues to support that the mental mechanisms with specific functions could be localized, but he emphasizes the *integrations* of the areas in a larger framework of cortex.[2] (Bechtel in press) In order to support

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[1] I mention that in the last articles, Bechtel tries to incorporate his mechanism's approach within the dynamical system theory.

[2] The relationship between segmentation and integration is one of most important topics in cognitive neuroscience in our days. For a very recent approach regarding the relationship between "local autonomy" or fragmentation (segmentation or differentiation) and "global integration" of neural states and processes, see for instance, Fingelkurts et al. (2010) In their quite complicated approach, despite the fact that the mind and the brain are usually associated with different spatial-temporal frameworks, Fingelkurts et al. (2010) try to relate somehow the mind and the brain within a unified and common spatial-temporal framework. According to the authors, there is a physical spatial-temporal framework, there is a spatial-temporal framework for the mind, and finally, an "operational" spatial-temporal framework in the brain that binds the brain and mind together. They construct the "Operational Architectonics" for relating ("correlating" or supervenince) the brain and the mind. (p. 199) EEG and/or MEG show us the "existence of particular *operational space–time* (OST) which literally resides within the brain *internal physical space–time* (IPST) and is functionally isomorphic to the *phenomenal space–time* (PST)". (Fingelkurts et al. 2010, p. 217) In the review on comments of their article we find

these ideas, Bechtel introduces Sporns and Zwi's (2004) "*dual role of cortical connectivity*": (1) The *functional specificity* of certain cortical areas that manipulates specific information ("functional specificity of small world network from clustering of units into local subsystems") and (2) The *integration* of this kind of information in a coherent behavior and cognitive states ("integration into coherent global states through oscillations in thalamic neurons play in producing global states such as attentive awakeness, drowsiness, and sleep, which modulate processing in many local circuits").[1]

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this paragraph: "The central claim of the target review paper (…) is the '*ontological monism*'. However, unlike '*dual-aspect monism*', which argues that the mental and the physical are two different ways to characterize the one and the same phenomenon, we rather speak about '*emergentist monism*' according to which the relationship between the mental and the physical (neurophisiological) is hierarchical and metastable (…)." (p. 265).

[1] Analysing the functional neuroimaging, Laureys, Boly and Tononi emphasize that by now, "the view is that the cortical infrastructure supporting a single function (and a fortiori a complex behaviour) may involve many specialized areas that combine resources by functional integration between them. Hence, functional integration is mediated by the interactions between functionally segregated areas, and functional segregation is meaningful only in the context of functional integration and vice versa." (Laureys, Boly and Tononi 2009, p. 38) He and Raichle (2009) introduce the notion of "slow cortical potential" (SCP), a low-frequency end of field potentials (<4 Hz), that seems to be the best alternative for carrying out large-scale information integration in the brain. Berens et al. (2010) consider that long-field potential offers information about integration of cortical processing and computation but not a complete one. For Damasio, the thalamus plays an important role on integration: coordinator of cortical functions, (interconnecting local or large areas of the cortex). (Damasio 2011, p. 51) For a very interesting relationship between segregation and segmentation in visual system, see Seymour et al. (2009). The main conclusion of their experiment shows that the primary visual cortex includes information not only about motion direction and color hue but also about *conjunction* of these two features. (Seymour et al. 2009, p. 180) Mentioning various experiments, Bartels write that V2 neurons "mediate not only cross-feature attentional selection of objects (object-based binding), consistent with the integrated competition model […], but also cross-feature binding […]." (Bartels 2009, p. 301) Bartels confirms that large parts of the brain interact for mental processes like attention, binding and segmentation. (Bartels 2009) Watanabe et al. (2011) indicate also that we have to reconsider the functional role of V1 in visual awareness. Bressler and Menon (2010) strongly argue that cognition is much better explain at "large-scale networks". Using diffusion-weighted imaging (DWI), "an MRI technique that measures the propensity of water to travel along myelinated axons",

(Bechtel, in press) It is unclear even the route for finding a solution to the specialization-integration problem.[1]

With the help of fMRI, it has been noticed that the synchronization of neural oscillations requires the communication among the independent oscillators (fcMRI), this communication indicating an integral function of the network of neuronal areas. Using fMRI, some researchers endeavor to show that the long-distance neuronal areas coordinate their functions through synchronization. In -----, I used recent scientific knowledge from cognitive neuroscience to indicate that the "synchronized oscillations" is not an alternative to the binding problem[2], let alone other more complicated

