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# The Self and Its Time – A Non-Reductive Neuro-Phenomenological Perspective on the Brain's Spontaneous Activity

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**Abstract**

The self has been inherently connected with time, i.e., duration and temporal continuity, in the phenomenological approaches by Husserl and others. The key concept here is pre-reflective self-consciousness featured by its inherently temporal nature as distinguished from reflective self-consciousness. Taking a non-reductive neuro-phenomenological perspective, we propose that the intimate connection of the self with duration/temporal continuity on the phenomenological level can be linked to the temporal structure of the brain's spontaneous activity. Specifically, we show that the role of the brain's spontaneous activity for the self also includes its temporal structure, as quantified with dynamic measures like scale-free activity and autocorrelation window. This suggests a close and intimate connection of self and time, i.e., duration/temporal continuity on the neural level as somewhat analogous to the phenomenological level. In conclusion, we provide a first exploratory step towards a non-reductive neuro-phenomenological synthesis of self and time. We tentatively postulate a convergence of neural and phenomenological levels with regard to their inherent relationship of self and time as described by the brains scale-free activity (empirical) and pre-reflective self-consciousness (phenomenological).

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## 1. Introduction

In this paper we address the issue of the self and its intimate relationship to time from two different perspectives: philosophical and neuroscientific. This interdisciplinary method of research has proven its benefit when trying to understand and describe fundamental, complex human phenomena. The problem of self is in the focus of numerous philosophical and experimental undertakings. Ensuring the right balance and proper relation between findings from different scientific fields is still in need of careful positioning, in an attempt not to fall into the reductionist temptation, in which one field of research will dominate over the other and force upon it its methods and interpretation. We thus presuppose a methodological strategy that was recently described as "non-reductive neurophilosophy" as distinguished from reductive neurophilosophy (Northoff 2014b, 2016, 2018, Klar 2020).

Acknowledging the different perspectives and equal importance of philosophical and neuroscientific accomplishments, we will structure our paper in the following order. In the first part we will provide a brief insight into the phenomenological description of ego with the help of Edmund Husserl. We will deal with topics connected to ego, such as the I-pole of experience, pre-reflective self-consciousness and temporalization of ego. In the second part we will elaborate on neuroscientific findings in a manner described as "neuro-phenomenal hypotheses" (Northoff 2014a). These are non-reductive hypotheses about the relationship between specific neuronal mechanisms and specific phenomenal features of our experience.

The main focus of our neuro-phenomenological discussion of the self is time. Husserl linked self-consciousness closely to time and, more specifically, to inner time-consciousness. The intimate relationship of time and self within our experience (as expressed in the phenomenological literature) fits well with recent neuroscientific findings that show how the neural features mediating the self are, at the same time, also closely related to those underlying inner time-consciousness. We thus propose a neuro-phenomenal hypothesis regarding the relationship between self and time.

The conclusion aims at providing the synthesis of the elaborated topics to support the main aim of this paper. We note that our investigation is exploratory, focusing on possible similarities of phenomenological and empirical concepts. Given that we focus on their connection, we cannot but leave out many details on either side, the phenomenology of prereflective self-consciousness and the neuroscience of self. Specifically, we remain unable to go into all phenomenological details about the relation of time and pre-reflective self-consciousness or all the different neuroscientific concepts of self and its distinct neural correlates (see Qin *et al.* 2020, Frewen *et al.* 2020, Gallagher and Daly 2018 for recent overviews).

We acknowledge that both phenomenological and neuroscientific proponents of self may be sceptical towards our approach to converge on both. We fully agree that there remains a gap between both types of concepts and we do not claim to resolve this gap. Rather our approach can be understood as a first exploratory attempt to make this gap a little smaller by drawing some similarities (rather than connections) between the temporal nature of pre-reflective self-consciousness (as discussed in phenomenology) and the temporal basis of the self in the brain's spontaneous activity (as observed in neuroscience).

This can be seen as a continuation of our previous attempt of drawing similarities between the experience of a lived body and the neuronal basis of interoceptive awareness (Northoff and Stanghellini 2016) as well as of the more general attempt to develop specific neuro-phenomenal hypotheses (Northoff 2014a,b).

## 2. The Ego

From the very first days of its life, a new-born child is involved in the dynamics of distinguishing itself from the rest of the world and developing a first-person perspective (Neisser 1993, p. 4, Neisser 2015, p. 122). With the gradual development of basic human abilities, the human being begins to understand and develop an implicit and irreplaceable notion of the "I". The essential midpoint and the bearer of all these experiences becomes their "I", with each and every experience being inseparable from the "I-perspective" (also called first-person perspective).

