becomes aware that specific contents are related to his or her own self. By contrast, self-related processing describes the basic relation between stimulus and organism independent of the person's awareness of whether the associated content of the stimulus is related to his or her self (or not).

Is this a purely conceptual issue? Let me describe what happens when an intero- or exteroceptive stimulus approaches the brain. The stimulus encounters the resting-state activity of the brain, with the rest–stimulus interaction determining the degree to which the stimulus becomes related to the neural activity of the brain [4]; therefore, a better might be brain-relatedness rather than self-relatedness. The degree of self- or brain-relatedness of a stimulus might in turn determine its processing in subsequent homeostatic, sensorimotor, affective and cognitive functions (Figure 1) [5,6]. This scenario is supported not only by results from recent investigations in healthy subjects [7,8], but also by observations in psychiatric disorders such as schizophrenia [9] and depression [10] in which resting-state abnormalities are associated with an abnormal self and disturbed subjectivity.

Self-related processing in this sense (i.e. as brain-relatedness) can no longer be characterized by specific functions and their respective contents, be they homeostatic, sensorimotor, affective or cognitive. Instead, self- or brain-related processing is better described as neural code, the formal mechanism whereby the relationship between brain and stimulus is realized in the neural activity of the brain. The focus here is on the type of neuronal coding and on neuronal processes such as rest–rest and rest–stimulus interactions. (It should be noted that the term process is understood here as purely neuronal process pertaining only to changes in brain neuronal activity during rest–rest, rest–stimulus and stimulus–rest interaction, independent of any psychological processes and functions associated with these purely neuronal processes.) This might be characterized as a code- and process-based approach to the brain rather than as the function- or content- and region-based approach presupposed by Christoff *et al.*

How should subjectivity be defined? Christoff *et al.* and many others associate subjectivity with the first-person perspective (FPP) as distinguished from objectivity in the third-person perspective (TPP). Neural coding of rest–stimulus interaction in terms of self- or brain-relatedness might imply a more basic sense of subjectivity that is manifest before any homeostatic, sensorimotor, affective and cognitive functions, including their subsequent distinction between FPP and TPP. Such a more basic sense of subjectivity might come close to what the German philosopher Kant had in mind when arguing that we remain principally unable to access and know ourselves and the world independent of ourselves (e.g. our brain) and to consecutively obtain objective knowledge (in an absolute sense).

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Letters Response

Clarifying the self: Response to Northoff

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Northoff [1] raises three issues in response to our article [2]: (i) how to define self-related processing; (ii) the relation between self-related processing and brain activity; and (iii) the nature of subjectivity.

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Conceptual issues

We define self-related processing as 'processing requiring one to evaluate or judge some feature in relation to one's perceptual image or mental concept of oneself' [2]. This definition is based on the widespread experimental paradigm that requires subjects to assess specific stimuli in

relation to their perceptual or cognitive representations of self, and follows established usage in psychology, ethology and cognitive neuroscience (see [3] for a review). By contrast, Northoff calls such processing 'self-referential processing' and uses 'self-related processing' to refer to processing of any stimulus in relation to the organism independent of the person's awareness of the content of the stimulus as self-related or not.

From our perspective, this usage seems unhelpful. The crucial distinction is between (i) processes that relate stimuli to a representation of the self as a perceptual or cognitive object (the 'Me'), regardless of whether those processes or representations are conscious or not ('self-related processing'); and (ii) processes that implicitly specify the self as subject and agent (the 'I') by implementing a self/non-self distinction in the ongoing interactions between the organism and its environment ('self-specifying processes') [4]. We also distinguish between 'self-related' features and features that are 'self-specific' in the strict sense of being exclusive and essential to the self as agent [4]. For example, my facial features as recognized in a mirror count as self-related but not self-specific: they are neither exclusive (my identical twin shares the same features) nor essential (changing them does not necessarily alter me as a perceptual subject and agent). By contrast, my subjective perspective in perception, action, cognition and emotion is self-specific because it is exclusive to me and changing it entails changing me as subject and agent. Northoff's terminology does not capture these crucial distinctions and thus does not demarcate the aspects of self we are concerned to address and explain.

Ongoing brain activity

Having defined 'self-related processing' as the processing of any stimulus in relation to the organism construed as the self, Northoff then speaks of 'brain-relatedness' to refer to the degree to which a stimulus becomes related to the brain's 'resting state activity'. We believe this conflates both ongoing brain activity with the resting state and the brain with the self, while also misinterpreting our viewpoint.

A wide variety of evidence indicates that the way a stimulus is processed depends crucially on how it is integrated into the context of the brain's ongoing activity ('intrinsic' or 'spontaneous' activity) [5,6]. Our model of self-specifying processes embraces this evidence. For example, intrinsic neuronal activity (e.g. synchronous oscillations) arising far from the sensors and effectors strongly shapes the dynamics of self-specifying processes in sensorimotor integration by creating predictions about forthcoming sensory events [7,8]. On the one hand, such ongoing activity occurs during both attention-demanding tasks (whether externally or internally oriented) and the resting state (when subjects have no particular task to perform). On the other hand, the resting state remains poorly characterized in relation to self-experience, because various types of self-related processing and self-specifying processes can co-occur in the resting state, from mental time travel to regulating one's emotions in the claustrophobic scanner environment.

Northoff collapses the conceptual distinction between the brain and the self when he replaces 'self-relatedness' with 'brain-relatedness'. This begs the question of how to characterize self-experience in relation to brain processes. We maintain that the concept of 'self' applies to the organism, not the brain *per se*. Our proposal focuses on a specific type of physiological process, efferent–reafferent coupling, which, we argue, can implement self-specifying processes that distinguish the self as agent from non-self at the level of the organism in relation to its environment. By describing how such efferent–reafferent loops can be implemented at multiple levels of the nervous system, we postulate that self-specifying processes occur throughout the brain. We thus provide a clear and testable proposal for relating the conceptually distinct levels of the self and the brain.

Northoff misinterprets our proposal when he describes it as a function/content- and region-based approach rather than a code- and process-based one. Our proposal is that the neural coding of signals as exafferent versus efferent is crucial for establishing a self/non-self distinction. We do not map self versus non-self contents onto brain regions; instead, we show, first, how such neural coding can establish efferent–reafferent loops at multiple neurophysiological levels, and second how such loops can support the sense of self as agent at the level of the whole organism in perception, action, cognition and emotion.

Subjectivity

Finally, we do not associate subjectivity with the first-person perspective and objectivity with the third-person perspective. This conceptualization appears nowhere in our article. On the contrary, as a cognitive process, taking a third-person perspective presupposes subjectivity in the form of the self-experience of being a cognitive agent. Rather, we relate subjectivity to the self-experience of being a knower and agent, and we make the point that subjectivity thus understood is self-specific. Northoff's 'more basic sense of subjectivity' seems obscure, both conceptually and in relation to brain activity. Instead of Kant's noumenal self, we would invoke Husserl's concept of the self as a 'lived body' as a more fruitful notion that can bridge phenomenology, neuroscience and embodied cognitive science [9].

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