Immanuel Kant's mind and the brain's resting state

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The early philosopher Immanuel Kant suggested that the mind's intrinsic features are intimately linked to the extrinsic stimuli of the environment it processes. Currently, the field faces an analogous problem with regard to the brain. Kant's ideas may provide novel insights into how the brain's intrinsic features must be so that they can be linked to the neural processing of extrinsic stimuli to enable the latter's association with consciousness and self.

Kant's view of the mind

The philosopher René Descartes assumed mental properties intrinsic to the mind to be distinct from the physical features of body and brain. This was countered by the Scottish philosopher David Hume, who opposed such intrinsic mental properties. Instead, Hume advocated an extrinsic view of the mind, believing that mental activity can be entirely traced back to the extrinsic features of stimuli in the world [1]. His German successor, Immanuel Kant, combined both intrinsic and extrinsic views of the mind: he claimed that consciousness and self must be considered a hybrid of processes that result from an interaction between the mind's intrinsic features and the world's extrinsic stimuli.

In order to reveal the nature of such intrinsic-extrinsic interactions, Kant attributed various faculties (i.e., intrinsic features) to the mind, primarily described in his *Critique of Pure Reason* [2]. The mind's intrinsic features included unity of consciousness, self as 'I think', and various templates of spatiotemporal continuity (which were subsumed under the umbrella term 'categories'). According to Kant, the mind uses its intrinsic features to structure and organise the effects of extrinsic stimuli. This, in turn, allows the latter to become associated with consciousness, self, and spatiotemporal continuity. Hence, consciousness, self, and spatiotemporal continuity are based on the interaction between the mind's intrinsic features and the environment's extrinsic stimuli.

Extrinsic and intrinsic views of the brain

Charles Sherrington, the British neurologist working at the beginning of the 20th century, considered the brain to be a mere passive sensorimotor reflex apparatus [3]. In his view, extrinsic stimuli from the environment trigger neural activity in pathways that result in sensorimotor reflexes. This extrinsic view of the brain has been challenged by authors such as Graham Brown, Karl Lashley, and Rodolfo Llinas, based on the observation of intrinsically generated activity in the brain [3]. The recent discovery of high resting-state activity in a particular set of brain regions, the default-mode network (DMN), has once again raised the argument for an intrinsic view of the brain's neural activity [3]. Since its initial description, the functions of the DMN have been debated and associated with the self [4] and consciousness [5,6]. However, the exact features of resting state activity in the brain and how it yields functions such as consciousness and self remain unclear.

How does the intrinsic resting state activity of the brain interact with the extrinsic stimuli from the outside world? The relevance of such rest-stimulus interaction is supported by recent findings showing that the level of pre-stimulus resting-state activity predicts the neural, phenomenal, and behavioural effects of subsequent stimuli [7,8] (Figure 1).

What remain unclear, however, are the exact neuronal features of the resting state itself that make possible such rest-stimulus interaction. These neuronal features must be intrinsic to the resting state itself, while at the same time they must be able to create the tendency (i.e., neural predisposition) to associate stimulus-induced activity with consciousness and self.

Hence, in order to better understand observations during rest-stimulus interaction, we may need to achieve a better understanding of the resting state's intrinsic features. Additionally, we must learn how they predispose rest-stimulus interaction in such a way that the stimulus becomes associated with consciousness and self. We may thus need to develop an intrinsic-extrinsic interaction model with regard to the brain.

Kant and the brain

Kant's view of the mind's intrinsic features has often been interpreted within a predominantly cognitive context. Philosophers, such as Brook [9], as well as neuroscientists, such as Palmer [10] and Zeki [11], associate higher-order cognitive functions with Kant's intrinsic features of the mind. This is in line with predominantly cognitive and reflective characterizations of consciousness (as, for instance, 'access consciousness'[12]) and self [4].