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Saygin et al. (2011) show that only from the activation of individual's pattern of structural connectivity (fusiform face area – FFA) predicts the function of face selectivity. In other words, brain structure (extrinsic connectivity) determines function. "Voxels with higher responses to faces had characteristic patterns of connectivity to other brain regions that distinguished them from neighboring voxels with lower responses to faces, or higher responses to scenes." (Saygin et al. 2011, p. 5)

[1] In our days, the alternative in fashion for integration (the binding problem) is the synchronized oscillations with von der Malsburg, Singer, Engel and later Tallon-Baudry, Moser, Fries, etc. Nevertheless, in the last years, the new discoveries on oscillations have created problems in the correlations between a particular frequency band with a mental states. For instance, Tallon-Baudry strongly emphasize that there is no strict correspondence between a frequency band and a cognitive process (2009, p. 239 or p. 325). Moreover, Baars and Gage indicate that the EEG results grasp only the surface of the waves but, underneath the visible EEG, there are various kinds of interactions among waves (locked in synchrony with each other, phase-locked, transiently coordinated, cross-frequency coupling) with different ranges, (recent discoveries indicate ranges from 0.01 to 1000 Hz) (Baars and Gage 2010, p. 254). *"Keep in mind that brain rhythms are a moving target, as new evidence appears with remarkable rapidity."* (Baars and Gage 2010, p. 261) For more details about recent work on oscillations.

[2] One of the most important problem in cognitive (neuro)science is the binding problem. Some authors claim that we need to solve this problem in order to understand the function of the mind and the relationship between the mind and the brain. There are various definitions of binding, but the classical one refers to the relationship between certain activated neural patterns of neurons that are correlated with various features/properties of an object (color, size, motion, orientation) posit in different parts of the brain and the mental unity of that object. Essential is the fact that binding is "almost everywhere in the brain and in all processing levels." (Velik 2010, p. 994) The most accepted alternative for the binding problem are Treisman's "feature integration theory" and synchronize oscillations (van Malsburg, Singer,

functions. If we could not solve the binding problem, Bechtel's localization has less chance to be a solution to integration. [1] In the paper mentioned above (in press), Bechtel insists to combine integration with parallel localization of certain various functions.[2]

Engel, Gray, more recently Fries and Tallon-Baudry). For the synchronize oscillations, see…

[1] Against Bechtel's mechanistic approach, Chemero and Silberstein (2007) (among others) offer a holistic and an "explanatory pluralistic" view of the cognitive science.

[2] For Bechtel, the "integration into coherent global states" takes place due to the "role oscillations in thalamic neurons play in producing global states such as attentive awakeness, drowsiness, and sleep, which modulate processing in many local circuits." (Bechtel in press) Very recently, Rolls and Treves (2011) strongly criticize the synchronized oscillations approach for the binding problem (vision). A particular case of "integration" (binding) is the cross-modal or multimodal interactions. For instance, someone perceives a colored and in motion object with a particular form at a particular distance. For Shams and Kim (2010) the traditional view classifies vision as a modular system, self-contained and independent of other senses. Even if different sensory modalities are realized in different pathways and do not communicate, the human subject has a unified perception of the world due to the unification produced by the higher levels of processing. (Shams and Kim 2010, p. 12) The authors emphasize the "problem of multisensory integration". (p. 11) Against the traditional view, some experiments illustrate that the primary visual cortex (V1, V2, V3) is affected by certain crossmodal stimulation (auditory or even tactile stimuli). (Shams and Kim 2010) "While most neurons in areas V1 and V2 respond to local contrast borders and are orientation selective, about half of the neurons in V2 are also selective for the side on which a border is 'owned' by a figure (border ownership, Zhou et al., 2000). The left-hand side of a square, for example, produces high firing rates in neurons of figure-right preference and low firing rates in neurons of figure-left preference. Although these neurons can see only a small segment of border through their classical receptive field, they seem to 'know' that this segment is part of the contour of a larger object. They integrate global shape information with various local cues, such as stereoscopic depth and occlusion cues, to infer which side is foreground and which side is background (…)". (O'Herron and von der Heydt 2011, p. 1) "Cortico-thalamo-cortical routing could provide a fast feed-forward pathway by which information from remote cortical areas responsive to different sensory modalities could interact." (Shams and Kim 2010, p. 9) Evans and Treisman (2010) pled for the crossmodal integration (visual and auditory features): auditory pitch and visual dimensions of position, size and spatial frequency. Such integrations are correlated with activations of neuronal areas in the multisensory convergence zone of the temporal-parietal-occipital zones. (Evans and Treisman 2010, p. 10) Kubovy and Schutz offer detail about audio-visual objects (cross-modal objects) that presuppose a crosmodal interaction between vision and