For Edmund Husserl the I is at the center of all our subjective experiences. Husserl's research focused on the structures of consciousness that *a priori* enable conscious experience, and he wanted to answer the question of how objects appear to us the way they do. In his view, all human conscious events appear in "the stream of lived experience" (*Erlebnisstrom*). Because experiences are in this stream, they can be reflected by the subject, they can be hit by the "reflective look" (*das der reflektive Blick zu treffen vermag*; Husserl 1913, p. 61).

Husserl often used the concepts of "subject" and "self" synonymously. Furthermore, he also applied concepts of "I" and "ego", developing his theory of the egological consciousness in which all meaning is constituted, whereby the phenomenological investigation is directed towards a transcendental subjectivity. In his later thinking, this idea has been extended to take into account that experiences are lived by a concrete subject in relation with other subjects (other egos) and things in the world (Mertens 2014, pp. 169, 174, 177). During the development of his phenomenological path, Husserl developed several features of the ego. Here we will distinguish and briefly discuss the pure or transcendental ego and the empirical or personal ego.

The pure ego is the identical pole of all our subjective experiences, although simple, empty of components, unchangeable. The pure or transcendental ego stands before everything that is worldly, before any experience or relation enabling the world to come to be for me. In contrast, the empirical or personal ego stands against a particular milieu. This ego is a unity of all mental or bodily experiences and calls them its "own" (Baldwin 2013, pp. 54-56/59). The personal ego is close to the notion of a person.

In the invariant structural forms of consciousness, the personal ego is aware of itself as always transforming (Husserl 1927, pp. 80, 82). Furthermore, the personal ego is "constituted in the genesis pervading the flux of lived experiences" (Husserl 2000, p. 263). The personal ego is in relation with other humans belonging to one's surrounding world (Husserl 2000, p. 261). Furthermore, in Husserl's view, the personal ego is active and always assumes a position, such as in considerations, judgments, valuations, etc. Yet, the personal ego can also be passive, when experiencing stimulation from things and appearances, or when it is attracted by something (Husserl 2000, pp. 224-225). Either being active or passive, it is one and the same personal ego (Husserl 2000, p. 260).

The transcendental and empirical ego or not just two egos, but two ways of engaging the ego: "it is a matter of two different ways in which the ego can relate to anything else besides itself" (Carr 1977, p. 685). The transcendental subject is subject in its primary constitutive function, while the empirical subject is understood and interpreted as an object in the world, as a constituted being (Zahavi 2011, p. 80). Although Husserl distinguishes more features of the ego beyond the transcendental and the empirical, it is always one and the same ego; only the circumstances of observation and methodology differ.

### 2.1. Pre-Reflective Self-Consciousness

It is worth noticing another phenomenological insight – one that claims our experiences are not primarily given to our ego as objects, but in a pre-reflective manner. Even as such, our pre-reflective experiences have an "I-pole".

Throughout our typical day, we experience a variety of situations and actions: we have a cup of coffee, we commute to and from our work, and enjoy an evening sunset. Still, we do not reflect on every single activity that was performed during the day. We don't reflect on every sip of coffee we drink in the morning, and we go past buildings without exactly noticing them on our way to work, or even the people we bump into on an elevator. Yet, the experiential fact remains that I am aware of all that and I live through these experiences. If I should wish to do so, I could reflect on them instantly or later on during the day. All beings from

the outside world enter the stream of my lived experience. However, the phenomenological viewpoint claims that these beings in our consciousness are not reflected upon in the first place. First we perceive something, then we have the possibility to posit the perceived content as being *opposite to us*, and only then we are able to reflect on this content. In the words of Husserl (1982, p. 10):

> Reflecting, I can at any time look at this original living and note particulars; I can grasp what is present as present, what is past as past, each as itself.

Reflection is possible because there is content onto which we can reflect. This content is prior to the content given to us as reflected. This primal type of experience is constituted by the pure ego (Husserl 2000, p. 224). As we have seen, experiences we live through our consciousness are primarily pre-reflective and subjective in pre-reflective self-consciousness. Husserl distinguishes the ego as subject of all affects, actions, etc. from the ego that itself becomes an object for the first-mentioned ego, in this way *constituting* the ego itself (Crowell 2015, pp. 36–37). With reflection and the reflecting consciousness, we can clarify and describe experiences and subjective processes of the structure of the consciousness in its original mode (Mertens 2014, pp. 170–171).

### 2.2 Temporalization of Ego

Finally, we turn to the third issue of our interest here: the relationship between time and ego. Time is for Husserl one of the most important notions, but also one of those notions that get us "entangled in the most peculiar difficulties, contradictions, and confusions" (Husserl 1991, p. 3). Every object that we are in relation to has its own temporal duration. Yet, this objective temporal duration is different from the time that is apprehended and grasped in one's consciousness. Thus, on the one hand, there is objective time that can be measured with instruments designed for such purposes, for instance clocks. On the other hand, there is also consciousness of time as a modality in which the phenomenality of objects is given to us through consciousness itself.

