CHAPTER

4

Embrainment and Enculturation: Culture, Brain, and Self

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Abstract

Embrainment and enculturation are central concepts in cultural neuroscience, but their mechanisms remain unclear. Embrainment describes how cultural contexts are encoded into the brain's neuronal activity, whereas enculturation means that neuronal activity is impacted by cultural contexts as manifested in the brain's affective and cognitive functions. This chapter takes the self as a paradigmatic example of embrainment and enculturation. It discusses different concepts of self and shows the neuronal correlates of self, which highlight spatiotemporal, scale-free (i.e., across different spatial and temporal scales operating in a self-similar way), and stochastic mechanisms. That very same spatiotemporal, scale-free, and stochastic encoding is manifested on the mental level in human selves, which, therefore, are relational and spatiotemporal. The chapter concludes that embrainment and enculturation reflect two distinct aspects of one and the same underlying process, that is, self-related processing as manifested in the self as relational self. Moreover, as human selves provide the basis of mental health, the here-described mechanisms of embrainment and enculturation of self are central for global mental health as people with their self and the underlying brain's spontaneous activity move across different cultures.

Key Words: embrainment, enculturation, self, cortical midline structure, scale-free properties, spatiotemporal features

Introduction

Cultural neuroscience has demonstrated that culture permeates our affective and cognitive functions as well as their underlying neuronal mechanisms in the brain (Han & Northoff, 2008, 2009; see also Chiao et al., "Cultural Neuroscience," in this volume). Even our self (i.e., sense of self or self-consciousness) is strongly dependent upon the respective cultural context. Markus and Kitayama (1991, 2003) distinguished two different styles or types of self: an independent self that is more focused on itself and less on its respective social context and thus presupposes a more individualistic cultural view (see also Masumoto and Hwang, "Culture and Psychology"; Goto, "Culture and Self-Construal"; and Wang, "Culture and Autobiographical Memory," this volume), and an interdependent self that is less focused on itself and emphasizes more its social relation and context and thus presupposes a more collectivistic view. Following Markus and Kitayama (1991), the independent self is predominant in the Western world, while the interdependent self dominates more in the Far Eastern part of the world. Most interestingly, recent brain imaging studies demonstrated neural differences between independent and interdependent selves (see Han & Ma, 2016; Han & Northoff, 2009; see also Goto, "Culture and Self-Construal" as well as Wang, "Culture and Autobiographical Memory," this volume).

These findings on the self and many other findings in cultural neuroscience raise the question about the mechanisms by which culture comes into the brain. Specifically, we are asking about the mechanisms by which the brain's neuronal activity and the associated self can encode cultural context and are shaped by them. This is the question about what has been described as "embrainment" and "enculturation" or, more or less synonymously, "culture–brain nexus," "neuroculture interaction," or "encultured brain" (Northoff, 2016). Briefly, embrainment describes that cultural contexts are encoded into the brain's neuronal activity such that the latter is shaped by the former—one can thus speak of "embrainment of culture." Enculturation describes that our affective and cognitive functions, including their underlying neural correlates, are adopted to the respective cultural context and thus encultured—one can thus speak of "enculturation" of the brain.

The main aim in this chapter is to understand some of the mechanisms underlying embrainment and enculturation. For that, I take the self as a paradigmatic example appropriate to reveal the mechanisms underlying embrainment and enculturation. The first part will focus on recent concepts of self, which will be complemented in the second part by showing recent empirical (neuroscientific) findings on self. The third part will address the mechanisms of embrainment and enculturation, while the fourth part will focus on the implications of these mechanisms for mental features like the self. The main thesis is that, as based on empirical data, I consider embrainment and enculturation as two distinct aspects of one and the same underlying neuroecological process, that is, self-related processing as manifested in the self as relational self.

Concept of Self

Is the Self a Mental Substance or Property?

What is the self? What must it look like to presuppose experience and be the subject of our experience? The self has often been viewed as a specific "thing." Stones are things; the table on which your laptop stands is a thing. And in the same way the table makes it possible for the laptop to stand on it, the self may be a thing that makes experience and consciousness possible. In other words, metaphorically speaking, experience and consciousness stand on the shoulders of the self.

However, another question is whether the self is a thing or, as Western philosophers such as Rene Descartes argued, a substance or a property as it is nowadays formulated in Western philosophy. A substance or property is a specific entity or material that serves as a basis for something like a self. For instance, the body can be considered a physical substance, while the self can be associated with a mental substance. Nowadays one would speak no longer of substance but of properties, like a mental property that is enduring, not subject to change, and that can therefore best account for the continuity of the self over time.

Is our self real and thus does it exist? Or is it just an illusion? Let us compare the situation to perception. When we perceive something in our environment, we sometimes perceive it as not a real thing, but an illusion that does not exist. The question of what exists and is real is what philosophers call an ontological question. Earlier philosophers, such as Rene Descartes, argued that the self is real and exists. Descartes also argued that the self is different from the body. Hence, self and body exist, but differ in their nature and essence. Thus, from this perspective, the self cannot be a physical substance and is a mental substance instead. It is a feature not of the body, but of the mind.

However, the Western characterization of the self as a mental entity has been questioned. For example, the Scottish philosopher David Hume argued that there is no self as a mental entity. There is only a complex set or "bundle" of perceptions of interrelated events that reflect the world in its entirety. There is no additional self in the world; instead, there is nothing but the events we perceive. Everything else, such as the assumption of a self as mental entity, is an illusion. The self as mental entity and thus as a mental substance does not exist and is therefore not real.

To reject the idea of self as mental substance and to dismiss it as mere illusion is currently popular. One major proponent of this view today is the German philosopher Thomas Metzinger (2003). In a nutshell, he argues that through our experience, we develop models of the self, so-called self-models. These self-models are nothing but information processes in our brain. However, since we do not have direct access to these neuronal processes (e.g., all those processes and activities of the cells and neurons in the brain), we tend to assume the presence of an entity that must underlie our own self-model. This entity is then characterized as the self.

