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ORIGINAL PAPER

Neuroscience and Whitehead II: Process-Based Ontology of Brain

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Abstract While neuroscience has made enormous progress in understanding the brain, the implications of these empirical findings for ontological questions in philosophy including the mind–body problem remain yet unclear. In the first paper, I discussed the model of brain that as implied and supported by the empirical data. This leads me now to the question of an empirically plausible ontology of brain. Therefore, the aim in this second paper is the ontological characterization of the brain in terms of a process-based ontology that avoids what Whitehead described as "simple location" and "fallacy of misplaced concreteness". The discussion of the model of the brain is complemented by developing a process-based ontological characterization of the brain. Specifically, as based on Whitehead, I argue that "simple location" of the brain as thing or object in time and space amounts to nothing but an abstraction rendering what Whitehead described as "fallacy of misplaced concreteness". Instead of describing the brain as static, non-temporal and isolated thing or object, I characterize the brain ontologically by dynamic, temporal, and relational processes. This leads me to a process-based ontology of brain which may be specified in spatiotemporal terms. Since the world's larger spatiotemporal range or scale contains, e.g., nests, the smaller one of the brain, I characterize their ontological relationship by "spatiotemporal nestedness" and "spatiotemporal directedness". Such spatiotemporal relationship between world and brain precludes the confusion between the world as whole and the brain as part, e.g., "mereological confusion". I conclude that process-based or better, more specifically, spatiotemporal ontology of the brain and its relationship to the world may offer novel views

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on the question for the ontological relationship between mind and brain, e.g., the mind–brain problem, by converting or reformulating it as "world-brain problem".

Brain · Process ontology · Whitehead · Fallacy · Spatiotemporal ontology

1 Introduction

1.1 General Background

The brain is a central organ and advances in recent neuroscience suggest that it is closely related to the mind. That raises the question for what neuroscience can contribute to philosophical issues like the mind–body problem. While several suggestions have been made to conceive the question for mind–body relationship as merely empirical problem, this disregards the difference between the empirical realm of neuroscience and the ontological domain of philosophy. In order to bridge the gap between neuroscience and philosophy, one may therefore need to consider the brain no longer exclusively within the empirical context but rather in an ontological framework. Briefly, an ontology of brain is required.

Most often, as in current philosophy of mind, the brain is conceived ontologically as thing or object that can be characterized by physical properties (except when one presupposes mental properties within the brain itself (McGinn 1991) or some sort of panpsychism which will not be discussed here). Such property-based ontology features the brain as static (rather than dynamic), non-temporal (with no inner temporal dimension or duration), and isolated from the rest of the world (rather than being relational) (see below for details).

One may conceive of alternative ontological approaches though, as for instance a process-based ontology, as it has been developed by Alfred North Whitehead (1929/1978), in order to characterise the brain. The brain may then ontologically be characterized as dynamic (rather than static), temporal (rather than non-temporal), and relational (rather than isolated, e.g., non-relational) (see below for details). Which type of ontology, e.g., property- versus process-based ontology, is the most suitable and empirically plausible when it comes to the brain? The question for the ontological characterization of the brain is the second major aim in this paper.

How does such process-based ontology of brain stand in relation to the neuroecological model of brain as developed in the first paper? The first paper demonstrated that the neuro-ecological model of brain is the most empirically plausible one. This leaves open the question for the underlying ontological features of the brain that must be presupposed in order to make possible such neuro-ecological model of brain. I assume that process-based rather than property-based ontology is best suitable and well compatible with a neuro-ecological model of brain. This leads us deeper into Whitehead's process ontology which shall focus here on one particular aspect, his notion of "simple location" and the "fallacy of misplaced concreteness" which, after introducing these concepts, will be applied specifically to the brain. Note again that, for the sake of simplicity, I here focus solely on the ontological characterization of the brain itself independent of its relationship to mental features

like consciousness, e.g., the mind which has to be dealt with separately in the future. Accordingly, the questions of consciousness and mind–body problem including the one for panpsychism (as often raised in the context of Whitehead's process ontology) shall be set aside here (see Cobb 2008; Griffin 1998, for a discussion of this issue as well as Northoff 2014a, b, c; Northoff 2012, 2016).

1.2 General and Specific Aim and Main Assumption

The *general aim* in this second paper is to develop a first tentative account of an ontology of brain process-based terms. I here focus exclusively on the brain itself and its process-based characterization. In contrast, I leave open the explicit discussion of how the brain stands in relation to mental features like consciousness which ontologically touches upon the mind–brain or mind–body problem (see for instance Griffin 1998 for a discussion of the mind–body problem in a process-based ontological context) (see Northoff 2016 for a further discussion of this question).

The *specific aim* in this paper is to develop a first tentative outline of an empirically plausible ontology of brain. I suggest that the neuro-ecological model of brain as developed in the first paper requires and is well compatible with a process-based (rather than substance- or property-based) ontological account of the brain. Such process-based characterization of the brain can be based on Whitehead's process ontology and his rejection of the "simple location" of things or objects in time and space. Applied to the brain this means that the brain cannot be conceived as thing or object at one particular point or location in time and space within the world. Accordingly, a property-based ontology of brain may be empirically implausible even of logically plausible (see Part I).

Instead, we need to put and conceive the brain within the context of the world and its spatiotemporally-based coordinates and processes. One may thus want to opt for a process-based ontology of brain as based on Whitehead's process philosophy (see Part II). This leads me to ontologically characterize the brain including its relationship in spatiotemporal terms entailing process-based spatiotemporal ontology. Due to the fact that the world and its larger spatiotemporal scale or range contains, e.g., nests, the brain and its smaller spatiotemporal scale or range, I characterize their ontological relationship by what I describe as "spatiotemporal nestedness" and "spatiotemporal directedness". These are features of what I describe as "spatiotemporal ontology of brain" as it shall be developed in the third part (see Part III).

1.3 Limitations

It shall be noted that I cannot go into detail about the ontological characterization of the brain in a process-based way in this paper. The main focus here is on the model of the brain and how to apply process ontology to the brain rather than on process ontology itself. Whitehead himself refers to the brain in his main work "Process and Reality" a couple of times in the context of different modes of perception (Whitehead 1929/1978, 120, 323–324). In another passage Whitehead describes the brain as the "organ of novelty" (Whitehead 1929/1978, 339; see also pp. 105–106). I here also neglect the difference between the micro-level of actual entities and

occasions (see below for details) and the macro-level of what Whitehead describes as "societies" and "nexus" with regard to the brain. Instead, my focus is mainly on the brain's role as subject and object as it will be outlined in especially parts I and II.

Finally, I only focus on the brain itself and its neural activity independent of its potential role in mental features like consciousness or experience (as for instance Pred 2005, who interprets the neural correlates of consciousness as suggested by the neuroscientist G. Edelman in the context of Whitehead) (see Pred 2005 for his excellent book as well as the work by Jason Brown). This does not mean though that the model and ontology of brain as developed here are not relevant for or have implications for the question of how the brain stands in relation to mental features and ultimately the possible existence and reality of a mind, e.g., the mind–brain or mind–body problem. The development of these implications cannot be the focus of this paper that solely concentrates on the brain itself (see Northoff 2016 for more elaboration of the mind–brain problem and its reformulation as "world-brain problem").

2 Part I: *Property*-Based Ontology of Brain

2.1 Property-Based Ontology of Brain I: "Simple Location" and "Fallacy of Misplaced Concreteness" in Ontology

The major hallmark feature of process ontology is that processes are conceived as the most basic and fundamental unit of existence and reality. The emphasis on processes introduces time and change as central ontological categories: there is continuous change which entails an inherently dynamic and temporal dimension (see part II). The ontological features of processes, e.g., time and change, are different than in the traditional substance ontology that focuses on substances or properties (for the sake of simplicity, both terms are used here in a synonymous way). Substances or properties are rather static than dynamic, fixed rather than changing, and non-temporal, e.g., without "inner duration" (see below) rather than temporal.