Since every being as such or every lived experience is given to us in some kind of temporal character, the issue of time is fundamental in Husserl's philosophy. His analyses are concerned with the origin of time that is located at the transcendental level of time-consciousness (or "'inner time-consciousness"; Warren 2014, p. 191), or the immanent time (how the subject experiences time), of the flow of consciousness (Husserl 1991, p. 5):

> What we accept, however, is not the existence of a world time, the existence of a physical duration, and the like, but the appearing time, appearing duration, as appearing.

Zahavi (2005, p. 312) posits that the inner time-consciousness is the name of "the pre-reflective self-awareness of our experiences".

In his work *On the Phenomenology of the Consciousness of Internal Time* Husserl (1991) developed a three-layered temporal structure of consciousness made of: protention, primal impression and retention. To elucidate his idea, we will use the first words of the Croatian national anthem *Our Beautiful Homeland* as an example, having in mind the difference between the enduring object (the song) and its parts, and the inner temporal structure of lived experience of the anthem.

The primal impression refers to the moment the song is just being sung, and which is present in our consciousness. Let's say it's the word "beautiful" (our *beautiful* homeland). Retention is the aspect that keeps away from expiring the word "our" that we heard before the word "beautiful" (*our* beautiful homeland). "Our" was a now-moment that has passed into the now-past, but is retained. Protention is the aspect that anticipates the upcoming moment of the enduring object. In our example it is the word "homeland" that is protended (our beautiful *homeland*). In this way, the unity of the duration of tones is constituted in the flow of consciousness. And not only that, but "the flow itself becomes constituted in turn as the unity of consciousness of the tone-duration" (Husserl 1991, p. 84).

Understanding the inner time-consciousness as "a field of experiencing, a dimension of manifestation", for Zahavi (2010, p. 324) it "encompasses all three temporal modes". Time-consciousness as a component of consciousness contributes to enabling experiences that are (Gallagher and Zahavi 2012, p. 80)

> unified both at one time and over time, both synchronically and diachronically. We need to account for this temporal unity and continuity.

Furthermore, Husserl discovered that "time-consciousness is inseparable from self-awareness in its primordial form as *pre-reflective* self-awareness" (Warren 2014, p. 192). Since every experience has an *I-pole*, every experience is evidence for the ego of himself, and so "in himself, he is continuously constituting himself as existing" (Husserl 1982, p. 66). The ego is dynamic and unifies all lived experiences, in this way becoming a transcendence in the immanence of lived experiences.

For Husserl, the constitution of the ego is enabled by time: the time-constituting flow in which objects are constituted is the absolute subjectivity that has absolute properties (Husserl 1991, p. 79). Subjective time, in which all objects of perception appear, is "constituted in the absolute timeless consciousness, which is not an object" (Husserl 1991, p. 117). Note that the term "absolute" does not mean the same as in "absolute divine being". Absolute subjectivity stresses the importance of subjec-

tivity for reality in providing its validation and meaning – "consciousness as a necessary condition for reality" (Zahavi 2010a, pp. 80, 81, 87). The term "absolute" in the absolute time-constituting flow of consciousness stresses the irreducible and singular notion of self-manifestation of time-consciousness (e.g., I am aware of myself having just heard the tones of this anthem; Warren 2014, p. 192).

In his later work, Husserl wrote that every occurrence in one's ego has a temporality that belongs to all-inclusive temporality with which the ego constitutes itself (Husserl 1982, pp. 74–75). In this way, time is the universal form of all egological genesis. The subjective processes of the transcendental ego flow within the unitary form of the flux, producing a unity of universal genesis of the ego. As such, our past, present and future can become unitarily constituted, as the unity of a history.

The ego has its own time and lives within time, but it also has its own temporalization (*Zeitigung*) with which it becomes an *enduring ego* (Husserl 1970, p. 172)

> ... constituting itself in its time-modalities: the same ego, now actually present, is in a sense, in every past that belongs to it, another – i.e., as that which was and thus is not now – and yet, in the continuity of its time it is one and the same, which is and was and has its future before it

In this way subjectivity is "an ego functioning constitutively" (Husserl 1970, p. 172) From its present point, ego "constitutes itself in self-temporalization as enduring through 'its' pasts" (Husserl 1970, p. 185).

In other words, all the different past experiences we have once had, are now simply accumulated sediments for the personal ego to return to repeatedly, if it should want so. For example, imagine an elderly person who is immersed in memory, in remembering things and thus becoming "the guardian of memory" (Roszak 2019, p. 95). Throughout life, through retelling and reflection of these memories (especially autobiographical ones) we shape the "narrative self" – a concept that encompasses a personal identity that lasts throughout the changing course of life (d'Argembeau *et al.* 2014).