Is the Self Based on Integration and Cognition?

What is the self if not a mental entity? Current authors such as Metzinger (2003) and Churchland (2002) argue that the self as mental substance or entity does not exist. How do we come up with the idea of a self, or the self-model as Metzinger calls it? The model of our own self is based on summarizing, integrating, and coordinating all the information from our own body and brain.

What does such integration look like? Take all that information together, coordinate and integrate it, and then you have a self-model of your own brain and body and their respective processes. In more technical terms, our own brain and body are represented in the neuronal activity of the brain. Such representation of our own brain and body amounts then to a model of your self. The self-model is therefore nothing but an inner model of the integrated and summarized version of your own brain and body's information processing. The self is thus a mere model of one's own body's and brain's processes.

The original mental self, the self as mental substance or entity, is in this line of thinking replaced by a self-model. This implies a shift from a metaphysical discussion of the existence and reality of self to the processes that underlie the representation of body and brain as a self-model. Since this representation is based on the coordination and integration of the various ongoing processes in the brain and body, it is associated with specific higher-order cognitive functions such as working memory, attention, executive function, and memory, among others.

What does this imply for the characterization of the self (presupposing a broader concept of self beyond the self as mental substance)? The self is no longer characterized as a mental substance but as a cognitive function. Methodologically, this implies that the self should be investigated empirically rather than metaphysically.

We therefore need to search for the cognitive processes underlying the special self-representation. The self is consequently no longer an issue of philosophy, but rather one of cognitive psychology and ultimately of cognitive neuroscience. According to this model, the self is no longer a metaphysical matter, but merely empirical and, more specifically, cognitive as related to various cognitive functions (Sui & Humphreys, 2015). However, as it will become clear in the following, the self is more than just integrational and cognitive—it extends beyond the cognitive realm to the social and cultural context in which it is situated.

Is the Self Social?

How does the self interact with other selves? So far, we have described the self in an isolated and purely intraindividual way. However, in daily life, the self is not isolated from others but always related to other selves. This is called interindividualism rather than intraindividualism. This raises questions about what is described as the "problem of other minds" or, more generally, questions concerning intersubjectivity. Here we will give a brief description of the problem of intersubjectivity.

How can we make the assumption of attributing mental states and thus self and mind to other people? Philosophy has long relied on what is called the "inference by analogy." What is the inference by analogy? The inference by analogy goes like this. We observe person A to show the behavior of type X. And we know that in our own case the same behavior X goes along with the mental state type M. Since our own behavior and that of the person A are similar, we assume the other person A to show the same mental state type M we experience when exhibiting behavior X.

What kind of inference do we draw here? There is similar or analogous behavior between ourselves and the other person. In addition, my own behavior is associated with a particular mental state. Since now the other person shows the same behavior, I infer that she also shows the same mental state as it is associated with my own behavior. Hence, by indirect inference and analogy via our own case, we claim to obtain knowledge of the other person's mental state. How can we make such inference? We may make it on the basis of our own mental states and their associated behavior. And what we do may also hold true for the other person who in the same way attributes mental states to us by inferring them from the comparison between our behavior and their own mental states.

However, both empathy and the attribution of mental states to another person are puzzling: despite the fact that we do not experience the other's mental states and consciousness, we nevertheless either share them (as in empathy) or infer them (as in inference by analogy). We have no direct access to other persons' experience of a self and its mental states in first-person perspective and nevertheless share their mental states and assume that they have a self. How is that possible?

Different Perspectives of the Self?

This is where we need to introduce yet another perspective. There is the first-person perspective—tied to the self itself and its experience or consciousness of objects, events, or persons in the environment. Additionally, the first-person perspective could also result from the integration of the different selves and their distinct features as described earlier. Then there is the third-person perspective—this perspective allows us to observe the objects, events, or persons in the environment from the outside, rather than from the inside. The picture is not complete though, as it must be complemented by the second-person perspective.

What is the second-person perspective? The second-person perspective has initially been associated in philosophy with the introspection of one's own mental states. Rather than actually experiencing one's own mental states in first-person perspective, the second-person perspective makes it possible to access others' mental states and understand the other as self. At the same time, the second-person perspective also allows one to reflect about one's own self as just another self in the world besides other selves (see also Pfeiffer et al., 2013).

The second-person perspective thus allows us to put the contents of our consciousness as experienced in first-person perspective into a wider context—the context of oneself as related to the environment—as well as to connect that to other persons' mental contents and selves. In other words, the second-person perspective makes it possible to situate and integrate the purely intraindividual self with its first-person perspective into a social context of other persons' selves. This transforms the intraindividual self into an interindividual self, while other selves are also transformed into interindividual selves. Taken together, the second-person perspective allows us to determine the concept of the self as "social self."

How can we define the concept of the social self? The concept of the social self describes the linkage and integration of the self into the social context of other selves. This shifts the focus from experience or consciousness in the first-person perspective to the various kinds of interactions between different selves as associated with the second-person perspective. As we already indicated, there may be different kinds of social interactions including affective precognitive and more cognitive ones that involve meta-representation as described previously.

Independent Versus Interdependent Self?

The social self is closely linked to the culture within which the self socially interacts. Different cultures entail different forms of social interaction and consequently different forms of self. This is most apparent in the distinction between inter- and independent self (Markus & Kitayama, 1991, 2003). Briefly, the independent self is a self that focuses more on itself and its inner states and is also structured more or less independently of the others and the social context—such an independent self is considered to dominate in the Western world. The interdependent self is more focused on social relationships with close others, and especially the family—the self thus structures, stabilizes, and constitutes itself through others and social relationship rather than by and through itself as the independent self. Such an interdependent self is a knot or hub in the social-cultural web—this view of self is more dominant in the Eastern world (Han & Ma, 2016).