Bechtel introduce Raichle's notion of "default network": certain areas are more active in *absence* of task and deactivated in task conditions. Related to default network are "*mind-wandering*" and "*self-relevant*" mental explorations[1] that are not localized in a single brain region, but in a network of regions. Let me investigate in more detail Raichle's idea about the "default network" (Raichle 2009) or the "dark energy of the brain" (Raichle 2006; Raichle and Mintun 2006). The question is what does the brain need so much energy for? "The brain apparently uses most of its energy for functions unaccounted for – dark energy, in astronomical terms." (Raichle 2006, p. 1249) In the last years, using PET and fMRI, researchers realized that the energy necessary for the brain to manage the demands of the environment is less then 1%. Who produces this energy for the brain? It is glycolysis and oxidative phosphorylation produce energy in the form of adenosine triphosphate (ATP)". (Raichle and Mintun) It is well know that glycolysis is much faster than oxidative phosphorylation (McGilvery & Goldstein 1983 in Raichle and Mintun). The brain's metabolism and its circulation for specific mental tasks in interaction with the environment requires only a little of the energy consumed by the brain. More exactly, "the cost of intrinsic functional

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audio modalities. (Kubovy and Schutz 2010) Through certain experiments involving different sensorial mechanisms, Zmigrod and Hommel (2011) suggest integration between auditory stimulus features (loudness and pitch) and multimodal stimulus features (pitch and color) and between stimulus (unimodal or multimodal) and response. (Zmigrod and Hommel 2011, p. 148) "Multimodal perception (such as with audiovisual stimuli) faces binding problems that are far more complicated than within a single modality, due to the fundamental differences both in the physical properties of, say, sound and light and in the sensory transduction mechanisms (e.g., in transduction latencies, which prevent the use of tight temporal-synchrony criteria for crossmodal binding). And yet, our conscious perception of multimodal stimuli is commonly coherent and unified, suggesting that binding works." (Zmigrod and Hommel 2011, p. 143 or 144) For Layreys, Boly and Tononi, "multi-modality integration" means the combination of the results offered by two apparatus, for instance, fMRI and EEG or fMRI and PET. With such combinations, we get a more "complete characterization of the different aspects of the brain activity during cognitive processing". (Layreys, Boly and Tononi 2009, p. 41) However, it is not clear at all what does it mean "different aspects of the brain" in relationship with the mind! Morever, using EEG, the notion of localization becomes useless.

[1] The function of mind-wandering is „to facilitate flexible self-relevant mental explorations – simulations – that provide a means to anticipate and evaluate upcoming events before they happen". (Bechtel, in press)

activity which far exceeds that of evoked activity and dominates the overall cost of brain function". (Raichle 2009) In this context, the logical answer seems to be that the energy is necessary for the intrinsic activity of the brain.[1] But what does "intrinsic activity" mean? Raichle analyzes some possible answers to this question: spontaneous cognition, intrinsic functional activity facilitates responses to stimuli, and interpreting, responding to and predicting environmental demands. Finally, Raichle suggests that further research is needed to clarify the spontaneous activity of neurons. (Raichle 2006, p. 1250)

Such default function is a property of all brain areas. Task-specific decreases from a resting state occur in many areas of the brain". (Raichle and Snyder 2009, p. 85) Moreover, "the spatially coherent spontaneous activity of the fMRI BOLD signal persists despite major changes in levels of consciousness." (idem) Moreover, as we saw above, the "aerobic glycolysis provides for us a window (a 'glycolytic window') through which we can observe changes in brain activity with fMRI BOLD". (Raichle and Mintun 2006, p. 465) The intrinsic activity of the brain or the spontaneous fluctuations was noticed the first time by Biswal and colleagues (1995). (Raichle and Mintun p. 465) Important is that