In our present study, however, we will not be guided by the notion of the "narrative self" – which is recognized in the fields of philosophy, psychology, and neuroscience, thus remaining close to the terms Husserl used. Instead, our approach targets more towards what is described as "minimal self" which, phenomenologically, can be characterized by pre-reflective self-consciousness including its inherent temporality (Gallagher and Daly 2018).

The "I" that lived through all the past experiences and the "I" that returns to them after some time, is the same "I" – the same pure ego

that is self-identical across time. This is possible because of the synthesis (Husserl 1982, p. 66; see also Husserl 1973, p. 367)

> ... which embraces all the particular multiplicities of *cogitationes* collectively and in its own manner, namely as belonging to the identical Ego, who, *as the active and affected subject of consciousness*, lives in all processes of consciousness and is related, through them, to all object-poles.

Husserl also uses the term persisting ego (the same as the pure ego), further stressing that ego persists through temporal duration and through different experiences as an identical substrate (Husserl 1982, p. 68): "I exist for myself and am continually given to myself, by experiential evidence, as 'I myself' ".

To conclude the first part of this paper, Husserl's phenomenology endows us with invaluable insights about the ego, as well as the manner in which the ego is present in experience. Moreover, we have seen the unbreakable bond between the ego and time, since the ego is not only in time, but is also self-constituted in time itself.

## 3. Non-Reductive Neurophenomenology: Methodological Characterization

In his philosophical work, Husserl sought to understand and describe human conscious acts and their *a priori* structure. Any phenomenological analysis should provide "the complete exclusion of every assumption, stipulation, and conviction..." (Husserl 1991, p. 4). In an attempt to describe what appears to us, phenomenologists need to keep the distance from metaphysical insights and naturalistic explanations that seek to explain their biological development or neurological basis (Zahavi 2011, pp. 25–26). But Husserl was not against natural scientific explanation, he was against a scientism that holds that everything can be fully explained by natural science (Gallagher 2015, p. 71). Put into the current context, this means that Husserl would not object to a non-reductive neurophenomenological or non-reductive neurophilosophical approach, whereas he would reject reductive neurophilosophy (Northoff 2014a,b, 2016, 2018, 2021, Klar 2020).

Within such a non-reductive neurophenomenological approach, we pose the following question: can Husserl's descriptions of the ego be put in relation to neuroscientific experiments on the self? We do not aim to delve deeper into the conceptual riddle of different concepts of the self, as discussed in psychology and neuroscience (see Northoff 2016, Qin *et al.* 2020, Frewen *et al.* 2020, Gallagher and Daly 2018 for overviews), nor can we discuss all the different approaches to time in both neuroscience and philosophy. Instead, we aim to point out that some of the features

characterizing Husserl's descriptions of the ego, on phenomenological level of experience, are analogous with neuronal mechanisms operating in the human brain.

We are not claiming that one type of investigation – phenomenological or neuroscientific – is more basic than the other, but that they are two different kinds of research not reducible to one another (Gallagher 2015, p. 73). This is a process of "mutual enlightenment" (Gallagher 1977), or engagement in a "fruitful exchange" (Zahavi 2004, p. 343) reflecting a non-reductive neurophenomenological-philosophical approach (Northoff 2014a,b, 2016, 2018, Klar 2020).

As mentioned above, the central hallmark of the ego consists in its temporal nature, being self-similar across the span of time. Moreover, this self-similarity of the ego over time introduces the most basic subjectivity in our consciousness, i.e. our subjective experience of the world. The world is experienced in our consciousness in a subjective way, in the form of for-me-ness. Hence, temporal continuity, subjectivity, and relation to the world seem to be intrinsically linked and connected in pre-reflective self-consciousness.

Note that our investigation is preliminary and exploratory as we cannot go into full details on either the phenomenological or the neuroscientific side. After having introduced Husserl's ideas on the ego and its phenomenal features, we now venture into recent neuroscientific data on the self and its relation to time. Leaving out many recent neuroscientific details (see Gallagher and Daly 2018, Qin *et al.* 2020, Frewen *et al.* 2020), we here focus specifically on the relationship of the self to the brain's spontaneous activity and its temporal structure.

One key feature of such a non-reductive neurophenomenological approach is the recently introduced concept of "common currency" (Northoff *et al.* 2020a,b). Roughly, the concept of "common currency" describes that neural and mental levels, and ultimately brain and experience, share some feature that demonstrates their intimate connection. Importantly, such shared feature does not entail any specific relationship like causal or otherwise between neuronal and mental features. This must be left open. We here develop the "common currency" framework on the relationship of brain and experience by showing analogous inherent relationships of self and time on both neural and phenomenological levels.

## 4. Self-Consciousness, Brain, and Time

### 4.1 Spatial Structure – Cortical Midline Structures and "Rest-Self Relationship"

The brain's spontaneous activity is measured in the absence of any task or stimuli – the subjects have to lie still in the scanner without performing

any task or processing a specific stimulus. Among brain imagers, this is called the "resting state". Assessing the resting state in fMRI studies has to exclude stimuli and tasks that would disturb the brain's spontaneous activity. Resting-state activity has been shown to be correlated with the experience of the self (Northoff 2014a,b).