However, it must be noted that the distinction between inter- and independent self is not absolute, but relative, where both types are found in Eastern and Western culture to different degrees (Han & Ma, 2016; Han & Northoff, 2009). How is it possible that the self is socially and culturally embedded and thus encultured, while at the same time being embrained? To understand the enculturation and embrainment of the self, we now turn toward neuroscience and what it tells us about the self.

Brain and Self

Cortical Midline Structures and the Self

Anterior midline regions like the 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 the cortical midline structure [CMS]) have been most consistently activated during self-related processing (see Araujo et al., 2013; Hu et al., 2016; Murray et al., 2012; Northoff & Bermpohl, 2004; Northoff et al., 2006; van der Meer et al., 2010). Though the VMPFC/PACC and PCC (and other midline regions like the dorsomedial prefrontal cortex, supragenual anterior cingulate cortex, and medial parietal cortex) are related to differential aspects of self-related processing, they are most often conjointly recruited and activated (in different degrees) during different degrees and aspects of self-related processing (Araujo et al., 2013, 2015; Hu et al., 2016; Lou et al., 2016; Murray et al., 2012, 2015; Northoff et al., 2006; van der Meer et al., 2010).

Moreover, data show significant neural overlap between the high resting state and self-related activity levels in the VMPFC/PACC and PCC. Several studies observed that

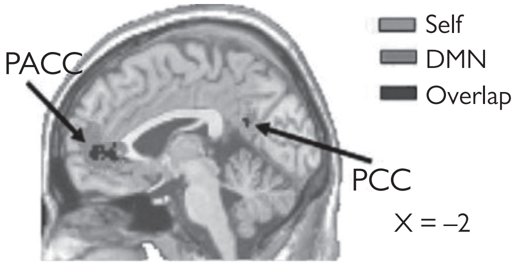

Figure 4.1. Rest-self overlap in default mode network (DMN).

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 (D'Argembeau et al., 2005; Davey et al., 2016; Schneider et al., 2008; Whitfield-Gabrieli et al., 2011); such "rest-self overlap" (Bai et al., 2015) was further confirmed by a meta-analysis showing the VMPFC/PACC and PCC as overlapping regions during both resting state and self-related processing (Qin & Northoff, 2011; Figure 4.1).

Recent studies went even one step further, showing that resting state activity and pre-stimulus activity levels predict the degree of self-consciousness, that is, being aware of being a self with certain psychological features (Huang et al., 2016), or self-specificity assigned to subsequent stimuli (see Bai et al., 2015; Qin et al., 2016). If these findings of rest–self-prediction are further confirmed, one may suppose that the resting state itself encodes or contains some information about self-specificity in yet unclear ways. The assumptions of "rest–self overlap" may then be accompanied by the one of "rest–self-containment" (Northoff, 2016), which, reformulated in a cognitive way, amounts to "self-representation" (Sui & Humphreys, 2016, p. 4) or, in a more literary and less tendentious way, "reflection."

The central role of the resting state for mediating self-specificity is further supported by the assumption of a so-called self-network. Based on functional connectivity analysis of a large resting state data set, Murray and colleagues (2012, 2015) demonstrated that anterior midline regions like the PACC and VMPFC together with the anterior insula form a "self-network" in the resting state (see also Huang et al., 2016; Lou et al., 2010, 2016). The co-involvement of the PACC/VMPFC and insula in self-specificity is further supported by these regions' coactivation in task-related studies (see Enzi et al., 2009). The self-network must be distinguished from what they describe as "other network," which includes posterior midline regions like the PCC and the temporoparietal junction (TPJ) (Murray et al., 2015).

Experience Dependence of Cortical Midline Structures

How is it possible that the self is encompassed by the spontaneous activity of the brain (more specifically, the CMS)? The self must have been encoded into the brain's spontaneous activity (see Northoff, 2014a, 2016). This raises the question of how the self is encoded into the brain's spontaneous activity—in addition to the question about the neural code (Northoff, 2014a, 2016), we must address the question of how the self is encoded. The data show that the self is encoded into the spontaneous activity in an experience-dependent way—illustrated by a recent study by Duncan et al. (2015).

Duncan et al. (2015) showed that the CMS resting state's spatiotemporal structure in adulthood is strongly associated with subjects having incurred childhood trauma (Duncan et al., 2015; Nakao et al., 2013). Duncan et al. (2015) employed a measure of entropy, quantifying the degree to which one neuronal state at one specific time point, (e.g., t1) can predict neuronal states at subsequent time points (e.g., t2, t3, etc.), thus describing the degree of order or disorder in neural activity across time. In addition to entropy, they also measured the concentration of glutamate in the same specific core region, the PACC, during the CMS resting state. Adult subjects were investigated whose degree of early childhood trauma was measured with a standard questionnaire, that is, the Child Trauma Questionnaire (CTQ).

The first result was that Duncan et al. (2015) could observe a direct relationship between the degree of early childhood trauma and the entropy in the PACC: the higher the degree of early childhood trauma, the greater the entropy in the PACC resting state's spatiotemporal structure in adulthood (Duncan et al., 2015). This means that higher degrees of early childhood trauma disrupt the order—the degree of prediction of neural activity in the PACC across time—while lower degrees of early childhood trauma lead to a more ordered and stable (i.e., predictable) neural activity pattern in the PACC resting state in adulthood.

Most surprisingly, there was also a relationship between the biochemical and the psychological data. Specifically, the level of glutamate in the PACC was directly related to the degree of early traumatic childhood events: the higher the glutamate in the PACC, the lower the degree of early childhood traumatic life events. This suggests that the early traumatic life events are also encoded at the biochemical level of the brain's neural activity.

Spatiotemporal Memory of the World in the Brain's Spontaneous Activity

What do these data tell us about the brain and the temporal nature of its relation to the world, the world–brain relation (Northoff, 2016, 2018)? First and foremost, the data show the diachronic nature of the brain's spontaneous activity. It contains the traces of the events during early childhood even in adulthood, as Freud and many other early psychologists postulated. The brain's spontaneous or resting state activity can thus be characterized as truly temporal and, more specifically, diachronic with respect to the relation between world and brain (i.e., the world–brain relation).