Process ontology radically rejects the existence of things or objects by themselves independent of any processes. Instead, things or objects are conceived as the manifestation of processes with one process leading or transitioning to another processes (which Whitehead describes by the concept of prehension that therefore replaces the one of things; see above). It shall be noted that this does not entail some dualism between processes and things/objects in a two-tier model of reality. What we describe as things or objects are nothing but abstractions (see below for further detail about abstraction) from the processes themselves; this is clearly stated by for instance N. Rescher: "A process ontology thus greatly simplifies matters. Instead of a two-tier reality that combines things with their inevitably coordinated processes, it settles for a one-tier ontology of process alone. It sees things not just as *products* of processes (since one cannot avoid doing) but also as *manifestations* of processes—as complex bundles of coordinated processes. It replaces the troublesome ontological dualism of *thing* and *activity* with an

internally complex monism of activities of varying, potentially compounded sorts." (Rescher 2001, 9; italics in original quote).

The assumption of processes (rather than substances or properties) as basic unit of existence and reality carries major consequences for how one conceives the physical world in particular and nature, e.g., natural world in general. Traditionally, substance- or property-based ontology conceives the world as collection of things and objects with for instance the brain being one such thing or object (see below). These things and objects are featured by one particular point in time and space within the world. For instance, the brain as mere object is located spatially and temporally within the body.

Due to their location at discrete points, slice, instants, or regions in time and space, such view entails what Whitehead refers to as "simple location" of things or objects or, even more basic, of matter as being located in time and space: "One such assumption underlies the whole philosophy of nature during the modern period. It is embodied in the conception which is supposed to express the most concrete aspect of nature. The Ionian philosophers asked, What is nature made of? The answer is couched in terms of stuff, or matter, or material—the particular name chosen is indifferent—which has the property of simple location in space and time, or, if you adopt the modern ideas, space–time. What I mean by matter, or material, is anything which has this property of *simple location*. By simple location I mean one major characteristic which refers equally both to space and time, and other minor characteristics which are diverse as between space and time. The characteristic common to both space and time is that material can be said to be *here* in space and *here* in time, or *here* in space–time, in a perfectly definite sense which does not require for its explanation any reference to other regions of space–time. Curiously enough this character of simple location holds whether we look on a region of space–time as determined absolutely or relatively. For if a region is merely a way of indicating a certain set of relation to other entities, then this characteristic, which I call simple location, is that material can be said to have just these relations of position to the other entities without requiring for its explanation any reference to other regions constituted by analogous relations of position to the same entities." (Whitehead 1925, 48–49; see also Whitehead 1925, 58 as well as Griffin 1998, 119).

What does such "simple location" imply for the characterization of things and objects like the brain? Presupposing such "simple location", things and objects are fixed at one particular point, instant, slice or region in/of time. In contrast, they do not possess any time, e.g., temporal duration by themselves and can therefore be characterized as non-temporal rather than temporal. Nor do they possess any space by themselves, e.g., an inner extension thus remaining non-spatial in themselves. Due to the fact that they remain non-temporal (and non-spatial), things and objects remain static rather than dynamic: the dynamic and changing nature is not constitutive for the existence and reality of things and objects but, if at all, remains secondary, to a primary core of non-changing and hence fixed, static, and non-temporal features (see also Griffin 1998, 120).

Since they remain fixed, non-temporal, and static, the existence and reality of specific things and objects can ultimately not be impacted by other things and objects in particular and the world in general. Things and objects exist independent

of each other and the world within which they exist. This means that, ontologically speaking, things and objects remain isolated from the world and thus non-relational in their existence and reality. In short, substance or property-based ontology is not only fixed, static, and non-temporal but also non-relational. The supposedly non-relational nature of things/objects further contributes to our tendency to simply locate things and objects at one particular point, slice, or instance in time and space. Such "simple location" entails that the things/objects' existence and reality remains independent of other particular points, slices or instances in time and space as related to the other things and objects.

Why and how can we develop the idea of the "simple location" of things and objects as fixed, static, non-temporal, and non-relational? Whitehead argues that the mistaken view of the "simple location" of things and objects in space and time stems from our abstraction of their inner time and space: we abstract from the concrete inner time and space of the things and objects themselves, e.g., their "inner duration" and "inner extension", in our observation and locate them instead at the points, instants, regions, or slices in the outer time and space at which we observe them. Observation of objects/things takes places within the outer space and time as featured by specific discrete points in time and space; this biases us for abstracting from their "inner duration and extension" and includes us for assuming "simple location" at those very same discrete points.

If one now infers from our scientific observations and its abstraction from the inner duration and extension of the things and objects to their existence and reality, one fallaciously infers from, e.g., misplaces, an abstraction, such as their simple location in outer time and space, to something concrete, such as the existence and reality of things and objects at these discrete points or locations in time and space. Whitehead speaks therefore of what he describes as "fallacy of misplaced concreteness": "I hold that by a process of constructive abstraction, we can arrive at abstractions which are the simply-located bits of material, and at other abstractions which are the minds included in the scientific scheme. Accordingly, the real error is an example of what I have termed: The Fallacy of Misplaced Concreteness." (Whitehead 1925, 58); see also (Whitehead 1925, 50–51; Whitehead 1985, 39; Griffin 1998, chapter 8).

The "fallacy of misplaced concreteness" does not only signify the fallacious inference from an abstraction to something concrete but also the confusion between methodology and ontology. The abstraction from the inner duration and extension of things and objects is based on scientific observation. Scientific observation can ultimately be characterized as a particular way or method by means of which we investigate the world. When we now infer from the abstractions as yielded on the basis of the scientific observation of things and objects to their existence and reality in the world, we fallaciously infer from a methodological strategy to an ontological assumption. This amounts to what I describe as "methodological–ontological fallacy". The concept of the "methodological–ontological fallacy" concerns the fallacious inference from features (like discrete points in time and space) based on the application or use of a particular methodology (like the scientific method) in investigating things and objects to their underlying ontological existence and reality

in the world. We will see further down that such methodological–ontological fallacy becomes particularly virulent in the case of the brain.

2.2 Property-Based Ontology of Brain II: "Simple Location" and "Methodological–Ontological Fallacy" in Ontology of Brain

How can we conceive brain in the context of substance- or property-based ontology? Both philosophy and neuroscience usually presuppose and view the brain as thing or object that can be featured by physical properties (and, in some cases, mental properties as in (McGinn 1991) and panpsychism). The view of the brain as thing or object supposes that it is featured solely in terms of specific points in outer time and space. In contrast, the brain itself is not supposed to possess any inner time, e.g., inner duration, or space, e.g., inner extension thus remaining non-temporal and non-spatial. The brain is conceived as static and thus non-dynamic, remaining the same and therefore non-changing throughout time. Finally, the brain's existence and reality is supposed to remain independent of other brains in particular and the world in general entailing its non-relational character (see Fig. 1a).

Due to its supposedly non-temporal, fixed, static, and non-relational features, the concept of brain as presupposed in philosophy and neuroscience can be considered a paradigmatic example of what Whitehead describes as "simple location". In our scientific investigation, we observe the brain at particular points, instants, regions or slices in outer time and space. We then infer from such scientific observation to the existence and reality of the brain in the world: the discrete points in outer time and space (at which we observe the brain) are supposed to demarcate the existence and reality of the brain in the world. Since we locate the brain's existence and reality at these particular discrete points in outer time and space, the brain is conceived as fixed, static, non-temporal/non-spatial and non-relational amounting to what Whitehead describes as "simple location".