However, this still leaves open the question of mechanisms for the most basic forms of consciousness (i.e., phenomenal consciousness [6,12]), self (i.e., a pre-reflective sense of self [4,13]), and spatiotemporal continuity [10,13]. These basic forms of consciousness and self may be closely related to how the intrinsic features of the resting state interact with extrinsic stimuli. The exact neuronal mechanisms of such rest-stimulus interaction remain unclear, however [7,8,13]. This is where Kant's view of the mind may become useful.

What Kant described as the mind's intrinsic features, providing order and regularity to the extrinsic stimuli from

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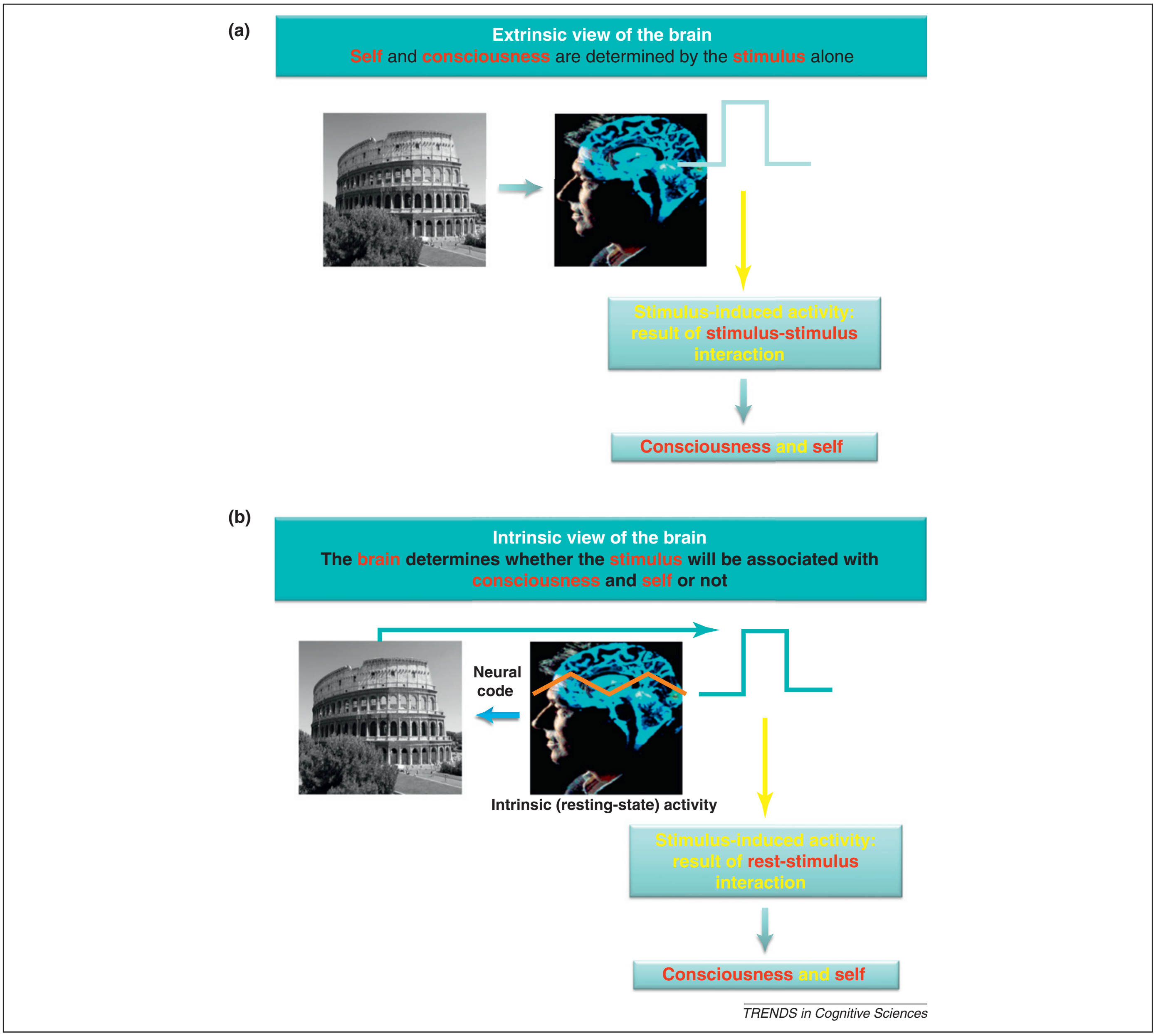