Second, early life events are encoded in a spatiotemporal way into the brain's spontaneous activity—this is reflected in the measure applied, entropy, which is spatial and temporal at the same time as it describes the degree to which the spatial pattern of neural activity can be predicted across time. One can thus speak of the "spatiotemporal encoding" of experience into the brain's spontaneous activity, which in turn shapes and constitutes the self.

Third, such spatiotemporal encoding must be distinguished from "cognitive encoding." Briefly, cognitive encoding refers to the encoding of specific contents, such as the traumatic events themselves—this amounts to what is generally described as "memory." Specific memories were not investigated in the Duncan et al. study (2015), however. They did not measure task-evoked activity related to specific contents in memory. Instead, they measured only the resting state itself and its spatiotemporal structure. One may now want to distinguish between different memories.

Traditionally, episodic memory is considered as cognitive, in that it is based on specific contents such as the traumatic events themselves. Our data, and those of other researchers, suggest that there is yet another form of episodic memory, namely a noncognitive memory (Sadaghiani & Kleinschmidt, 2013) or, more precisely, "spatiotemporal memory" (Northoff, 2017), where events in the world (like the early childhood traumatic events) are encoded in terms of spatiotemporal features (rather than as cognitive contents). This remains distinct from procedural memory, which is not event related.

Fourth, such spatiotemporal memory does not encode and store contents—it is not declarative, content-based memory. Instead, spatiotemporal memory is probabilistic—it encodes and stores spatiotemporal patterns, based on the statistical frequency distributions that occur in the respective environmental context. Hence, rather than being content based and cognitive, spatiotemporal memory is stochastic, which can be measured statistically. The spontaneous activity's spatiotemporal structure is stochastic, and thereby can be closely related to the statistical frequency distributions in the environment (Northoff, 2014b). Such stochastically based encoding by the brain must necessarily encode the stochastic spatial and temporal differences of the various environmental events as they occur across time and space. Hence, the spatiotemporal nature of the brain's memory and its diachronic features go hand in hand with its essentially stochastic nature.

Why is such spatiotemporal memory relevant for the self? The data on rest–self-containment suggest that the brain's encoding of spatiotemporal memories constitutes the self—the self is the brain's spatiotemporal memory during its interaction with the world. The way in which the brain encodes spatiotemporally the life events in the world constitutes the self. The self is thus based on what conceptually I describe as the world–brain relation (Northoff, 2016, 2018), which can be described by its spatiotemporal structure and memory. The self can consequently also be characterized by spatiotemporal structure and memory, as based on the world–brain relation.

Spatiotemporal Nestedness and Embrainment/Enculturation

Temporal Nestedness of Brain and Self Within the World

Let us consider the empirical data as a whole. The temporal, and more specifically diachronic, nature of the world–brain relation may be manifested in multiple layers of different spatiotemporal scales—the world–brain relation is thus diachronic and spatiotemporal. The most basic and longest spatiotemporal scale is the one of evolution and history—present in the brain's overall organization, including the CMS as the cortical extension of the evolutionarily old limbic system (Northoff, 2011). A shorter time scale, the person's lifespan, is present and manifested in the encoding of early childhood life events into the spontaneous activity's spatiotemporal structure.

One can well assume that the brain's spontaneous activity encodes a wide range of different time scales, from extremely long to very short, for which the brain's own fluctuations in different frequency ranges may be instrumental (Northoff, 2014b). The presence and encoding of multiple time scales in and by the brain's spontaneous activity is empirically well reflected in its high degree of scale-free activity that measures the power relationship between different frequencies (He, 2011, 2014; Huang et al., 2015, 2016; Figure 4.2).

We can now extend these empirical observations within the brain's spontaneous activity itself to the more conceptual level of the world–brain relation. The world–brain relation encodes and is constituted by multiple time scales at one and the same time. Therefore, the world–brain relation can be characterized by what is empirically described as scale-free activity that is characterized by temporal nestedness (Northoff, 2016b, 2018). Temporal nestedness describes the integration and relation between different time scales and, more specifically, that one time scale mirrors and/or is self-similar to the others. That can be compared to the various Russian dolls that, despite their difference in spatial size, show all the same shape—temporal nestedness describes the same principle of self-similarity on the temporal level. Most interestingly, those very same scale-free properties of the spontaneous activity are directly related to—that is, predict—the degree of self-consciousness (Huang et al., 2016; Wolff et al., 2019). The self may thus reflect the temporal nestedness of the brain within the world (i.e., the world–brain relation) and thus the self-similarity between world and brain (Figures 4.3a and 4.3b).

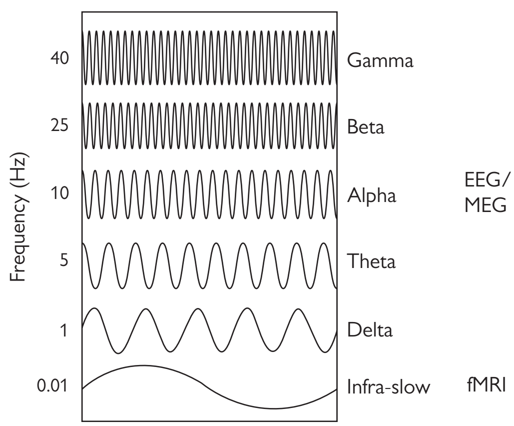

Figure 4.2. Temporal nestedness between different frequencies in the brain's neural activity.