> if blood flow and glucose utilization increase by 10%, but oxygen consumption does not, the local energy consumption increase owing to a typical task-related response could be as little as 1%. It becomes clear, then, that the brain continuously expends a considerable amount of energy even in the absence of a particular task (i.e., when a subject is awake and at rest) (p. 467)

Raichle and Mintun conclude that a great amount of energy is consumed by the intrinsic activity of the brain.[2] The problem is that fMRI and PET do not furnish information about this intrinsic energy of the brain. In relationship with neuroimaging (fMRI, PET, etc.) who furnish us information about external or even internal stimuli, the intrinsic energy of the brain becomes problematic. What kinds or parts of the energy of the

[1] "While spatial patterns of coherence in resting-state fluctuations of the fMRI BOLD signal were first noted by Biswal and colleagues in 1995 in their studies of the somatomotor cortex of humans, it was for us the observation of Greicius and colleagues of resting-state coherence in the default network that ignited our interest." (Raichle and Snyder 2009).

[2] About the "spontaneous activity" of the brain, see Logothetis et al. (2009).

brain show us tools like fMRI or PET? Obviously, only a small part of the brain that has to be incorporated within the whole intrinsic energy involved by the entire brain. Probable, we have to analyze the localizations of fMRI/PET in relationship with the intrinsic energy. We cannot completely isolate parts of the brain in our attempt to find the above "correlations".

3. UTTAL'S SKEPTICISM

Emblematic for the contemporary skepticism regarding the localization of certain mental functions through the imagistic procedures is Uttal (who is not a philosopher, but a researcher in cognitive neuroscience). His main book against localization is from 2001, but Uttal pushes further these ideas with the latest researches from the cognitive neuroscience of the last years. He constructs many arguments against localization under the umbrella of the identity theory. In an ontological postulate, Uttal considers that the mental processes are the results of interactions from the micro-level of the brain. Since fMRI and PET "localize" the mental functions at the "macro-level" (large neural patterns), then the results are completely wrong. (Uttal 2011, p. 11) Through a corollary of this postulate, Uttal believes that "the neural network approach is computationally intractable" and thus the mind-body problem cannot be solved. (p. 26) Moreover, he undertakes a general view in cognitive neuroscience that the "brain activity associated with mental activity is broadly distributed on and in the brain."[1] (Uttal, p. 45) We can see an epistemological-ontological framework that shows us that the neural networks are indeed "computationally intractable".[2] We can find no computations within the brain. Computation is a property that is only for the mind. Within the brain, computation is a notion without meaning, an empty notion. Uttal believes that localization through fMRI and PET is the wrong method of identifying the mental states. Interesting here is the movement from spatial localizations to processes that are less possible to be localized. Uttal claims in his first epistemological postulate for neuroscience

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[1] Important is that "a priori no brain imaging or electrical recording activity, no matter how direct they may seem to be in recording the activity of the brain, can <u>in principle</u> provide solutions to the mind-brain problem." (Uttal 2011, p. 26) Moreover, "many different cognitive processes can activate the same area or system of areas of the brain." (Uttal 2011, p. 55) and "many different regions of the brain has activated during any kind of cognitive task." (p. 66)

[2] On the same line, Piccinini believes that "when it comes to explaining cognitive capacities, computational explanation is proprietary to psychology – it does not belong in neuroscience." (Piccinini 2006, p. 343)

that the “brain activity associated with mental activity is broadly distributed on and in the brain. The idea of phrenological localization must be rejected and replaced with a theory of broadly distributed neural systems accounting for our mental activity.” (Uttal 2011, p. 45)

Uttal underlies many problems in cognitive neuroscience on certain “relevant technical issues” that are necessary for localization: subtraction, quantification, indirectness of measurement, time scale difference, variability and statistical errors. Uttal mentions other authors from the cognitive neuroscience (for instance, Vul and his colleagues, 2009) that are quite skeptical regarding the localization of mental states/functions in the brain. The authors investigate the “correlations between the behavioral and self-report measures of the personality or emotion and the measures of brain activation obtained using fMRI” showing that “these correlations often exceed what is statistically possible assuming the (evidently rather limited) reliability of both fMRI and personality/emotion measures.” (Vul et al 2009) Vul et al. inquire about the questions and methods used in social neuroscience from 54 articles! The main task of the authors of these papers was to find empirical data in order “to bridge the divide between mind and brain” and to investigate the “extremely high correlations between measures of individual differences relating to personality, emotionality and social behavior, and measures of brain activity obtained with functional magnetic resonance imaging (fMRI)”. (Vul et al. 2009) Without analyzing this investigation in detail, we introduce the conclusion of this article: Vul et al. show that such correlations are “impossible high”. Even if Vul et al. urge the authors of the articles under their investigations to correct the results of such correlations, we believe that these correlations would never be perfect![1]