Following Whitehead, the ontological characterization of the brain by "simple location" in the outer space and time of our scientific observation amounts to a "fallacy of misplaced concreteness". We take our scientific observation and its abstraction with the location of the brain at particular points in outer time and space for something concrete, e.g., real and existent, which, in turn, leads us to locate and thus misplace the brain's existence and reality at the very same points in outer time and space. Accordingly, by inferring from our abstractions in the scientific investigation of the brain to its underlying ontological existence and reality, we commit the "fallacy of misplaced concreteness" in our ontological characterization of the brain.

As indicated above, the "fallacy of misplaced concreteness" implies what I described as "methodological–ontological fallacy": we infer from the way we view the brain on the basis of a particular method of investigation, e.g., the scientific method, to its underlying ontological existence and reality. We easily infer from the simple location of the brain in outer space and time, as yielded on the basis of our scientific method, to the ontological existence and reality of the brain in the world. The brain's methodological features, e.g., the simple location as based on our use of

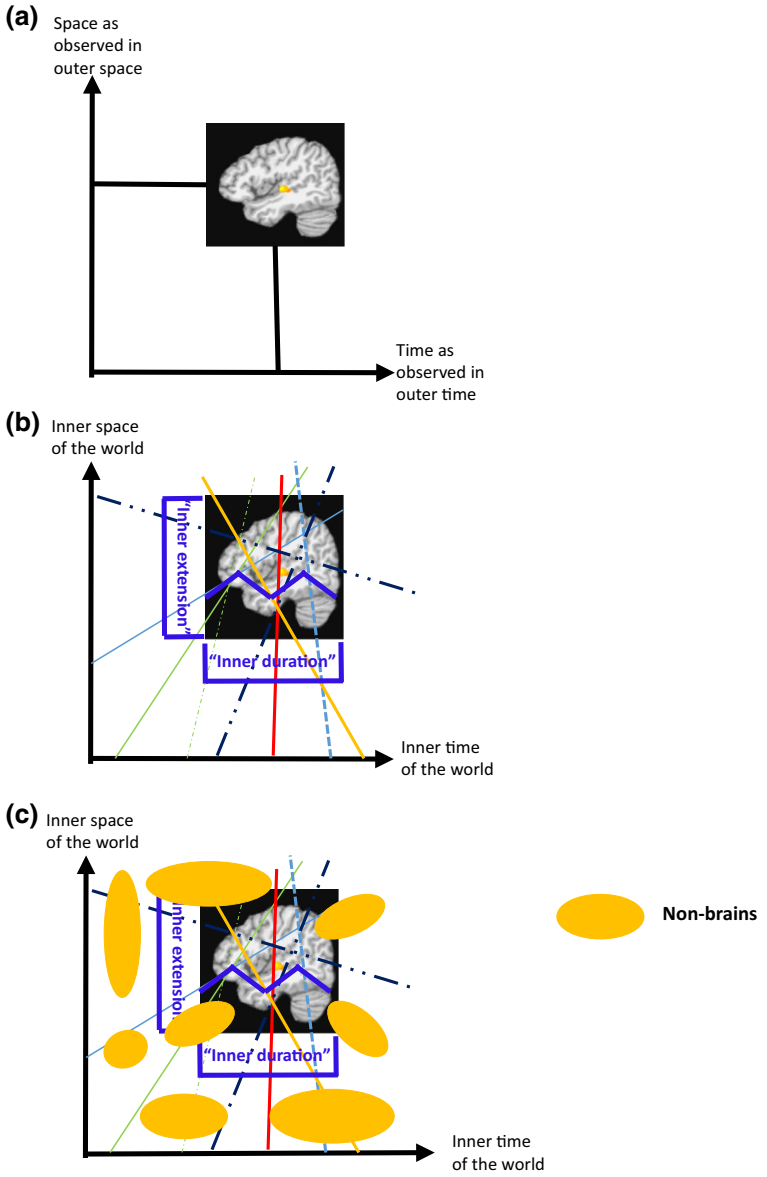

Fig. 1 **a** "Simple location" of brain in outer time and space as we observe them. **b** Brain as "spatiotemporal exchange" between different spatiotemporal processes (with the different lines illustrating different processes). **c** Brains and non-brains in the inner time and space of the world (with the different lines illustrating different processes)

the scientific method, are no longer detached and separated from the ontological features we assign to the brain. This amounts to what I described above as "methodological–ontological fallacy" with regard to the brain.

Consider the analogous example of functional brain imaging, such as fMRI. fMRI is an imaging method which represents the brain's neural activity in terms of colourful dots and spots. Nobody would infer from these colourful dots and spots that the brain's neural activity is by itself colourful. Why? Because they are related to the method or technology, e.g., fMRI by means of which we investigate the brain. The colourful activity as related to our method we use to investigate the brain, e.g., fMRI, is clearly distinguished from neuronal activity as related to the brain itself. We can thus clearly detach or separate the methodological features, e.g., the colourful dots and spots as related to fMRI, from their underlying empirical features, e.g., the brain's neural activity.

Such clear-cut separation seems to remain rather difficult when it comes to the relationship between methodological and ontological features. We apparently remain not as able to detach and distinguish the method we use to investigate the brain, e.g., the scientific method of observation, from the ontological characterization of the brain, e.g., its existence and reality. Here we seem to easily slide from the methodological to the ontological domain which, following Whitehead's fallacy of misplaced concreteness, is based on misplacing the existence and reality of the brain at those points in outer time and space at which we observe the brain.

2.3 Property-Based Ontology of Brain III: "Simple Location" of the Brain and "Methodological–Ontological Fallacy" in Neuroscience and Philosophy

The threat of such methodological–ontological fallacy looms, for instance, in the background of both neuro-sensory and neuro-cognitive models of brain. The neuro-sensory model conceives the brain as mere stimulus–response device in terms of stimulus-induced activity that can sufficiently and necessarily be accounted for by external stimuli (see above). Scientific investigation of the brain (as in fMRI) relies on the application of single external stimuli to probe the brain's neural activity. If one now infers from the scientific investigation of the brain in terms of single sensory stimuli to its characterization as stimulus–response device, e.g., as machine without any intrinsic or spontaneous activity, as in the neuro-sensory model, one commits a fallacious inference from the scientific method to the brain's ontological existence and reality, e.g., methodological–ontological fallacy.

The same holds in the case of the neuro-cognitive model. Here scientific investigation focuses on probing the brain's cognitive functions by applying particular cognitive tasks in fMRI. However, the cognitive tasks only probe the brain's neural activity in response to the cognitive tasks as we apply them in our scientific investigation. This does not imply though that the brain's cognitively elicited stimulus-induced or task-evoked activity must correspond to or be equivalent to the brain's neural activity in general independent of our cognitive investigation and probing. More specifically, the fact that we probe the brain's neural activity by using our cognitive tasks does not entail or justify the assumption that the brain itself is a cognitive device (see for instance Thagard 2012; Churchland 2012). Like its neuro-sensory sibling, the neuro-cognitive model is thus prone to the methodological–ontological fallacy.

Without being able to go into detail, such methodological–ontological fallacy may also be prevalent in more philosophical accounts of the brain as in current mind–brain theories (see Griffin 1998 for a detailed analysis). This is for instance the case in materialistic (or physicalistic) mind–brain theories. The brain is here usually conceived as object (or thing) that is located at one particular point, region, slide, or instant in the outer time and space in which we observe the brain, e.g., simple location, in our scientific investigation. This, in turn, serves as starting point to infer the brain's ontological features, e.g., the characterization of its existence and reality in terms of physical properties that are supposed to be located at those very same points in outer time and space. Analogously, one may also infer mental properties to exist at those particular points in outer time and space where the brain is supposed to be located—the brain itself may then be featured ontological by mental properties (see for instance McGinn 1991).