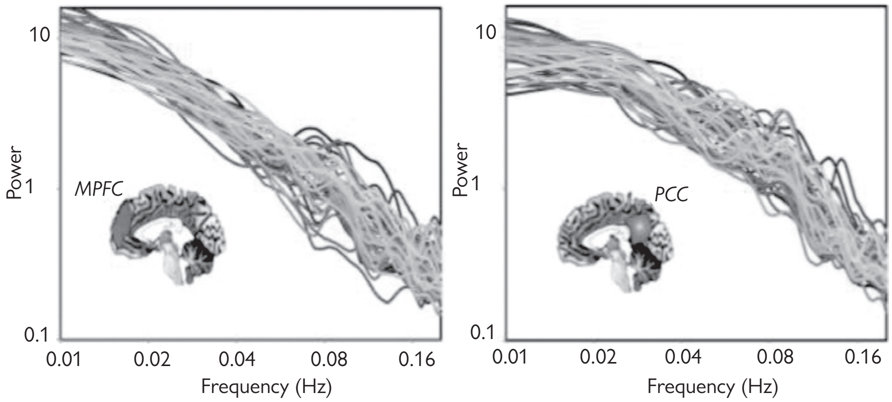

Figure 4.3a. Power spectra in two midline regions in different subjects.

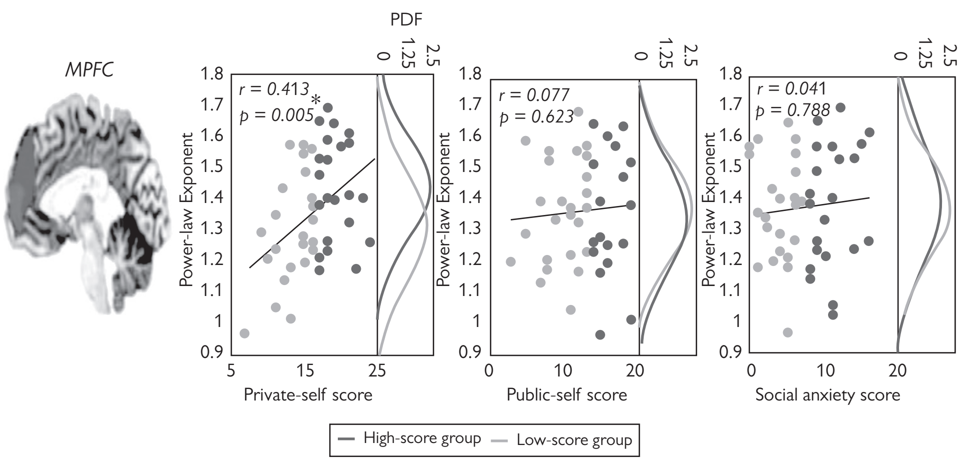

Figure 4.3b. Correlation between power law exponent (y-axis) and self-consciousness scale (x-axis).

In sum, the brain's spontaneous activity can be characterized as temporal, stochastic, and scale-free and as linking the brain in terms of temporal nestedness to its respective environmental context in terms of the world–brain relation. That very same world–brain relation provides the basis for the encoding of life events in terms of experience dependence, which constitutes the self. Therefore, the self may be characterized by temporal nestedness of the brain's spontaneous activity within its respective environmental context. Metaphorically speaking, the self is just a brain-based (temporally) nested and thus self-similar Russian doll within the spatiotemporally more extended world.

World–Brain Relation and Spatiotemporal Nestedness

What exactly do I mean by world–brain relation and nestedness? The world–brain relation is primarily spatiotemporal. More specifically, the world constructs its own time and space, the passage of time and the configuration of space, in a continuous way. One can therefore speak of the world's time and space. As we have seen earlier, the brain and its spontaneous activity construct their own time and space, "inner time and space," as distinguished from the world's "outer time and space," as one may want to say (Northoff, 2018).

This raises the question of how the brain's inner time and space are coordinated with the world's outer time and space. The brain can align and integrate its own inner time and space to the world's outer time and space. For instance, when we listen to music and move our legs and arms automatically in synchronization with the beat of the music, such entrainment has been described as temporospatial alignment, which is central for consciousness (Northoff & Huang, 2017). Conceived on a more conceptual level, temporospatial alignment allows the brain's inner time and space to integrate within and become part of the world's ongoing outer time and space. Since temporospatial alignment allows for spatiotemporal integration of the brain within the world, I speak of the world–brain relation (see Northoff, 2018, for more philosophical details). If, in contrast, the brain were integrating within the world, with the latter becoming part of the former, one would speak of the brain–world relation (Northoff, 2018).

Let us conceive of the spatiotemporal nature of the world–brain relation in more detail. The different spatiotemporal scales or ranges of world and brain are linked and integrated in their relation. Specifically, the smaller spatiotemporal scale or range of the brain is aligned and thus related to the much larger one of the world: the former (i.e., the brain) is thereby nested within the latter (i.e., the world). We can therefore describe the world–brain relation using the term "spatiotemporal nestedness." In the same way that, in a set of Russian nesting dolls, the smaller doll is nested within the next larger one, the brain is nested within the world.

How are different (i.e., larger and smaller) spatiotemporal scales related to each other? We saw in the case of the brain's spontaneous activity that, purely empirically, the phase (i.e., cycles of slower frequencies) is coupled to and thus contains or nests the amplitude of faster frequencies—this is described as cross-frequency coupling (Northoff & Huang, 2017). Taking the different frequencies together results in an elaborate temporal structure where slower frequencies contain or form a nest for the next faster one and so on—one can thus speak of a "slow–fast nestedness" or, better, "spatiotemporal nestedness" (see later), which indicates a certain directedness, that is, from slow to fast, in the brain's spontaneous activity.

I now assume an analogous slow–fast nestedness for spatiotemporal nestedness in the relation between world and brain (see later for details). The world's slower frequencies nest and contain the brain's faster frequencies—taken in purely spatiotemporal terms, the brain is thus nested and contained within the world. This is yet another reason I speak of the world–brain relation rather than the brain–world relation (see later).

World–Brain Relation and Mental Health

The concept of spatiotemporal nestedness can be understood in a purely neuronal sense remaining within the limits of the brain. It then describes how the smaller spatiotemporal scale or range of single stimuli or tasks is integrated, that is, nested, within the relatively larger spatiotemporal scale or range of the brain's spontaneous activity. Taken in this sense, spatiotemporal nestedness must be understood in a purely neuronal sense as confined to the boundaries of the brain.