Figure 1. The figure illustrates schematically two different views of the brain, extrinsic and intrinsic, and how they relate to consciousness and self. **(a)** Extrinsic view of the brain. The extrinsic view assumes that all neural activity in the brain is induced by and is related to stimuli external to the brain [that is, extrinsic, from either the body (interoceptive) or the environment (exteroceptive)]. What neuroscientists observe as stimulus-induced activity can be completely and exclusively traced back to the stimulus itself. Consciousness and self are then associated with different forms and/or specific degrees of stimulus-induced activity in the same or different regions. **(b)** Intrinsic view of the brain. In this case, the brain shows neural activity generated by itself, independently of the stimulus it encounters. This spontaneous or intrinsic activity is described in operational terms as resting-state activity. What neuroscientists observe as stimulus-induced activity is a mixture of both the brain's intrinsic activity and the neural activity changes related to the stimulus. Consciousness and self are consequently assumed to be predisposed by the brain's intrinsic activity (i.e., resting state activity) and become manifest during the resting state's modulation by extrinsic stimuli from body and environment.

the world, could be attributed to the brain's resting state and its intrinsic features. More specifically, the brain's resting-state activity may structure and organise stimulus-induced activity in such a way that the latter can be associated with consciousness, self, and spatiotemporal continuity [13]. Hence, the brain itself, the resting state's intrinsic features, may provide an input yet to be explored specifically in relation to the neural processing of extrinsic stimuli.

Kant's account of the mind's intrinsic-extrinsic interaction may provide some clues about the kind of intrinsic features within the brain's resting state activity and how they interact with the extrinsic stimuli from the world. We may thus want to search for those intrinsic features that predispose the brain to associate consciousness, self, and spatiotemporal continuity with the extrinsic stimuli during subsequent rest-stimulus interactions.

Self and rest

Let us discuss the example of self. Several imaging studies that use personally relevant or self-specific stimuli have been conducted. In these studies, subjects viewed stimuli that were closely related to themselves, such as a piano for a concert pianist. These self-specific stimuli were compared to non-self-specific ones (being unrelated to the person). Most of these studies observed strong activity in anterior and posterior midline regions, such as the cingulate (peri- and supra-genual anterior and posterior) cortex, ventro- and dorso-medial prefrontal cortex (VMPFC, DMPFC), the precuneus, and the retrosplenium [4].

These cortical midline structures (CMS) are core regions of the default-mode network (DMN), which shows particularly high neural activity in the resting state. Since CMS are implicated in the processing of self-specific stimuli, their neural activity may strongly overlap with the high resting-state activity observed in these same regions. This appears indeed to be the case as several studies have demonstrated (at least at the macroscopic level [4,14]).

What does this neural overlap between self and rest imply for the resting state? These findings suggest that there is some kind of, yet unclear, matching process between the neural activity associated with extrinsic stimuli and that associated with the resting state. This match seems to be almost perfect in the case of stimuli that are personally relevant, that is, highly self-specific. Self-specificity thus seems to be encoded (or represented as philosophers may want to say) in the resting state's neural activity. In short, resting state activity may be organised and structured in a self-specific way.

The resting state's self-specific organisation may be imposed upon the stimulus during subsequent rest-stimulus interaction. Depending on the degree of match between stimulus and resting state, the latter's self-specific organisation is assigned to the stimulus in different degrees. In other words, the better rest and stimulus match, the higher the degree to which the resting state's self-specific organisation is imposed upon the stimulus; the higher the latter's degree of self-specificity; and the lower the degree of activity change (i.e., deviation from the resting state).