In either case of ascribing physical or mental properties to the brain, the methodological domain as introduced by the scientific observation of the brain at particular points in outer time and space, is not clearly detached from the ontological domain. This biases us to take them for something concrete and to consequently characterize the brain's existence and reality by physical (or mental) properties that are located at those very same points in outer time and space at which we observed the brain. The characterization of the brain by either physical (or mental) properties rendering the brain a physical (or mental) object or thing may then be traced to a methodological–ontological fallacy or, as Whitehead would say, a "fallacy of misplaced concreteness".

How can we avoid the "fallacy of misplaced concreteness" or methodological–ontological fallacy in our models and ontology of the brain? For that we may need to abandon the ontological background of property-based ontology altogether and revert to featuring the brain in terms of process-based ontology. Such process-based ontological account of the brain can obviously not be developed in full detail here; I nevertheless aim to at least indicate some features of such process-based ontological characterization of the brain in the following.

3 Part II: *Process*-Based Ontology of Brain

3.1 Process-Based Ontology of Brain I: "Inner Time and Space" of the Brain's Spontaneous Activity

I rejected the characterization of the brain in terms of a substance or property-based ontology with simple location that features the brain as non-temporal, static, fixed, and non-relational. How now can we characterize the brain in a process-based way?

The brain and its spontaneous activity display an inner time, e.g., inner duration, and space, e.g., inner extension. This is, for instance, empirically manifest in the brain's various frequency fluctuations that show different inner durations, as well as in the spontaneous activity's functional connectivity with its inner extensions. Taken all together, these inner durations and extensions including their different temporal and spatial ranges constitute the spontaneous activity's spatiotemporal

structure. Moreover, the frequency fluctuations display a certain temporal range as from 0.001 to 200 Hz that may distinguish the inner time of the human brain from the inner time (and extension) of non-human brains and other organs (like kidneys, hearts, etc.). Moreover, the inner temporality and spatiality of the brain and its spontaneous activity's spatiotemporal structure that must be distinguished from the outer temporality and spatiality on the basis of which we observe the brain. Taken in this sense, the brain must be conceived as temporal and spatial, e.g., by inner duration and extension, by itself rather than remaining non-temporal and non-spatial, or without any temporal and spatial features on its own that distinguishes it from non-brains and our observation of brains.

The inner duration and spatial extension of the brain and its cells can be viewed as the "inside" of the brain that distinguishes it from its "outside" in which we observe time and space and consequently the brain in our scientific investigation. The temporal (and spatial) "inside" of the brain, e.g., its inner time (and space) allows for prehension (see above) as it is well expressed in the following quote by David Griffin (who generalizes for bodily cells in general): "Each event seems essentially to prehend aspects of past events and to pass on aspects to future events, which prehend it. What we know from sensory perception by combining inner and outer knowledge, accordingly, is that bodily cells are analogous to our own experiences, at least in respect to being prehenders. And if they are prehenders, they cannot be purely spatial entities. They must have an inside, into which the prehended material is taken before it is passed along to subsequent prehenders. Having an inside would mean that they can have an inner duration, which is the time it takes each event to occur—the time between its reception of information and its transmission of this information into subsequent events. Looking at sensory perception from this perspective, accordingly, gives us a much different idea of the nature of nature than we get simply from the sense data of presentational immediacy alone." (Griffin 1998, 144).

In addition to its inner duration and extension, the spontaneous activity's spatiotemporal structure is continuously changing as it can empirically be measured in variability and entropy (see above). This means that the brain is not fixed, static, and non-changing but rather dynamic and continuously changing. Finally, as we have seen in our empirical example, the brain's spontaneous activity is continuously related to its respective environmental context whose encoding it can actively modify by amplification or attenuation. The brain is consequently related to and directly interacts with other brains in particular and the world in general. This marks the brain as truly relational rather than non-relational.

The characterization of the brain as temporal and spatial, dynamic, and relational defies any featuring of the brain as thing and object in the sense of property-based ontology. The brain does not conform to the features, e.g., non-spatial and non-temporal, static, and non-relational, that characterize things and objects. The brain is simply not a thing or object as it is so often tacitly presupposed in both philosophy and neuroscience when for instance ascribing physical (or mental) properties to the brain. Instead of being a thing or object, the brain must ontologically be characterized as process—the brain's existence and reality consists in processes that are temporal and spatial, dynamic, and relational (rather than properties that remain

non-temporal/non-spatial, static, and non-relational). These ontological features are paradigmatically exemplified or manifest in the empirical features of the brain's spontaneous activity which therefore is, as I postulate, ontologically relevant.

3.2 Process-Based Ontology of Brain II: "Inner Versus Outer Time and Space" of the Brain

One may now doubt that these features of the brain's spontaneous activity are really ontologically relevant. One may say that they remain merely empirical while, on an ontological level, the brain may nevertheless be characterized by physical properties. What empirically surfaces as spontaneous activity including its inner duration and space may then ontologically be traced to its underlying physical properties at one particular discrete point in the outer time and space of the world. In that case one would expect the brain's existence and reality to remain independent of its spontaneous activity and its inner time and space: even if the spontaneous activity is no longer present including its inner duration and extension, the brain should nevertheless remain present and thus continue to exist. One thus supposes dissociation between the empirical features of the brain's spontaneous activity and the brain's existence and reality with the latter remaining present even though the former is already absent.

Such dissociation with the absence of empirical and presence of ontological features is not empirically plausible though. The moment the brain's spontaneous activity terminates, as measured by zero line in EEG, we conceive the brain to be dead, e.g., brain death. Even though we can still observe a brain in outer space and time, the brain no longer possesses any inner time and space by itself anymore (e.g., independent of the outer time and space in which we observe the brain) and is consequently dead, e.g., it no longer shows any existence and reality by itself independent of our observation. There is thus dissociation between empirical and ontological features albeit in a different and reverse way: despite the fact that the brain is still present in the outer space and time of our observation, the brain itself, due to the absence of its inner time and space, is no longer present in its existence and reality (as measured it by the zero line in EEG). Accordingly, despite being empirical by itself, the brain's spontaneous activity seems to be nevertheless ontologically relevant in that it indexes the presence or absence of the brain's existence and reality.

How is it possible that one and the same empirical feature, e.g., the absence of the brain's spontaneous activity including its inner duration and extension, can lead to opposite ontological conclusions about the brain's existence and reality as either being present (first case) or absent (second case)? This is possible only by supposing different ontologies, e.g., property- and process-based, with regard to the brain. In the first case, a property-based ontological account of the brain is supposed: the brain's existence and reality is conceived here in terms of the discrete points in outer time and space in which we observe the brain. Since the brain's physical properties are supposed to be located at these points in outer time and space (see above), we assume the brain's existence and reality to remain present as long as we can observe a brain in outer time and space.

The observation of the brain in outer time and space including our ontological inference of the brain's existence and reality remain obviously independent of the brain's inner time and space as related to its spontaneous activity. Such independence makes possible to infer the presence of the brain's existence and reality from our observation of the brain in outer time and space even if its spontaneous activity including its inner time and space are already absent. The possibility of such inference can then ultimately be traced to the dissociation between inner and outer time and space: the empirical features are characterized in terms of inner time and space while the ontological features are aligned to outer time and space.