I here extend the use of the same concept beyond the boundaries of the brain to the brain's relationship with the world. Spatiotemporal nestedness is now no longer purely neuronal, but neuroecological, referring to the neuroecological continuum between world and brain. That very same neuroecological continuum consists in the degree to which different spatiotemporal scales or ranges are linked and integrated and thus nested within each other: the better the brain's smaller spatiotemporal scale is integrated and thus nested within the much larger one of the world, the more continuous the neuroecological continuum is (Figure 4.4).

While being sketched as primarily conceptual (and ontological; Northoff, 2018), the world–brain relation carries major clinical implications. Schizophrenic patients, for instance, suffer from disruption in their world–brain relation—this can be measured by lack of synchronization (as mediated by what can be measured as phase locking or entrainment) of their brain's neural activity with the temporal structure of their respective environment context. The brain's ability to synchronize with its environmental context and thus constitute a world–brain relation may be central when subjects change cultural context. If, for instance, subjects move from east to west while at the same time being prone to labile or unstable synchronization of their brain's neural activity with its novel environmental context, the risk for psychosis among these immigrants may increase. That remains speculative at this point, though, requiring specific empirical testing.

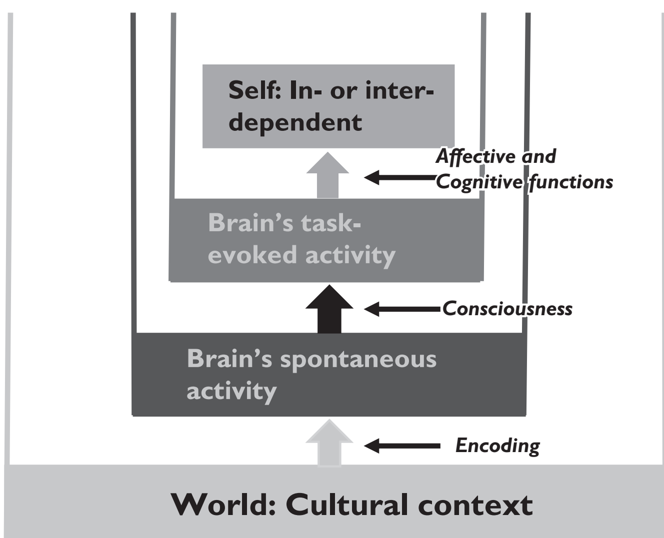

Figure 4.4. Spatiotemporal nestedness of self and brain within the world and its cultural context.

What this example makes clear is that the world–brain relation, despite being a novel and abstract concept, carries major implications for our understanding of the brain's relation to the world and mental health. Especially, the world–brain relation opens the door for a more comprehensive and extended understanding of the spatiotemporal and neuroecological nature of psychopathological symptoms. Psychopathological symptoms, as in schizophrenia and depression, can be conceived as spatiotemporal alterations of the brain's spontaneous activity and its spatiotemporal structure—one can therefore also speak of "spatiotemporal psychopathology" (Northoff, 2016, 2017). Importantly, as the spontaneous activity's spatiotemporal structure extends beyond the brain's boundaries to the respective environmental context, psychopathological symptoms are not only spatiotemporal but also neuroecological (rather than merely neuronal). As culture provides and is part of specific ecological contexts, the neuroecological characterization of psychopathological symptoms is well in line with the cultural effects on mental health (see Scott, "The Cross-National Epidemiology of Mental Health Disorders," this volume).

Embrainment and Enculturation: Brain and Self

How does the spatiotemporal nestedness of the brain within the world stand in relation to the concepts of embrainment and enculturation? Let us briefly define the concepts of embrainment and enculturation.

Briefly, taken in a standard way, the concept of embrainment denotes the encoding of social and cultural contexts by the brain's neuronal activity. Embrainment in this sense, for instance, is manifested in the neuronal differences related to the independent versus the interdependent self (Han & Ma, 2016; Han & Northoff, 2009; Han et al., 2013), while enculturation denotes how the neuronal activity of the brain and its respectively associated sensory, motor, affective, and cognitive functions are shaped and constituted by the respective cultural contexts.

Such enculturation is, for instance, investigated in cultural neuroscience, which shows that the neuronal activity underlying various cognitive and affective functions is strongly dependent upon the respective cultural context (Han & Ma, 2016; Han & Northoff, 2008, 2009). Related concepts used in the literature are "culture–brain nexus," "neuroculture interaction," and "encultured brain" (see Northoff, 2016, for details), which, ultimately, can be traced to the long-standing debate between nature versus nurture and tries to overcome this distinction.

Embrainment and Enculturation: Self-Similarity of Culture and Brain

How can we now shed further light on the concepts of embrainment and enculturation? Given the brain's strategy for encoding its spontaneous activity, embrainment must be considered scale-free; that is, it operates across different time (and spatial) scales. This is especially relevant in cultural neuroscience. Cultural traditions and values have been shaped over thousands of years, thus requiring a rather long-time scale. They are nevertheless entirely present at each moment of time, as, for instance, in our present life span. Importantly, we assume that cultural values are present across time in a more or less self-similar and thus temporally nested way, given that scale-free properties and their spatiotemporal nestedness are ubiquitous in nature and culture and thus in the world in general (He et al., 2010).

This is the moment where cultural context and brain with its spontaneous activity converge. The empirical data, as described earlier, show that the brain, being part of the world, is also characterized by scale-free properties and spatiotemporal nestedness (and consequently our self is too).