The assumption of the resting state's self-specific organisation may explain the above described findings on the linkage between self and rest. And it may, for instance, also account for the recently observed neural overlap between resting state activity, social cognition, and emotional processing, especially in anterior subcortical and cortical midline structures [15]. Social cognition and emotional processing are closely related to self-relatedness: the more they are relevant for the respective person and thus self-related, the stronger the respective social cognition and emotional processing [4,13]. This link to self-relatedness may be mediated by the recruitment of regions with high resting-state activity such as the midline structures. The latter's self-specific organisation enables them to associate social cognition and emotional processing with the self of the respective person, thereby providing a common reference for both (and other) functions.

How, though, is this related to Kant's intrinsic-extrinsic interaction model? The degree of self-specificity of the stimulus may depend not only on the stimulus itself but also on the resting state, that is, its structure and organisation. The resting state's self-specific organisation may be regarded an intrinsic feature of the resting state itself. This intrinsic feature structures and organises the neural processing of extrinsic stimuli such that the latter are assigned self-specificity and are ultimately experienced as part of one's self. Hence, what we observe as the final result, the different degrees of both self-specificity and stimulus-induced activity, may be traced back to different forms of interaction between intrinsic resting state and extrinsic stimuli.

Box 1. How Kant's 'I think' and 'unity' can inform neuroscientific research on consciousness

Kant characterized the mind by 'I think' and 'unity' as intrinsic (i.e., transcendental) features of the mind and distinguished them from mere extrinsic (i.e., empirical) stimuli. How can Kant's transcendental view of the mind inform the neuroscientific investigation of consciousness?

The concept of 'I think' entails that any cognition of extrinsic stimuli must be accompanied by the 'I' (i.e., the self) and its thinking activity. Why is that necessary? This is where neuroscience can shed light on Kant's thought. If the resting state is indeed organized in a self-specific way (see main text), no extrinsic stimulus can 'avoid' the encounter with the resting state, that is, rest-stimulus interaction and its association with the self. But how can Kant help neuroscientific investigation? Kant deemed 'I think' to be essential for consciousness: we cannot be conscious without the mind's accompanying 'I think'. If 'I think' is indeed related to resting-state activity, it may help decipher the neuronal features of the resting state and its role in consciousness.

Current neuroscientific research focuses mainly on stimulus-induced activity, which is supposed to be sufficient for consciousness, the neural correlate of consciousness (NCC) [6]. This, however, neglects one central feature, 'I think' and, in neuronal terms, resting-state activity. Resting state activity itself must contain certain features that are central in constituting consciousness. In the same way that Kant suggested 'I think' to be necessary for consciousness, we may assume the resting state to be necessary for associating stimulus-induced activity with consciousness. The resting state may then be regarded a necessary, non-sufficient condition, a neural predisposition of consciousness (NPC) [13].

What are the features of the resting state that predispose consciousness? Besides 'I think', Kant considered 'unity' (i.e., transcendental unity) to be an intrinsic feature of the mind. Following Kant, one may assume a particular, but as yet unknown, unity of neuronal activity in the resting state to predispose consciousness. Relying on Kant, the neuroscientist Semir Zeki [11], for instance, assumes such unity to be pre-programmed and central in the neural constitution of visual consciousness. According to Kant, such unity must be described as neurotranscendental, as it must be predisposed by the resting state itself and its specific but unknown spatiotemporal organization [13]. This in turn may, for instance, make possible the binding and grouping of different stimuli in consciousness as discussed in the binding problem [13].

Concluding remarks

What can we learn about the brain from Kant's mind? Future work may want to explore the exact neural mechanisms underlying different forms of rest-stimulus interaction. This, however, is possible only if we achieve a better understanding of the neuronal mechanisms underlying the brain's intrinsic activity, its resting state. In order to achieve that, we may draw on Kant's insights about the mind's intrinsic features such as 'I think' and unity (see Box 1). This may allow us to understand better how the brain's resting state activity is structured and organized. And, most importantly, how that predisposes certain kinds of rest-stimulus interaction and, as Kant might say, consciousness and self.

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