How about the second case? Here, one and the same empirical finding, the absence of the brain's spontaneous activity including its inner duration and extension, leads to opposite ontological conclusion, e.g., the absence of the brain's existence and reality or brain death. How is that possible? The brain's existence and reality is here no longer determined by our observation of the brain in outer time and space but rather by the brain itself and its inner time and space, more specifically, its spontaneous activity including its inner duration and space. Since, as detailed above, the spontaneous activity and its inner duration and extension cannot be determined by properties in general including both physical and mental, we need to revert to a different kind of ontology, a process-based ontology.

Process-based ontology allows us to determine the brain's existence and reality in a way that aligns to and is in accordance with the empirical features of the brain's spontaneous activity, e.g., as dynamic, temporal and spatial, changing, and relational (see above). Such a process-based view of both empirical and ontological features of the brain allows us to align the inner time and space of the brain and its spontaneous activity to its ontological characterization, e.g., the brain's existence and reality that then is also determined by inner time and space. Consequently, we can infer the absence of the brain's existence and reality, e.g., brain death, from the absence of the empirical features, e.g., EEG zero line, of the brain's spontaneous activity including its inner time and space.

Let us compare the two cases with regard to the role of the brain's spontaneous activity. In the second case, both empirical and ontological features refer to one and the same time and space, e.g., inner time and space, as implied by process-ontology; this makes it possible for the spontaneous activity including its inner time and space to be ontologically relevant beyond its merely empirical features. That is different in the first case. Even if the spontaneous activity and its inner duration and extension are acknowledged in empirical terms, they nevertheless remain ontologically irrelevant because property-based ontology conceives the brain (and the world) solely in terms of outer (rather than inner) time and space. Such empirical-ontological dissociation with regard to inner versus outer time and space renders the brain's spontaneous activity ontologically irrelevant.

3.3 Process-Based Ontology of Brain III: "Spatiotemporal Exchange" and "Vivid Originality" of the Brain

One may now want to argue that such process-based characterization of the brain makes the distinction of the brain from non-brains rather difficult if not impossible.

If the world itself including brains and non-brains are determined ontologically by inner time and space, the brain can no longer be distinguished from non-brains in particular and the world in general. This may hold indeed given especially that process-based ontological features like inner temporal duration and spatial extension, dynamic, and relational features may feature brains and non-brains as well as the world in general. Process-based ontology may thus succeed in aligning the brain's inner time and space to the world's inner time and space whereas it fails in distinguishing brain and non-brains.

What makes the brain's existence and reality special with regard to the one of non-brains? Traditional property-based ontology may want to assume mental properties and assign them to either some kind of mind (in which case the brain is not special at all) or, alternatively, to the brain itself (as for instance in McGinn 1991). The rejection of property-based ontology obviously precludes such avoidance of an ontological distinction between brain and non-brains. Both brains and non-brains are ontologically featured by processes and their inner time and space. There is thus no principal ontological distinction between brains and non-brains in process-based ontology.

However, the absence of an ontological distinction between brains and non-brains does not preclude the presence of empirical distinction. Specifically, brains may show a particular range or scale in their inner time and space which differs from non-brains. For instance, the brain's spontaneous activity may show a frequency range in its fluctuations that may be larger than the one of non-brains and consecutively be related to the world in a different way. Though ontologically being characterized by processes with inner time and space, brains and non-brains may then be distinguished empirically in terms of the ranges or scales of their inner time and space (see Fig. 1b, c).

Let us detail the empirical specificity of the brain's inner time and space. As discussed in the second part, the brain's spontaneous activity including its inner duration and extension allows the brain to actively modify the encoding of the external life events by what I described as "active modification by amplification or attenuation". This allows for bilateral interaction between environment and brain: the environment and its life events exert an "external disturbing power" on the brain which can counter and modify such impact by its own "internal modifying power". Though the empirical details need to be yet investigated, the brain's inner duration and extension of its spontaneous activity and thus its spatiotemporal scale or range seem to be ideally suited for such bilateral interaction with the environment. For instance, due to its specific spatiotemporal range or scale, the brain's spontaneous activity in humans may possess a particularly high degree of "internal modifying power" when compared to non-brains (and other species' brains).

The assumption of the brain's spatiotemporal scale or range being ideally suited for bilateral interaction with the environment is well compatible with the characterization of the brain by Henri Bergson and Whitehead. Based on the discovery of the telephone in his time, Bergson compares the brain to "telephonic exchange" (which in our times may be replaced by the current social media like Facebook or Twitter): "In our opinion, the brain is no more than a kind of central telephonic exchange: its office is to allow communication, or to delay it. It adds

nothing to what it receives; but, as all organs of perception send it to their ultimate prolongations, and as all the motor mechanisms of the spinal cord and of the medulla oblongata have it in their accredited representatives, it really constitutes a centre, where the peripheral excitation gets into relation with this or that motor mechanism, chosen and no longer prescribed." (Henri Bergson 1911, 19–20; see also p. 40 where he compares the brain to a conductor).

One may now want to specify the brain's role as "telephonic exchange" as "spatiotemporal exchange". The spontaneous activity's specific spatiotemporal range or scale of its inner duration and extension allows the brain to exert a strong degree of "internal modifying power" on the spatiotemporal ranges or scales it encounters in the environment, e.g., the "external disturbing power" of specific life events. If, for instance, the spatiotemporal scale or range of the spontaneous activity's inner durations and extensions were different, e.g., more or less overlapping with the ones of the world, its exchange with the environment, e.g., the balance between "internal modifying power" and "external disturbing power", would be different. This may hold in both non-brains and the brains of species other than humans. What Bergson described as "telephonic exchange" may then be specified as "spatiotemporal exchange" where different spatiotemporal scales or ranges, e.g., from environment and brain, encounter and exchange with each other.

The "spatiotemporal exchange" between environment and brain may make possible what Whitehead describes as novelty when he features the brain as the "organ of novelty": "It is by reason of the body, with its miracle of order, that the treasures of the past environment are poured into the living occasion. The final percipient route of occasion is perhaps some thread of happenings wandering in 'empty' space amid the interstices of the brain. It toils not, neither does it spin. It receives from the past; it lives in the present. It is shaken by its intensity of private feeling, adversion or aversion. In its turn, this culmination of bodily life transmits itself as an element of novelty throughout the avenues of the body. Its sole use to the body is its vivid originality: it is the organ of novelty." (Whitehead 1929/1978, 339).

How can the brain bring forth what Whitehead describes by the terms of "vivid originality" and "organ of novelty"? I suppose that this is possible by "spatiotemporal exchange" between environment and brain, e.g., the specific balance between the "external disturbing power" of environmental life events and the "internal modifying power" of the brain's spontaneous activity. This balance is special for the brain when compared to non-brains including other organs of the body. If, for instance, the balance, due to a different spatiotemporal scale or range of non-brains with lower degrees of "internal modifying power", is tilted more towards the "external disturbing power" of the environment, there will be less "vivid originality" and "novelty" in their bilateral interaction.

In sum, I characterize the brain ontologically in spatiotemporal terms as signified by inner time and space which, empirically, is manifest in the spontaneous activity's inner duration and extension. The empirical features of the brain's inner time and space, e.g., their specific spatiotemporal range or scale, may distinguish the brain from non-brains and ideally suit the brain for bilateral interaction with the environment. Such "telephonic exchange", as Bergson said, or better yet

"spatiotemporal exchange" between environment and brain makes possible what Whitehead describes as "vivid originality" and "novelty". How can we now describe the brain's spatiotemporal features in more detail? For that I turn to what I describe as "spatiotemporal ontology of brain" that can be seen as specification of process-based ontology in spatiotemporal terms, e.g., inner time and space.