Anterior midline regions like ventromedial prefrontal cortex (VMPFC) and perigenual anterior cingulate cortex (PACC) as well as posterior regions such as the posterior cingulate cortex (PCC) (as well as other regions inside and outside these so-called cortical midline structures) have been most consistently activated during self-related processing (Northoff and Bermpohl 2004, Northoff *et al.* 2006). Though VMPFC/PACC and PCC (and other midline regions like dorsomedial prefrontal cortex, supragenual anterior cingulate cortex, and medial parietal cortex) are related to different aspects of self-related processing, they are most often conjointly recruited and activated (in different degrees) during different aspects of self-related processing (Northoff *et al.* 2006, Uddin *et al.* 2009, Leech *et al.* 2011, Fingelkurts *et al.* 2016). For the sake of simplicity, we here focus on these cortical midline structures while leaving aside other regions like the insula that have also been implicated in relating time and self (Craig 2009).

Self-related processing means that a stimulus is processed in relation to the ongoing pre-existing self – the stimulus or content is thus not processed in an objective but subjective, self-related way. Moreover, data show significant neural overlap between the high resting state and self-related activity levels in VMPFC/PACC and PCC. Several studies observed that self-specific stimuli did not induce activity change in VMPFC/PACC and PCC during task-evoked activity when compared to their resting state activity levels. Such "rest-self overlap" was further confirmed by a meta-analysis showing VMPFC/PACC and PCC as overlapping regions during both resting state and self-related processing (Qin and Northoff 2011).

Recent studies went even one step further, showing that resting state activity and pre-stimulus activity levels predict the degree of self-consciousness, i.e., being aware of being a self with certain psychological features (Huang *et al.* 2016, Wolff *et al.* 2019) or self-specificity assigned to subsequent stimuli. Albeit tentatively, these findings suggest that the resting state itself is related to some information about self-specificity in yet unclear ways.

## 4.2 Pre-Reflective and Reflective Self-Awareness in the Resting State of the Brain?

### *4.2.1 Scale-Free Activity of Cortical Midline Structures*

The data clearly suggest that the spontaneous activity of the brain is related to the self. This leaves open the exact mechanisms by means of

which neuronal activity relates to our self in its spontaneous activity – we are thus searching for the neural features that relate the self to the brain's spontaneous activity. This leads us to the spontaneous activity's own inner time. The spontaneous activity exhibits and constructs a complex temporal structure with temporal duration (Jansen and Cheng 1988, Nunez 2000, Fingelkurts *et al.* 2003, 2013, Palva *et al.* 2013). Such temporal duration in the spontaneous activity is manifest in neuro-temporal features like auto-correlation, cross-frequency coupling, and scale-free activity.

Notably, such temporal activity can occur across different timescales, short and long. For instance, when measured with EEG and its typical frequency range (1-80 Hz), one speaks of temporal durations in the millisecond range below 1 sec. On the other hand, fMRI can measure slower frequencies in the infraslow domain of 0.01 to 0.1 Hz, which includes temporal durations of 100 sec (0.01 Hz) and 10 sec (0.1 Hz) (see below for details). We will see that the length of these temporal durations in the brain's spontaneous activity is key for their relationship to the self.

Huang *et al.* (2016) investigated how the spontaneous activity as measured in fMRI is related to the self in the infraslow frequency range between 0.01 and 0.1 Hz, which shows much power and follows a scale-free distribution (with slower frequencies exhibiting more power than faster ones). Specifically, he characterized this scale-free distribution using its power-law exponent in the spontaneous activity of the two central regions of the cortical midline structures, the PACC and the PCC. Interestingly, he observed that PACC and PCC exhibit the highest power-law exponents in their spontaneous activity when compared to all other regions in the brain. This means that, unlike all other regions, these two regions show the strongest power in slower frequencies and relatively weaker power in faster ones.

To illustrate this result, compare the scale-free behavior of ocean waves. When you sit in front of the ocean, you can observe waves of different speed and power. Faster waves come more often, and are usually small in their amplitude, and less powerful. By contrast, slower waves occur less often, are big in their amplitude, and can be extremely powerful as they may swipe away all your belongings on the beach.

We are facing an analogous scenario in the brain. Regions other than PACC and PCC provide smaller waves, faster, lower in amplitude, and less powerful. In contrast, PACC and PCC exhibit the strongest waves, slower but powerful and big in amplitude – they exert the real force behind the many smaller ones. Following the data by Huang, that real force is our self, i.e., reflective self-consciousness. Let us look at this in more detail next.