Culture and brain may thus be connected intrinsically with each other in terms of self-similarity as manifested in spatiotemporal nestedness, which then accounts for what is described as embrainment. Embrainment of cultural values may thus first and foremost be manifested in the brain's spontaneous activity, which, in a second step, serves as the basis for affective and cognitive functions. Since the spontaneous activity encodes cultural values in a spatiotemporal and self-similar way, the subsequent affective and cognitive function, being based on the spontaneous activity, are affected and shaped by the cultural values in an almost automatic way, that is, by default.

Embrainment and Enculturation: Convergence and Intertwining

What does this imply for the determination of the relationship between embrainment and enculturation? I propose that embrainment and enculturation are necessarily connected with each other. The empirical data suggest that embrainment, the impact of the brain on culture, is closely coupled with enculturation, which describes the impact of culture on the brain's neuronal activity. Why is there such an intrinsic or necessary connection between embrainment and enculturation? The data show that our brain and its spontaneous activity are spatiotemporally nested within the respective cultural context and thus the world. Due to such spatiotemporal nestedness, world/culture and brain are necessarily connected with each other, which I described as the world–brain relation in previous works (Northoff, 2016, 2018).

Such necessary connection between world/culture and brain, that is, the world–brain relation, in turn, makes possible a bidirectional relationship between world/culture and brain—that is, from world/culture to brain (i.e., enculturation), and from brain to world (i.e., embrainment). Therefore, embrainment does not happen without enculturation and related affective and cognitive functions. Conversely, enculturation cannot occur without embrainment and associated affective and cognitive functions. Embrainment and enculturation are thus distinct aspects of one and the same underlying process, the world–brain relation, which, ultimately, can be traced to the self as relational self and its underlying self-related processing.

Embrainment/Enculturation and Our Mental Life

Embrainment and Enculturation of Self and Music

Such view of embrainment carries major empirical and conceptual implications. Let us start with the empirical implications.

Empirically, we may want to investigate the impact of different cultural contexts on the brain's spontaneous activity with the various kinds of temporal (and spatial) measures. One would, for instance, expect that the scale-free properties of spontaneous activity would differ between Eastern and Western cultural contexts, which, psychologically, may be closely related to the self and, more specifically, its degrees of independence versus interdependence. Given that our previous findings show Western subjects' self-consciousness to be predicted by their spontaneous activity's scale-free properties (Huang et al., 2016; Wolff et al., 2019), one would expect the same to occur in Eastern subjects. Moreover, given the presently assumed spatiotemporal nestedness between culture/world and brain (i.e., world–brain relation), one would expect that the degree of scale-free properties (i.e., the exact shape of the power law curve in the power spectrum in the CMS) would differ between Eastern and Western subjects' sense of self (i.e., self-consciousness). Such investigation remains to be done, however.

Yet another empirical example is music, as thematized in the cultural distance hypothesis (CDH) by Demorest and Morrison (2016). The CDH claims that "the degree to which the music of any two cultures differ in the statistical patterns of pitch and rhythm will predict how well a person from one of the cultures can process the music of the other" (Demorest & Morrison, 2016, p. 189). As pointed out previously, scale-free activity and thus self-similarity and spatiotemporal nestedness are stochastically based, which puts them on the same basis as the CDH, which presupposes music to be stochastically based, as it is further supported by its scale-free properties (He et al., 2010). One may consequently assume that the cultural differences in affective and cognitive recruitment and associated neural activity during music may be based on differences in the spontaneous activity's scale-free properties.

Specifically, we expect that the scale-free properties of spontaneous activity are more closely matched with the scale-free properties of the music in the respective cultural context: the more similar the scale-free properties are between the brain's spontaneous activity and music, the better the music will be processed, the more the music will be perceived as self-related, and the more affective and cognitive functions will be recruited. If, in contrast, there is a difference or distance in the scale-free properties between music and the brain, the person may not perceive the music as self-related but strange and non-self-related, and consequently not recruit affective and cognitive functions to the same degree. Accordingly, what Demorest and Morrison (2016) describe as "cultural distance" with respect to music may ultimately be traced down to the degree of statistically and scale-free matching between music and the brain's spontaneous activity, that is, their statistically based scale-free distance or difference.

Concept of Self: Relational and Spatiotemporal

We started the chapter with the concept of self. What does embrainment and enculturation imply for our concept of self? First and foremost, the presence of embrainment and enculturation means that we cannot consider the self to be independent of its respective social and cultural context. The self is thus based on and shaped by the interaction between culture and brain, which we determined to be spatiotemporal, stochastic, and scale-free. If so, the concept of self itself may be described in these terms, that is, as spatiotemporal, stochastic, and scale-free.

The spatiotemporal, stochastic, and scale-free nature of the self situates it neatly between culture (i.e., world) and brain. Importantly, the spatiotemporal, stochastic, and scale-free features constitute or construct a spatiotemporal structure or organization that virtually spans the divides between world, body, and brain. Conceptually, the self may thus be considered a virtual spatiotemporal structure—the self concerns the virtual, that is, spatiotemporal, scale-free, and stochastic, relation between world and brain. Being intrinsically relational, the self signifies the presence of that relation across time and thus its temporal continuity. That is well compatible with the self being closely related to personal identity that describes the temporal continuity of the self across time—temporal continuity of the spatiotemporal, scale-free, and stochastic and culturally sensitive world–brain relation may thus transform on the mental level into the temporal continuity of our self and its personal identity.

Why and how is the relational characterization of the self in this sense relevant for cultural neuroscience? The two culturally differing concepts of self, that is interdependent versus independent self, may be regarded as two possible constellations of the relational self as virtually spanning between world and brain. Independent and interdependent self may thus be two manifestations of one and the same underlying relation (i.e., world–brain relation) that may vary according to the respective cultural context.

This carries major empirical implications. Taken in such a sense, independent and interdependent selves should be characterized by different forms and degrees of spatiotemporal nestedness, which should be manifested in different scale-free properties of the brain's spontaneous activity. The interdependent self is more dependent upon its respective cultural and social context. One would expect the interdependent self to be strongly coupled to those larger and slower-frequency spectra of the respective cultural and social context.