4 Part III: *Spatiotemporal* Ontology of Brain

4.1 Spatiotemporal Ontology of Brain I: "Spatiotemporal Mirroring" and "Spatiotemporal Discrepancy" Between World and Brain

What do I mean by "spatiotemporal ontology"? Roughly, without going into philosophical detail, the concept of "spatiotemporal ontology" refers to time and the space as the basic features of the processes that characterize existence and reality. This makes it clear that spatiotemporal ontology is not contradictory to process-based ontology but rather complementary by conceiving and specifying the processes as the basic units of existence and reality in spatiotemporal terms. Metaphorically speaking, spatiotemporal ontology is the spatiotemporal child of parents that carry the name process-based ontology.

This view becomes even clearer when conceiving the notion of time and space presupposed in spatiotemporal ontology. We already discussed above that property-based ontology presupposes outer time and space while neglecting inner time and space: the brain's existence and reality is here conceived in the outer time and space in which we observe it entailing "simple location" and "fallacy of misplaced concreteness" (see above). Spatiotemporal ontology, as understood here as derivative or process-based ontology, rejects such characterization of time and space in terms of outer time and space. Instead, spatiotemporal ontology conceives time and space in terms of inner time and space as they are presupposed in process-based ontology. The brain can then be ontologically characterized by inner time and space which empirically are manifest in the inner duration and extension of its spontaneous activity (see above). The same applies to non-brains and the world in general which all are characterized by their own inner time and space which, though, show different spatiotemporal scales or ranges when compared to the brain (see above).

Spatiotemporal ontology features the brain in terms of its inner time and space which, in part, e.g., more or less, may overlap with the spatiotemporal scales or ranges of the inner time and space of non-brains in particular and the world in general. Due to such overlap in the spatiotemporal scales or ranges of their inner durations and extensions, the brain can directly interact with both non-brains (like the organs of the own body) and the various events in the world (e.g., by actively modifying, e.g., attenuate or amplify the "external disturbing power" of the latter). Rather than being located in isolated way within the world, as presupposed in property-based ontology, the brain can relate to and actively participate in the ongoing processes in the world. The relation between world and brain is thus first and foremost spatiotemporal, e.g., featured by different scales or ranges of inner time and space, which allows for active participation rather than simple location.

The spatiotemporal relationship between world and brain including the latter's active participation in the processes of the former carries important implications. The world and its various events are then mirrored in the ongoing spatiotemporal processes in the brain just as we observed the early childhood life events to be related to the spontaneous activity's spatiotemporal structure in adulthood. Since the world and its various events including their spatiotemporal features are encoded and mirrored in the spatiotemporal features of the brain, one may want to speak here of "spatiotemporal mirroring".

Such "spatiotemporal mirroring" is nicely described by Whitehead with regard to the body in the following quote: "In being aware of the bodily experience, we must thereby be aware of aspects of the whole spatiotemporal world as mirrored within bodily life. This is the solution of the problem which I have in my last lecture. I will not repeat myself now, except to remind you that any theory involves the entire abandonment of the notion that simple location is the primary way in which things are involved in space–time. In a certain sense, everything is everywhere at all times. For every location involves an aspect of itself in every other location. Thus every spatiotemporal standpoint mirrors the world." (Whitehead 1925, 91; see also Whitehead 1968, 163–164 as well as Griffin 1998, 144).

We have to be careful, however. The brain and the spatiotemporal structure of its spontaneous activity do not mirror the world and its spatiotemporal structure in a one-to-one way with complete spatiotemporal correspondence. The brain only shows a limited spatiotemporal scale or range when compared to the one of the world; this makes it impossible for the brain's spontaneous activity to encode the full and much larger spatiotemporal range or scale of the world's spatiotemporal structure, e.g., its inner duration and extension. The relationship between world and brain may thus not only be characterized by "spatiotemporal mirroring" but also by "spatiotemporal discrepancy".

For instance, seismic earth waves as one feature of the world's spatiotemporal structure show an extremely slow temporal range that as such cannot be encoded and captured by the brain whose temporal range, e.g., its frequency fluctuations, is not as slow. That is why we as humans, for instance, remain unable to directly perceive seismic earth waves (and have so far not yet developed proper techniques and instruments to predict earth quakes). This amounts to an inverse relationship between "spatiotemporal discrepancy" and "spatiotemporal mirroring": the larger the spatiotemporal discrepancy in the spatiotemporal scales or ranges between the brain and a particular target event in the world, the lower their spatiotemporal overlap, and the less the brain's spontaneous activity can encode and mirror the target event in the world in its own spatiotemporal structure.

4.2 Spatiotemporal Ontology of Brain II: "Spatiotemporal Nestedness" and "Spatiotemporal Directedness" Between World and Brain

So far, I described the spatiotemporal relationship between world and brain by "spatiotemporal mirroring" and "spatiotemporal discrepancy". One may now want to describe the latter, "spatiotemporal discrepancy," in further detail. The spatiotemporal discrepancy consists in that the spatiotemporal scales or ranges of

the inner durations and extensions differ between world and brain. The brain shows a smaller spatiotemporal range or scale in its inner durations and extensions when compared to the larger range or scale of the world. Depending on their degree of spatiotemporal overlap, the brain's smaller inner duration and extension can participate in the much larger ones in the world (with the latter being mirrored in the former).

Despite its smaller spatiotemporal range or scale, the brain can nevertheless participate in the larger spatiotemporal scale or range of the events in the world. The brain is thus not spatiotemporally isolated within the world which precludes its "simple location" (see above). Instead, the brain and its smaller spatiotemporal scale may be assumed to be nested within the world and its larger spatiotemporal scale. One may consequently want to speak of "spatiotemporal nestedness". The concept of spatiotemporal nestedness refers to the spatiotemporal relation between world and brain in that the larger spatiotemporal scales of the world and its various events contain or nest the smaller ones of the brain.

For instance, a larger inner duration contains or nests a shorter inner duration. The same holds for space. A larger extension contains or nests, a smaller extension. That can for instance be paradigmatically observed in the case of the Russian dolls where the larger doll nests the next smaller one which, in turn, nests the next smaller one and so forth. Analogous to the way the different Russian dolls are spatially contained, e.g., nested within each other according to their respective inner extensions, the world's larger inner duration and extension nests the smaller one of the brain (see Fig. 2a).

Henri Bergson seems to touch upon such spatiotemporal nestedness of the brain within the world in the following quote when he points out the absurdity to detach the brain as "isolated thing or object" from the world: "But is it possible to conceive the nervous system as living apart from the organism which nourishes it, from the atmosphere in which the organism breathes, from the earth which that atmosphere envelops, from the sun round which the earth revolves? More generally, does not the fiction of an isolated material object imply a kind of absurdity, since this object borrows its physical properties from the relations which it maintains with all others, and owes each of its determinations, and consequently its very existence, to the place which it occupies in the universe as a whole?" (Bergson 1911, 11–12).

One important feature of the Russian dolls is that, despite their different inner extensions, they all nevertheless show the same shape: the shape of the larger doll is mirrored in the shape of the next smaller one and so forth (this has been described as "self-similarity" or "self-affinity"; see He et al. 2010). There is a similarity in shapes between the different dolls despite their different spatial scales, e.g., inner extensions (which has been described as "scale-free"; He et al. 2010). The same may analogously hold for the relationship between world and brain: events in the world, e.g., their spatiotemporal structures are (encoded and) mirrored in the spatiotemporal structure of the brain's spontaneous activity and its smaller scale (as it is empirically supported by the above described findings). One may therefore assume similarity, e.g., spatiotemporal mirroring, in the spatiotemporal structures between world and brain (e.g., self-similarity or self-affinity) across their different spatiotemporal scales or ranges in a scale-free way.