### *4.2.2 Self-Consciousness as Big and Powerful Wave*

How can we assess the self in relation to the brain's spontaneous activity? Huang *et al.* (2016) assessed the self of their subjects outside the scanner by employing the self-consciousness scale (SCS), a questionnaire about reflective self-consciousness as it is required by subjects to reflect about their own self, their inner (private) thoughts, and how their inner thoughts relate to the external (public, social) world. Specifically, the subjects are asked for various dimensions of their self, private (like "I am often in my own inner thoughts"), public ("I am an outgoing person"), and social ("I like to connect to other people").

They could then relate the individual subjects' scores of the SCS to their spontaneous activity as measured in resting state fMRI. What are the findings? They observed a direct relationship between the power spectrum of the frequencies and the level of self- reflection. Specifically, the degree of scale-free activity, as measured by the power-law exponent, directly correlated with the degree of specifically private self-consciousness: the higher the power-law exponent in the spontaneous activity's PACC and PCC, the higher the degree of the respective subject's private self-consciousness. This means that more power in the resting state is related to stronger reflective self-consciousness.

As mentioned, reflective self-consciousness is thus reflected in the power of the very slow frequencies: the more strongly the slower frequencies' power dominate and thus override the less powerful faster ones, the stronger the reflective self-consciousness when compared to our consciousness of the external world. If, in contrast, the faster frequencies are less dominated by the slower frequencies and have relatively more power, the reflective self-consciousness is less dominant, since then consciousness is more determined by the external environment.

Conceived in a phenomenological context, what is tested in the SCS studies is reflective self-consciousness: the studies require subjects to reflect upon their own self when answering the various items. This leaves open the relationship of SCS scales to the temporal features of pre-reflective self-consciousness, though. We now aim toward a first exploratory approach to address this relationship, being fully aware that we will remain unable to completely bridge the gap between the inherently temporal nature of pre-reflective self-consciousness on the one hand and the temporal structure of the brain's spontaneous activity.

In both approaches, empirical and phenomenological, we can see an inherent relation of self and time/duration. However, such similarity in temporal structure does not yet imply a concrete relationship of neural and phenomenological features beyond their analogy. For conceptual reasons and empirical insufficiencies there are currently no data on pre-reflective self-consciousness itself. Given that more direct relationships are still to

be elaborated on both conceptual and empirical levels, our proposal must be considered exploratory.

### 4.3 Forms of Self-Consciousness and Their Temporal Duration

The findings suggest that the self is experienced in a reflective way in terms of temporal duration. Such duration in the experience of self may be related to the long-cycle durations of the more powerful slower frequencies (when compared to the shorter-cycle durations of the faster frequencies). For instance, the cycle duration of the frequency 0.01 Hz is 100 sec while the duration of 0.1 Hz lasts only 10 sec – this demonstrates the relationship of frequency and the temporal duration of its cycles.

The fact that reflective self-consciousness is related to the slower frequencies means that the long-cycle durations are central for the former. The empirical findings suggest the following relationship: since the long-cycle durations introduce longer temporal duration, one can say that reflective self-consciousness is about temporal duration in resting state activity: the stronger the power of the slower frequencies, the longer and more extended their temporal duration, and the longer and stronger is the reflective consciousness about ourselves.

### 4.4 Pre-Reflective Self-Consciousness: Temporal Integration, Continuity, and Nestedness

Time is not monolithic. Especially the time constructed by our brain's spontaneous activity is a complex amalgam of different temporal features (Freeman and Holmes 2005, Tozz *et al.* 2016, Fingelkurts and Fingelkurts 2014, Northoff *et al.* 2019). One of them is cross-frequency coupling (CFC) that describes how one frequency is related to and thus integrated with another one – this entails temporal integration. There is also the auto-correlation window (ACW) that measures how a state at one point in time is related to and thus correlates with the state at a subsequent point in time – this ACW thus measures temporal continuity. Finally, there is temporal nestedness in the power between faster and slower frequencies as measured by the power-law exponent of scale-free activity: slower frequencies are more powerful than faster ones such that the latter contain or nest the former in a self-similar way (like Russian dolls showing the same shape but different size).

How can we characterize the spontaneous activity's temporal duration in a more precise way? Temporal duration includes distinct components like temporal integration, temporal continuity, and temporal nestedness. Temporal integration means that distinct stimuli are collated together, temporal continuity means that neural activity persists over time, while temporal nestedness operates across long and short time-scales. Is self-consciousness related to these three components of temporal duration?

This was tested by Wolff *et al.* (2019). Like Huang *et al.*, they measured the subjects' spontaneous activity, but they focused on the faster frequency range of 1-70 Hz using EEG. They also applied the SCS to measure subjects' reflective self-consciousness.