The independent self, in contrast, is more focused on its self and, put empirically, its own frequencies and less on those of its respective cultural and social context. Now, the very slow frequencies of the brain may be not as much needed anymore so that the power is more shifted toward the faster frequencies within the brain. One would consequently expect a less steep power spectrum with lower degrees of scale-free activity in the brain's spontaneous activity in Western subjects that show a strong independent (rather than interdependent) self.

Finally, there are also ethical considerations to consider. There are novel stimulation techniques like deep brain stimulation (DBS) and transcranial magnetic stimulation (TMS) for modulating remedying an altered sense of self (Northoff, 2017). These techniques supposedly modulate the spontaneous activity's spatiotemporal structure and subsequently its encoded information related to the self. However, purely neuronal intervention may be insufficient if the corresponding environmental or cultural context is not properly adapted. Put in a more abstract way, the therapy of the self should not be purely neuronal but better neuroecologically or, more specifically, neuroculturally.

Accordingly, a neurocultural therapy is ethically more proper and appropriate than a purely neuronal therapy as the latter disregards the neuroecological nature of our brain. That also implies that, depending on the respective cultural contexts, one and the same neuronal intervention like DBS or TMS may be applied in different frequency ranges to match the spatiotemporal features of both brain and cultural context. Neuronal or biological intervention may thus be culturally specified and tailored in the same way that we need to strive for individualization of the degree or strength of TMS and/or DBS. Such neurocultural tailoring of biological or neuronal intervention remains speculative at this point, however.

Conclusion

We have discussed the mechanisms of embrainment and enculturation for which we took the self as a paradigmatic example. The self is the basis of our mental health. Different concepts of self in different cultures strongly determine subjects' mental health in different cultures. Moving one's own culturally embedded self into a different culture that portrays and lives a different concept of self can especially impact the subject's mental health, leading to the often-described experience of anomie. To support such cultural appropriations of self, we need to better understand how the self is embrained and which mechanisms are underlying such embrainment of self.

Based on various empirical data, I here suggest spatiotemporal, scale-free, and stochastic embrainment of culture into the brain and, more specifically, its spontaneous activity as featured by its spatiotemporal structure and organization. Such embrainment, in turn, constitutes our self, which therefore, conceptually, can be described as relational, spatiotemporal, scale-free, and stochastic. As our spontaneous activity provides the basis for subsequent affective and cognitive functions, the latter cannot avoid being culturally shaped (i.e., enculturation).

Hence, embrainment and enculturation are two distinct features of one and the same underlying process, the self as relational or social self as mediated by self-related processing. Most importantly, the empirical data show that such intrinsic coupling between embrainment and enculturation (in the gestalt of the self as relational self) occurs by default, as our brain's spontaneous activity is very much tuned to encode its own relationship to its respective cultural and social context. We and our selves are, thus, embrained and encultured by default.

The default character of embrainment and enculturation renders it rather likely that there is a genetic basis for the way the spontaneous activity can develop and construct its spatiotemporal structure (see Greenfield and Vasquez-Salgado, "Sociocultural Developmental Neuroscience," this volume). In that case, one would assume that, for instance, the manifestations of embrainment and enculturation in the spontaneous activity's spatiotemporal structure are inherited between generations. One would then quasi inherit a certain cultural imprinting in one's brain and its spatiotemporal structure from the parents—that could account for intergenerational trauma. Like intrasubject trauma (see Duncan et al., 2015), intergenerational trauma may then be encoded in a spatiotemporal way into the brain's spontaneous activity. The difference between intrasubject and intergenerational trauma would then consist only in the time scale while they would share their spatiotemporal character. This remains rather speculative at this point, though.

The relational and spatiotemporal embrainment of self carries major implications not only for our understanding of the brain in general but also for mental features and their intrinsic cultural dependence. This suggests future empirical investigation as stated in various hypotheses. Moreover, as our self is central for our mental health, its investigation may shed a novel light on global mental health in an age where people including their selves move across the globe—this probes the spontaneous activity's plasticity of its spatiotemporal structure in response to changing cultural contexts (see Goh, "Acculturation by Plasticity and Stability in Neural Processes: Considerations for Global Mental Health," this volume).

We may need to analyze the spatiotemporal features (e.g., spatiotemporal stochastics) of cultural contexts and link them to the subjects' brains with their spontaneous activity's spatiotemporal structure. If cultural adaptation problems occur, resulting in mental health issues (see Scott, "The Cross-National Epidemiology of Mental Health Disorders," this volume), one would expect major misfit or mismatch between the spatiotemporal features of cultural context and the brain's spontaneous activity. These stochastic misfits or mismatches may then be treated by specific training as in music therapy or brain stimulation in an individualized and context-specific way. Accordingly, the here-suggested approach opens the door for the development of completely novel approaches for both prevention and treatment, for example, spatiotemporal intervention or therapy that is intrinsically neurocultural (rather than either exclusively neuronal or cultural). That will also enable us to screen subjects with their brain's spontaneous activity and its scale-free property to detect risk factors of difficulties in cultural adaptation and appropriation of their self to the novel cultural context.

Open Questions and Knowledge Gaps

- Is the self primarily spatiotemporal rather than cognitive?
- Is our brain adapted to and does it integrate culture primarily in a spatiotemporal rather than an affective or cognitive way?

- How can we define and investigate the spontaneous activity's spatiotemporal structure in a more specific and detailed way—what kind of measures do we need to specifically account for the structure and relation?
- How can we better define and operationalize the neuroecological and neurocultural mechanisms as implied by the world–brain relation? This is necessary not only on a conceptual level but also on a more empirical level as mental disorders can be characterized by disruptions in the neuroecological and neurocultural nature of their mental functions, such as sense of self and consciousness.
- What kind of neurocultural therapies with coordination between neuronal and cultural interventions can we develop in the future to better treat mental disorders? This chapter suggests that such neurocultural coordination must be spatiotemporal, but the details of this remain unclear at this point in time.

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