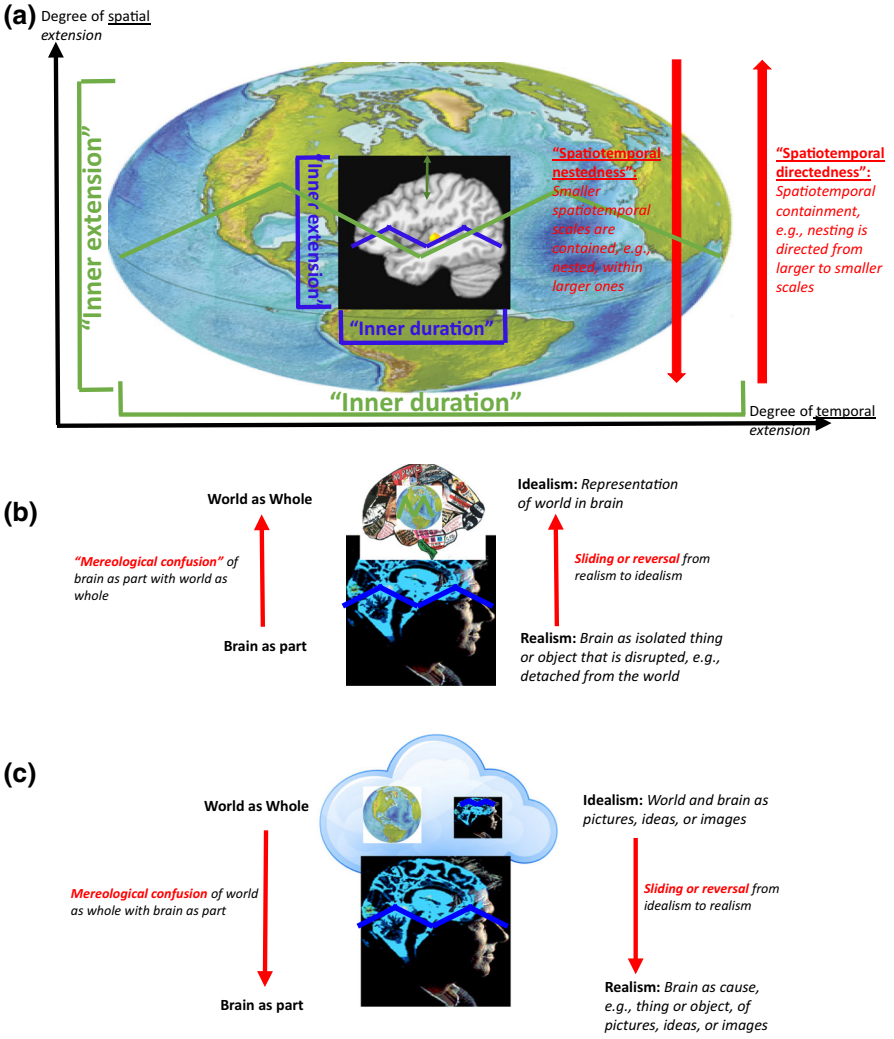

Fig. 2 **a** "Spatiotemporal nestedness" and "spatiotemporal directedness" between world and brain. **b** "Mereological confusion" of the brain as part with the world as whole (with conversion from realism to idealism). **c** "Mereological confusion" of the world as whole with the brain as part (with conversion from idealism to realism)

Finally, the Russian dolls exhibit yet another spatiotemporal feature, namely "spatiotemporal directedness" as I call it. The larger doll nests the next smaller one which, in turn, nests a yet smaller one and so forth. In contrast, the reverse scenario with for instance the smaller containing the next larger one (and so forth) remains impossible. If that were the case, we would no longer see the largest Russian doll at the outside but rather the smallest one. That sounds absurd though. There is thus clear spatiotemporal direction from the larger to the smaller doll in the way the former nests the latter while the reverse remains impossible.

Analogously, the world and its larger spatiotemporal scale nest the brain and its spatiotemporal scale. In contrast, the reverse relationship with the brain containing the world remains impossible. The spatiotemporal relationship between world and brain can thus be characterized by "spatiotemporal directedness" from world to brain rather than from brain to world. Due to such "spatiotemporal directedness", one may want to speak ontologically of 'world-brain relationship': the sequence of the terms 'world' and 'brain' reflects that the world nests the brain rather than the brain containing the world in which case one would speak of 'brain-world relationship' (see also Northoff 2016).

4.3 Spatiotemporal Ontology of Brain III: "Mereological Confusion" of the Brain as Part with the World as Whole

"Spatiotemporal nestedness" and "spatiotemporal directedness" in the ontological relationship between world and brain touch upon the question for the mereological relationship between whole and part. The world as whole cannot be confused with the brain as its part since the latter is spatiotemporally nested within the world. The spatiotemporal characterization of the ontological relationship between world and brain consequently precludes their mereological confusion.

Bennett and Hacker (2003) recently introduced the notion of "mereological fallacy" that concerns the fallacious inference from features characterizing the brain as part to the person as whole. Following them, such "mereological fallacy" underlies many assumptions made in both current neuroscience and philosophy of mind. Conceived within the present context, one may want to describe analogous inferences from the brain as part to the world as whole as "mereological confusion". I now postulate that the "mereological confusion" between world and brain can take on two different forms: (i) one may confuse the brain as part with the world as whole, or, alternatively (ii) one may confuse the world as whole with the brain as part. In the following I want to explicate both "mereological confusions" by referring to a conference paper on "Brain and Thought" by Henri Bergson (1904). Due to limitations in space, I will not be able to show the presence of both kinds of "mereological confusions" in current neuroscience and philosophy of mind which therefore I leave open for future investigation.

Let us start with the first mereological confusion of the brain as part with the world as whole. In his conference paper on "Brain and Thought" (1904), Bergson discusses the role and characterization of the brain in realism: "Now, —should I say to the realist, —you began by giving yourself a brain, and saying that objects external to it modify it in such way as to raise up ideas of themselves. Then you did away with these objects external to the brain, and ascribed to the cerebral modification the power of providing by its own resources the idea of the objects. But, in withdrawing the objects which encase it, you are withdrawing also, whether you will or not, the cerebral state, for it owes to them all its properties and reality. You *only preserve this cerebral state because you pass surreptitiously to the idealist notation-system, where you can posit as isolable by right what is isolated in idea.*"(Bergson 1904, 163; italics in original).

How does Bergson's description of realism relate to the mereological confusion between the brain as part and the world as whole? Bergson starts with the assumption that the brain of the observer is modified by the "objects external to it" in such way that "ideas of themselves", e.g., of the objects, are raised. This seems to be well compatible with either a neuro-cognitive or even neuro-ecological model of brain where the latter shows its own spontaneous activity that can (actively) "modify" the impact of the "objects external to it". However, the realist detaches and abstracts the brain including its "ideas of themselves", e.g., of the objects, from the "objects external to it". Put into spatiotemporal terms, the realist disrupts the spatiotemporal relationship, more specifically, the spatiotemporal nestedness and directedness between world and brain. Even if the realist had presupposed initially a neuro-ecological model of brain, this becomes now futile since the brain is no longer neuro-ecologically, e.g., spatiotemporally nested within the world.

The brain is spatiotemporally isolated within and detached from the world. Such spatiotemporally isolated and detached brain can no longer be ontologically characterized in terms of its inner time and space and their relation to the world and its inner time and space. Instead, the spatiotemporally isolated and detached brain is now featured ontologically in terms of outer time and space, that is, the time and space in which we observe the brain. One thus supposes "simple location" of the brain in the world which ultimately leads to the "fallacy of misplaced concreteness" and the characterization of the brain as mere thing or object (see above).