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[1] Against fMRI, there are some researchers that draw the attention on the limits (theoretical and empirical) of such tools of grasping the relationship between mental states and activated neural patterns. (See Uttal 2011) Raichle and Mintun (2006) strongly emphasize that BOLD signal has to be correlated with local field potentials (LFPs) and not with the spiking activity of neurons. Logothetis underlines that “many different types of electrical and optical measurements provide evidence that a substantial proportion of neurons, including the cortical pyramidal cells, might be silent. Their silence might reflect unusually high input selectivity or the existence of decoding schemes relying on infrequent co-spiking of neuronal subsets. Most important for the comparison of neuroimaging and electrophysiology results is the fact that lack of measurable neuronal spiking may not necessarily imply lack of input and subthreshold processing.” (Logothetis 2008, p. 875) Logothetis’ conclusion of his paper is that multimodal approach for studying the brain’s function is

For Uttal, the main reason of this point is that the actual tools operate at the wrong "level of analysis", the mind would be better grasp not at macroscopic level but microscopic level. Moreover, his major mistake is that, few pages later, he claims that suggesting that "mind and brain, in fact, are not causally or otherwise intimately related to the degree of identity or equivalence would invalidate the very essence of cognitive neuroscience." (Uttal 2011, p. 28) Fan of the identity theory, Uttal claims that there has to be an intimate relationship between mind and brain.

Hardcastle and Stewart are two people among many from evolutionary psychology and in cognitive neuroscience who criticize the modularity of mind hypotheses. The main attack is that not only on the fact that there are no empirical data for this strategy but also on the theoretical framework. They analyze three methods in which the neuroscientists believe in finding the modularity of the brain: localization and single cell recordings, lesion studies and the assumption of brain constancy, and functional imaging.[1] The authors argue that none of these methods can furnish a genuine modularity of the brain.

4. THE "COMPLEXITY" OF THE BRAIN AND THE EMERGENCE OF THE MIND

Some researchers introduced the "theory of complexity" as a new paradigm for the problems of cognitive neuroscience. I analyze only a very

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necessary more than ever. Baars and Gage emphasized that "neurons do more than fire spikes. The input branches of a neuron, the dendrites, also engage in important activity. By recording different parts of a neuron we get somewhat different measures of its activities."(Baars and Gage 2010, p. 96) Against "blobology" (localization of function in some particular blobs), Poldrack notices a new direction: the connectivity in relationship with a function. Moreover, Poldrack pleads for an absolute necessary methodological rigor in using fMRI in cognitive neuroscience. This rigor method would presupposes the avoidance of unccorected statistical results and requiring more robust method of statistical inference ("analyses of correlations between activation and behavior across subjects are highly susceptible to the influence of outlier subjects, especially with small sample sizes"), the problematical use of "small volume corrections". (Poldrack 2011, p. 2) One major problem for using fMRI in cognitive neuroscience in mapping the structure of the brain with functions seems to be that very different functions can be correlated with the same structure. (Poldrack, p. 3) (See also Uttal's opinion, footnote 13 of this article)

[1] In an article from 2009, Bechtel mentions the same methods in the favor of localization!

recent example: Bassett and Gazzaniga (2011) that relate the "complex system theory"[1] with the notion of "levels" and "emergence"[2]. In the abstract, their first paragraph is the following: the brain they argue "can be understood as a complex system or network, in which mental states emerge from the interaction between multiple physical and functional levels." Interestingly, the first paragraph of the article reflects exactly the actual status of cognitive neuroscience:

> "The human mind is a complex phenomenon built on the physical scaffolding of the brain (…), which neuroscientific investigation continues to examine in great detail. However, the nature of the relationship between the mind and the brain is far from understood (…)." (Bassett and Gazzaniga 2011, p. 200)