Higher degrees in all three measures, CFC, ACW, and power-law exponent, of the resting state EEG were related to higher degrees of private self-consciousness. That again suggests that the spontaneous activity's own temporal duration with its components, i.e., temporal integration, nestedness and continuity, is related to prereflective self-consciousness of the phenomenal I-pole, which then is manifest in reflective self-consciousness as tested by the self-questionnaire.

One may be puzzled that the data show the same results in two different frequency ranges, EEG and fMRI. The idea here was that the self operates across all frequencies including both the infraslow ones (0.01 to 0.1 Hz) of fMRI and the faster ones (1-80 Hz) of EEG. Hence, the self, i.e., self-consciousness, is not related to a particular frequency range. Instead, it is assumed that the self is related to the balance between slow and fast frequencies irrespective of the particular frequency range in which one investigates it. Hence, we assume the self to operate in a truly scale-free way driven more strongly by slower frequencies relative to faster ones.

Most importantly, the data suggest that reflective self-consciousness is essentially temporal: the self is featured by temporal duration with its components of temporal integration, continuity, and nestedness. The temporal features of the spontaneous activity's time thus seem to shape reflective self-consciousness in an intrinsically temporal way on the empirical level of the brain. Therefore, we suppose that inner time provides the "common currency" (Northoff *et al.* 2020a,b) between brain and reflective self-consciousness and, more generally, between neuronal and mental features. Again, we note that the shared feature of a "common currency" leaves the exact relationship of brain and experience for future investigation.

## 5. The Self between Brain and Experience – Discussion and Directions

Rather than developing full-fledged assumptions or hypotheses about the relationship of neural and phenomenological levels, we here aim to put forward some thoughts about relevant questions and future directions. This section should thus not be read as a firm statement about neuro-phenomenological relationships. Rather, it expresses ideas that might stimulate future discussion and research.

### 5.1 The Self between Brain and Experience – Neuro-Phenomenological Convergence

Firstly, Husserl pinpointed how all the objects from the surrounding world are originally constituted in acts of the ego – which amounts to an I-pole (Husserl 2000, p. 225). If this is so, then every kind of activity or passivity of the subject in neuroscientific studies should show, at least in the recorded neural activity, some portion of activity related to that very same ego or I-pole, as manifest in what has been described as a point of view (Nagel 1974). Accordingly, our brain's spontaneous activity and its temporo-spatial dynamics may, in yet unclear ways, be related to the I-pole or point of view as the most fundamental basis of any experience.

Consciousness necessarily includes pre-reflective self-consciousness, for which reason consciousness, just as self-consciousness, may by itself be intrinsically temporal – this is important to consider for the neuroscientific discussion of consciousness (Northoff and Lamme 2020). The theory of consciousness that includes such intrinsically temporal nature of consciousness is the temporo-spatial theory of consciousness (TTC; Northoff and Huang 2017, Northoff and Lamme 2020). This role for temporality distinguishes the TTC from others like integrated information theory or global neuronal workspace theory which conceive consciousness in an essentially non-temporal way (Kent and Wittmann 2021, Northoff and Lamme 2020).

Secondly, there could be no neuroscientific studies including any kind of stimuli, i.e. self- and non-specific stimuli that, in some way, avoid the activation of our ego. There should be no wake and active states of the human mind that are not connected to the ego or I-pole as, in some way, the human mind always assumes some point of view. One has to be careful, though, as there are some extraordinary states like in meditation where that point of view seems to be no longer experienced as such (Winter *et al.* 2020). Hence, in those states, the experience of temporality, i.e., temporal continuity and duration may predominate over the experience of a self as it is described in non-dual awareness (Cooper *et al.* 2021).

Thirdly, further examination is needed. Can we develop a certain hierarchy of the ego's states based on phenomenological insights, states which could correspond to different levels of processing of self-specificity assigned to the stimuli, as well as to the activity of the brain? Would it be possible to start with brain-based pre-reflective states or unreflected ego-life (Husserl 2000, p. 260) as a basis for states in which one is aware one exists, including self-experience, and ultimately ending with reflection on intersubjectivity?

Fourthly, pre-reflective self-consciousness, or the ego, is always present in our experiences; it is thus not a matter of degree. In contrast, there are different degrees in the manifestation of the reflective moment, i.e., in

reflective self-consciousness. This makes it rather difficult if not impossible to directly operationalize pre-reflective self-consciousness. Since empirical investigation requires verbal and therefore reflective access, it may be hard and difficult to empirically investigate prereflective self-consciousness in a direct way; we therefore require indirect research strategies to provide empirical support.

### 5.2 The Self between Brain and Experience – Neuro-Phenomenological Synthesis

Another important issue is that, for Husserl, the ego is generated through its past experiences. Sedimentation of past moments and retention enables us to return and reflect on them – in this way shaping our understanding of who we are right now. An analogous temporal structure is measured by the power-law exponent of scale-free activity, as sketched above. Specifically, one measures how the neuronal activity at one specific point in time correlates with the activity at all other points in time, across both slow and fast frequencies. The closer the points in time are to one another, the more they correlate with each other, while also correlating mutually over longer series of time points – this is called long-range temporal correlation (LRTC; Linkenkaer-Hansen *et al.* 2001).