How about the mereological confusion of the brain with the world? The spatiotemporal isolation and detachment of the brain from the world raises the question how the "ideas of themselves", e.g., of the objects, can enter the brain in such way that we can perceive and cognize the world and its objects. This is the moment, according to Bergson, where the realist slides and reverts to idealism by positing the "ideas of themselves" in an isolated way, e.g., "where you can posit as isolable by right what is isolated in idea", within the brain itself. What Bergson describes as positing of the "ideas by themselves" surfaces in the more current concept of representation: the "ideas by themselves" are represented in the brain and its cognitive functions in such way that they remain independent of the "objects external to it" and thus the world in general. More generally, the world and its various objects are represented within the brain in a way that remains independent of the world and the objects themselves. Metaphorically speaking, the brain becomes the world (see Fig. 2b).

This amounts to "mereological confusion": the larger spatiotemporal scale of the world as whole is now contained, or nested, within the smaller spatiotemporal scale of the brain as part and its representations. Even if one still supposes spatiotemporal nestedness, spatiotemporal directedness is nevertheless reversed since the brain as part contains the world as whole (rather than the world containing the brain). As pointed out above, such reversion in spatiotemporal directedness between world and brain is absurd though and both empirically and ontologically rather implausible.

4.4 Spatiotemporal Ontology of Brain IV: "Mereological Confusion" of the World as Whole with the Brain as Part

How about the reverse mereological confusion, e.g., the confusion of the world as whole with the brain as part? This, according to Bergson, is the case in idealism: "But the trust is that the philosopher unconsciously passes from the idealist to a pseudo-realist point of view. He began by viewing the brain as an idea or picture exactly like all other ideas or pictures, encased in the other pictures and inseparable from them: the internal motion of the brain, being then a picture in the midst of pictures, was not required to provide the other pictures, since these were given with it and around it. But insensibly, he comes to changing the brain and the intra-cerebral motion into things, that is to say, causes hidden behind a particular picture and whose power extends far beyond what is presented. Whence this sliding from idealism to realism?" (Bergson 1904, 161).

The idealist starts with the whole, e.g., the various pictures of the world that include the brain as one picture among others. The brain is here part of the world or, following Bergson, one idea or picture among all other pictures of the world and its objects, e.g., "brain as an idea or picture exactly like all other ideas or pictures, encased in the other pictures and inseparable from them". The brain is part of the world though not in an in ontological but epistemological sense, e.g., as picture or idea. However, that changes once the idealist searches for the basis or cause of the various pictures including the picture of the brain, e.g., "causes hidden behind a particular picture". He thereby slides not only from idealism to realism, as Bergson states, but also from the epistemological domain of knowledge, e.g., pictures or ideas, to the ontological domain of existence and reality, e.g., causes.

Within the context of such realism and its ontological domain, the brain is no longer conceived as one picture or idea among others and hence as part of the world but rather as cause of those very same pictures or ideas. The brain itself is supposed to generate the world, e.g., the pictures or ideas of the world. Such generation of the world in terms of pictures or ideas is assumed to be possible by attributing 'special powers' to the brain, e.g., "whose power extends far beyond what is presented". This entails "mereological confusion": the world as whole, e.g., the pictures or ideas of the world, is confused with the brain as part, e.g., as one picture or idea among the many pictures or ideas of the world, which is possible by rendering the latter into the cause or basis of the former. The larger spatiotemporal scale or range of the world is thus ontologically traced to the brain's smaller spatiotemporal range or scale. Metaphorically speaking, the world becomes the brain (see Fig. 2c).

Where do the 'special powers' of the brain, Bergson mentions, come from? The idealist turned realist simply postulates them. Alternatively, the idealist may assume the existence and reality of a mind that possesses the special powers that are necessary to generate the world, e.g., the pictures or ideas of the world. That raises the question of the ontological relationship of such mind to the brain though, the mind–brain problem. The realist is confronted with the same question. He needs to find an ontological basis or cause for the brain's capacity of representing the world. Such representational capacities may either be traced to the brain's cognitive function or some mental features, e.g., a mind.

Alternative to both realist and idealist, one may want take the process-based spatiotemporal relationship between world and brain including their "spatiotemporal nestedness" and "spatiotemporal directedness" as ontological starting point. This precludes any detachment and isolation of the brain from the world, as suggested by the realist and his mereological confusion of the brain as part with the world as whole. The "ideas themselves" of the "objects external to the brain" do then longer need to be accounted for by their representation in the brain but rather by the brain's participation in the ongoing processes in the world: the brain can mirror the "objects external to the brain" in the spatiotemporal structure of its own spontaneous activity, e.g., "spatiotemporal mirroring" (see above).

The spatiotemporal relationship between world and brain also precludes any supposition of the brain as sole or single basis, e.g., cause of our pictures or ideas of the world, as in the case of the idealist and his mereological confusion of the world as whole with the brain as part. The brain no longer needs to be conceived as the sole or single basis or cause of the pictures or ideas of the world. Instead, it is the world-brain relationship and its process-based spatiotemporal features, e.g., spatiotemporal nestedness and directedness, that allow for constituting the pictures or ideas of the world including the brain as one picture among them. Any supposition of the brain as sole or single basis or cause becomes thus superfluous if not absurd (as Bergson mentions in his above cited quote).

At the end of his paper, Bergson discusses the relationship between screw and machine. Both occur together in a "relation of solidarity" with the presence of the screw entailing the functioning and thus presence of the machine. However, such relation of solidarity does not imply "relation of equivalence" let alone "equivalence" or identity: "The presence or absence of a screw may decide whether or not a machine will work: does it follow that each part of the screw corresponds to a particular part of the machine, and that the equivalent of the machine is the screw?" (Bergson 1904, 167). Analogously to screw and machine, the brain stands in a "relation of solidarity" to the world, e.g., "spatiotemporal relation of solidarity," that makes possible "spatiotemporal mirroring" as one may want to say. Such "spatiotemporal relation of solidarity" does not imply "spatiotemporal equivalence or even identity" between brain and world though since that would violate the "spatiotemporal nestedness" and "spatiotemporal directedness" between world and brain.

5 Conclusion

I raised the question for an ontology of the brain that is not only ontologically but also empirically plausible. Based on Whitehead, I reject the "simple location" of the brain and its characterization at discrete points in outer time and space in the way we observe it. This, so Whitehead, leads to a "fallacy of misplaced concreteness" where the brain as we observe it in outer space and time is taken to exist as mere thing or object in that very same time and space. The rejection of the brain's "simple location" in outer time and space implies that any kind of property-based ontology of brain is no longer suitable. Instead, we need to recruit

process-based ontology in order to account for the brain and its inner time and space, e.g., "inner duration and extension" as distinguished from the outer time and space of our observation of the brain.

I suggest process-based ontology as the most empirically and ontologically plausible ontology of the brain. Such process-based ontology of brain focuses especially on the spatiotemporal relationship between world and brain which I characterize by "spatiotemporal mirroring", "spatiotemporal discrepancy", "spatiotemporal nestedness", and "spatiotemporal directedness". The spatiotemporal relation between world and brain, e.g., the "world-brain relationship" as I say, precludes any mereological confusions between the brain as part and the world as whole as they are prevalent in both current neuroscience and philosophy of mind. Finally, the assumption of such spatiotemporally featured world-brain relationship may also offer novel perspectives on the question of the ontological relationship between brain and mind, or the mind–brain problem, which then may be reformulated or converted in what might be described as "world-brain problem" (see Northoff 2016). That remains to be investigated in the future though.

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