Many people believe that the complex system theory ("applicable to the study of the human brain - a complex system on multiple scales of space and time that can be decomposed into subcomponents and the interactions between them", p. 201) would grasp quite well the complexity of the brain and its "multiscale" temporal and spatial organization.[3] Introducing new experiments with fMRI, the authors strongly argue for "functional and structural hierarchical modularity of the brain connectivity"[4] (modules of

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[1] In a glossary on the first page, we can find the definition of "complex system": "a system whose overall behavior can be characterized as more than the sum of its parts." (Bassett and Gazzaniga 2011, p. 200) If such famous authors appeal to the "theory of complexity", then maybe something is wrong with the general framework in which people work in cognitive neuroscience.

[2] With various meanings (weak and strong, epistemological and ontological, synchronic and diachronic), emergence (in general, having this spooky definition – "A emerges from B if A is something 'over and above' B") is a very complicated notion strong related with other problematic notions like "levels" and "supervenience" in cognitive science. For all these notions, see … The situation is even worst for an approach quite accepted today by many philosophers and scientists: the brain produces (causes) the mind. (See ….) Searle (1992) is the first who introduced this approach followed by scientists like Frith (2007) and other people from cognitive neuroscience. For Searle's approach, see …, for Frith's approach, see …

[3] For the theory of complexity applied to biology (the notion of life), see ….

[4] The authors introduce Meunier et al.'s ideas about the modular and hierarchical modular organization of the brain within the framework of the complex system theory and the dynamical system theory (with notions like topological structure, small-worlds, hub nodes, fractal property, lattice-like organization, graph, etc.

cortical and subcortical regions with "soft boundaries" like motor or visual networks) (p. 201). I think that Bassett and Gazzaniga have to clarify what does exactly mean "soft boundaries". The problem is if we use both fMRI and EEG, for instance, for grasping simultaneously different "aspects" of the brain (or crossmodal integration of audiovisual stimuli), can we talk about such "soft boudaries"? The authors are aware that not only anatomical structure (more exactly, the "structural connectivity" or "connectome" that represent the "wiring diagrams") imposes constraints on function but also the "neuromodulatory networks" that act in parallel.[1] Even if Bassett and Gazzaniga are quite optimistic regarding the theory of complexity and the "wiring diagrams", they write that although "the functional interpretation of the connectome is potentially immensely powerful it is also fraught with caveats. It is plausible that structural connectivity might enable us to predict function but it is not yet clear how to make that prediction."[2] (Bassett and

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(Meunier et al. 2009) "One of the earliest and most influential ideas was formulated by Simon (1962, 1995) who argued that a 'nearly decomposable' system built of multiple, sparsely inter-connected modules allows faster adaptation or evolution of the system in response to changing environmental conditions. Modular systems can evolve by change in one module at a time, or by duplication and mutation of modules, without risking loss of function in modules that are already well adapted." (Meunier et al. 2009, p. 2) Against modular organization of the brain, see also Prinz (2006). Moreover, Logothetis write that "a frequently made assumption is that the mind can be subdivided into modules or parts whose activity can then be studied with fMRI. If this assumption is false, then even if the brain's architecture is modular, we would never be able to map mind modules onto brain structures, because a unified mind has no components to speak of." (Logothetis 2008, p. 869) "As the discussion in this book progresses it will become clear that modularization and localization are no longer tenable interpretations." (Uttal 2011, p. 43)

[1] If we add the important role of glia cells in neuronal computations, the role of neurotransmitters and neuromodulators, the feedbacks from other neural areas, Baars' global workspace, Edelman re-entrant processes, Raichle's default network, Libet's "cerebral mental field", crossmodal interactions and synchronized oscillations, can we precisely localize any mental state in the brain?