This can be compared to a group of people: the closer two persons stand next to each other, the more likely is it that they communicate with each other and exchange ideas and thus somehow correlate. In contrast, people standing far from each other have a low likelihood of communicating and do, thus, correlate with each other to a much lower degree.

Given that LRTCs describe various degrees of correlation between close and more distant time points, they exhibit a structure somewhat similar to the one described by inner time-consciousness, where the past is connected to and merges with the present while the latter somewhat converges with the future. Analogous to inner time-consciousness, there is temporal continuity of past, present, and future in scale-free activity as measured by LRTC. However, more detailed LRTC analyses need to be done in the future. Also, its similarity or dissimilarity with the more fine-grained features of inner time-consciousness, including its specific manifestation in pre-reflective self-consciousness, needs to be examined more.

In Husserl's view, the I or the self is identical through different kinds of acts and through time, although it is constantly undergoing a change. Because of the synthesis of my past and present I, I perceive myself as the identical I. One can speak here of temporal synthesis and, specifically, of the synthesis of temporal continuity through temporal discontinuity. Temporal continuity is accounted for by the connecting link of past, present, and future, whereas temporal discontinuity is reflected in the distinction of past, present, and future. More importantly, such temporal synthesis,

i.e., the synthesis of temporal continuity through temporal discontinuity, is an active process rather than being merely passive.

It should be noted that one must distinguish different notions of "active". Active can be meant in either a cognitive way, in which case it is closely related to specific cognitive functions like attention, working memory, etc. We would say that such "active" constitution of time in a cognitive sense amounts to the perception and cognition of time. Alternatively, active can also be understood in a more basic sense in which constitution of time is still shaped by the self but in a non-cognitive way on a deeper dynamic level beneath the cognitive level. In that case, there is still synthesis of time. This distinguishes this deeper level from a purely passive account where the self would not contribute anything to the constitution of time.

However, that synthesis is not based on the specific cognitive function but rather on a more basic level of form, organisation, and structure. Compared to the active synthesis in a cognitive sense, such synthesis is passive (as Husserl said), but still distinguished from pure passivity in the empirical tradition of Hume and Locke (see also Chapter 1 in Northoff 2018 for a "spectrum model" of the brain that is neither purely passive nor purely active). It is in the latter sense that we understand the concept of active as the basis by means of which synthesis of time and synthesis of self are intrinsically connected. On the phenomenological level, this corresponds to Husserl's concept of passive synthesis and is supported by the empirical data presented above.

We tentatively assume that, on the empirical level of the brain, both temporal synthesis and self-constitution, i.e. the constitution of pre-reflective self-consciousness, are interrelated and interdependent in a way akin to Husserl's phenomenological assumptions. One may go even one step further and postulate that self and time are necessarily and intrinsically related with each other. The self as manifest in pre-reflective self-consciousness is intrinsically temporal: without its constitution in terms of temporal continuity the self would break down. Conversely, the constitution of temporal continuity intrinsically involves the self, entailing that without it there would be no temporal continuity.

## 6. Conclusion

In conclusion, both phenomenological description and interpretation of neuroscientific empirical findings suggest that the self or the ego is essentially temporal and constituted in and through time. Pre-reflective self-consciousness, or I-pole or point of view, is intrinsically temporal, i.e., it constitutes the self by constituting time in a dynamic sense as a continuous link and interconnection of past, present and future. Although Husserl's breakthrough in phenomenology and transcendental subjectivity

had no desire to connect to or be confirmed by measurements of scientific objectivity in a reductive neurophenomenological way, it leaves open the door for a non-reductive neurophenomenological-neurophilosophical approach.

Pursuing such a non-reductive approach, we can now propose such a link by conceiving the brain on a deeper level, i.e., in temporal dynamic terms that exhibit analogous temporal continuity across different time scales on both the neuronal (spontaneous brain activity) and the phenomenological (preflective self-consciousness) side. This opens the door for a non-reductive neuro-phenomenological hypothesis (Northoff 2014a,b, 2016, 2018).

The common ground for our neuro-phenomenological perspective may consist in analogous or even shared temporal continuity across different timescales in a scale-free way. This, in turn, may provide an intrinsic, i.e., necessary *a posteriori* relation of brain and self (Kripke 1972, Nagel 1998, Northoff 2018). Albeit tentatively, the scale-free temporal continuity may be shared by both the brain's spontaneous activity and pre-reflective self-consciousness, providing what has recently been described as a "common currency" (Northoff *et al.* 2020a,b) – as the hallmark of a temporally complex, multi-layered human being.

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