[2] On the basis of the last researches of fMRI, it seems that any mental state is correlated with largely distributed neuronal patterns of activation. The greatest success in the "mind-reading" using fMRI is the work of Nishimoto et al. (2011) (Gallant's laboratory). With a computer programming, it is constructed a quantitative modeling of brain activity based on fMRI results. Using the brain activity measurements, Nishimoto et al. (2011) reconstruct natural movies seen by three human subjects. It is the first study of reconstructing dynamic stimuli (natural movies) trough the brain activity using fMRI. The researchers of *Gallantlab* focus on

Gazzaniga 2011, p. 204) This kind of weak skepticism is imposed by the degeneracy (many) functions on the identical neuronal patterns. (idem) The next paragraph reflects exactly the state of affair today in cognitive neuroscience:

> Rather structure–function mappings are many-to-many and inherently degenerate because they depend on both network interactions and context. Therefore, although a one-to-one relationship between structure and function might be inconsistent with our current understanding of the brain, a more complicated emergence of function from multiscale structure is plausible..." (p. 204)

Bassett and Gazzaniga shortly analyze another problematic notion, the "emergence": certain properties of the system are more than the sum of its parts. Emergence occurs at multiple physical and functional "levels" (this idea being against reductionism) and the mind emerges from the physical brain. Having various meanings, emergence is a complicated notion (see again…). Here we can find the same mistake analyzed in …., even if the authors are aware that the brain is decomposable and the mental properties are indivisible![1] I finally close the analysis of this article with their conclusion:

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signals received by the early visual neural areas V1 (the functionality of this neural area being quite well studied), V2 and V3 (all areas being in occipitotemporal cortex lobes). They show how the spatial and temporal information are represented in several thousands of voxels of this visual cortex. (Gallantlab.org)

[1]The authors introduce other problematic notions like upward and downward causations between multiple levels (or "bidirectional causation"). In …, I clearly showed that the downward causation (accepted by some philosophers) is a wrong notion. Craver and Bechtel emphasize that the interlevel causation is meaningless. (Craver and Bechtel 2007) The authors introduce Bechtel's notion of "mechanisms" to avoid the top-down (that includes the mental causation) or even bottom-up relationships. Paradoxically, more and more scientists in cognitive neuroscience accept this notion. Maybe, in the context in which the researchers of cognitive neuroscience become "lost in localization" (Derrfuss and Mar 2009), they appeal to weird notions.

> Neuroscience desperately needs a stronger theoretical framework to solve the problems that it has taken on for itself.[1] Complexity science has been posited as a potentially powerful explanation for a broad range of emergent phenomena in human neuroscience (…). However, it is still unclear whether or not a program could be articulated that would develop new tools for understanding the nervous system by considering its inherent complexities. (p. 208)

Obviously, the authors refer to neuroscience in relationship with the explanation of cognitive states, that is cognitive neuroscience needs a new theoretical framework.[2]

5. A NEW FRAMEWORK OF THINKING?

There are many problems in cognitive neuroscience and the chances of solving them seem to be quite small. Therefore, maybe it is necessary a new framework of thinking for the researchers working in cognitive neuroscience.[3] From my viewpoint, I consider that people working both within the optimism and the skepticism viewpoints mix the epistemological conditions of observation with ontological conditions of existence. I illustrate this problem through an analogy between two pairs of entities: the table-microparticles and the mind-brain. In this first case, we have an identity theory based on two conditions of observation (the eyes and, respectively, the electronic microscope) for each member of the first pair. Both conditions of observations are epistemological tools for the human subject. I strongly emphasize that nobody check for the "localization" of the unity of a table or its color among the microparticles! In the second case, using the eyes or

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[1] In the context created by a necessary Kuhnian paradigm shift, Raichle mentions that integration "across the necessary levels of analysis will obviously be challenging and will demand the willingness to accept the multidisciplinary nature of the task." (Raichle 2011, p. 155).

[2] Gazzaniga stated this kind of investigation in his very interesting paper from 2010.

[3] I would like to point out some statements from a very recent handbook on cognitive neuroscience (Banich and Compton 2011, third edition) that are emblematic for the actual state of affairs in this domain. The main idea is that regarding many topics, the authors underline many times that the results are still controversial; one example: the area V4 "has been posited to play a special role in color perception, although that claim has been controversial" (p. 161). There are many such expressions throughout the whole book, for instance, in the first chapters: p. 153, p. 159, p. 161, p. 163, p. 182, p. 214, etc. (Banich and Compton 2011)

fMRI/PET/EEG, the human subject observes the brain (as a whole), parts of it or some of its features. We have here the human subject and certain conditions of observation. Using the introspection, for instance, the human subject has "access" to a particular mental state. In this case, it is not about an epistemological condition but about an ontological condition: any mental state is part of the human subjectivity (consciousness states are parts of human subjectivity)[1]. We do not use certain conditions of observation for observing the "I" or some mental states. Again, checking for correlation of the unity of human subjectivity/mind/consciousness within the brain is meaningless since checking for the correlation between a feature of a table (its color, for instance) and the microparticles is also meaningless! Working under the type identity theory[2], many people believe that the mind is identical with the brain. However, in the last years, many researchers in cognitive neuroscience accept that a mental state has to be correlated with *large distributed neuronal patterns*. Taking into account Ryle's "category fallacy" and Carnap's "linguistic frameworks" (mind, brain and their properties are described by completely different taxonomies or "linguistic frameworks"), from my viewpoint, it is meaningless not only to identify two entities (or processes) grasped by notions that belong to two linguistic frameworks, but also to check for the *exact correlations* between such entities/processes. With the progress of the last years in cognitive neuroscience, we can noticed that, even if we accept the identity theory, it became more and more difficult to find the exact "correlations" between a mental state/process and neural patterns of activation. In reality, we grasp completely different features using two completely different kinds of observational conditions.[3] In this context, I notice Sporns' statement that, due to evolution, we cannot separate the brain and the body. (See Sporn 2006; Lungarella and Sporn 2006) Both elements having evolved during an enormous amount of time, the consequence is that we cannot isolate one

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[1] In this paper, I do not analyze the complicated relationship between the human subjectivity, the self, qualia, and consciousness. Anyway, the "correlations" between these entities/properties and some neuronal areas are the most difficult problem of cognitive neuroscience!

[2] The definition of token identity: at one moment, a mental state is identical with one or more neuronal patterns of activation.

[3] We have to take into account Bohr's principle of including in definition of entities/processes the measurement apparatus! Applying this principle, the so used notion of "correlation" in cognitive neuroscience becomes a serious problem. (For this principle applied to cognitive science, see ….)

from the other.[1] Moreover, under the framework of dynamical system approach, the mind/brain is in strong relationship not only with the body but also with the environment.[2] Therefore, for explaining the mind, we need to relate the brain with the body and the environment.[3]

What can we conclude about the relationship between mind and brain, localization and fMRI results? I think that, because of the results of fMRI (and other tools of investigation the brain) in the last years, localization have become a quite problematic notion.[4] I do not claim that the work of researchers on fMRI, PET and EEG (and other tools of investigation) is useless, but their results (correlation between mental states/processes and neural patterns) are just rough approximations regarding the relationship between the mind and the brain. These results are quite useful for certain medical investigations, but philosophically, the people working in cognitive neuroscience have to be aware that the results of neuroimaging have great

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[1] Lungarella and Sporns (2006) made an experiment on robotics trying to correlate the intelligence (artificial) with the sensorimotor ability and the environment. Sporn was very surprised by these results. "Really, this study has opened my eyes. I'm a neuroscientist so much of my work is primarily concerned with how the brain works. But brain and body are never really separate, and clearly they have evolved together. The brain and the body should not be looked at as separate things when one talks about information processing, learning and cognition -- they form a unit. This holds a lot of meaning to me biologically." (Sporns 2006)

[2] About computationalism, connectionism, dynamical system approach (dynamical system, embodied cognition, situated action) and robotics, see …

[3] Within the dynamical system approach, is the mind the same thing with the brain or is the mind the same thing with the brain, body and the environment? Or do we explain the behavior of an organism in relationship with the mind (brain), body and the envirionment?

[4] In a very recent article, using diffusion spectrum MRI (DSI), Van Wedeen et al. (2012) offers a completely new image regarding the anatomical structure of the brain. The unexpected result is that the brain is wired in a rectangular 3D grid structure! DSI acquires a detailed image of the threedimensional pattern of water diffusion by measuring diffusion in dozens to hundreds of directions. "Far from being just a tangle of wires, the brain's white-matter connections turn out to be more like ribbon cables — folding 2D sheets of parallel neuronal fibers that cross paths at right angles, like the warp and weft of a fabric". Essentially, this grid structure "is continuous and consistent at all scales and across humans and other primate species." (Van Wedeen 2012) So, the brain is not a mechanism as complex as we have thought! On the contrary, as a result of evolution, the brain seems to be quite a simple machinery. Nevertheless, I think that within this new framework created by Van Wedeen, the mind-body problem remains still unsolved!

ontological limits characterizing the human subjectivity, consciousness and any mental state through particular neural patterns of activation.

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