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REVIEWS

dynamics of thought [3,10] is still gaining ground, it seems premature to abandon efforts to determine whether there may be a defining feature that can distinguish mind-wandering from other types of thought. There may also be other defining features, such as the 'ease' with which thoughts unfold [11], that have yet to be theoretically and empirically examined in depth..

Ultimately, for a research field to exist, it needs to have a definable focus that separates it from other fields. If we are unable to arrive at a definition that distinguishes mind-wandering from other types of thought, there is no 'field of mind-wandering research' separable from research on thought in general. Our dynamic framework [6] privileges the lack of strong constraints on thought as a necessary feature of mind-wandering. This approach is certainly incomplete and open for debate; the family-resemblances view, however, seeks to eliminate such debates, seeing them as "unproductive disagreement about 'mind-wandering' definitions." [1]. In contrast, we believe that determining what features of thought are essential for mind-wandering is crucial for the viability of the field itself. If we cannot achieve that, it is only a matter of time until people outside the field come to realize that, after all, the mind-wandering emperor really has no clothes.

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Letter

The Family-Resemblances Framework for Mind-Wandering Remains Well Clad

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Christoff *et al*. [1] reject our family-resemblances framework for mind-wandering research [2] and instead seek to characterize mind-wandering with a necessary defining feature. As an example, they point to their 'dynamic framework' [3] that defines mind-wandering as thoughts that 'proceed in a relatively free, unconstrained fashion.' We outline three primary points of disagreement with their commentary and two points of clarification on the family-resemblances framework.

Disagreements with Christoff *et al*.

(i) It is a false dichotomy (and an ignoratio elenchi) that researchers either adopt an exclusive 'scientific' definition of mind-wandering, or refrain from doing so and proceed unscientifically. Allowing for only two alternatives in defining mind-wandering ignores the third (scientific) alternative we proposed: Mind-wandering is a cluster concept with a probabilistic rather than a definitional structure, where membership is graded along multiple dimensions and some exemplars are more prototypical than others. It is similarly problematic to argue that, absent a single, agreed-upon definition, an identifiable field of mind-wandering research cannot exist. Despite the current, and historical, lack of consensus for a mind-wandering definition, the field's existence has not been questioned.

(ii) Christoff *et al*.'s fundamental argument against the family-resemblances framework is that it does not 'distinguish mind-wandering from other types of thought.' Rejecting our framework on this basis, they point to their dynamic framework as an example of a definition approach (with 'essential, defining' features) that separates mind-wandering from other thoughts. However, it would appear that their dynamic framework actually fails their own requirement: A 'relative lack of constraint' is insufficiently

Box 1. The Dynamic Framework Does Not Clearly Distinguish Mind-Wandering from Other thoughts

Suppose that people rated their thoughts on a 'thought constraint' scale from 1 (completely unconstrained) to 10 (completely constrained): Would a response of 2 qualify as mind-wandering? Would a response of 9? Christoff *et al*. [3] (see p. 719) argue, 'mind-wandering can be defined as a special case of spontaneous thought that tends to be more-deliberately constrained than dreaming, but less-deliberately constrained than creative thinking and goal-directed thought.' On this view, mind-wandering is (or 'tends to be') separable from other thought types due to its unique level of constraint. However, simply stating that only 'relatively unconstrained' thought qualifies as mind-wandering does not actually distinguish mind-wandering from other thoughts. Doing so requires a clear, digital marker that demarcates the boundary between mind-wandering and other thoughts, but such a marker is absent from the dynamic framework. Moreover, to propose such a marker (e.g., a response of 4 or higher on the 'constraint' scale) requires a reasonable justification for this arbitrary decision. Why should a response of 5 qualify as mind-wandering, but not a response of 4? And, more broadly, why should a response of 5 on a 'constraint' scale define mind-wandering, but not a 5 on a task-relatedness, stimulus-dependence, or intentionality scale? Again, the dynamic framework provides no answer to these critical questions, which are fundamental to definition approaches.

specific to allow one to distinguish mind-wandering from other thoughts (Box 1), just as a relative lack of task-relatedness, stimulus-dependence, or intentionality insufficiently demarcate such a conceptual boundary.

(iii) Even if an unconstrained-thought criterion, or any necessary and/or sufficient defining feature(s), could distinguish mind-wandering from other thoughts, Christoff *et al*.'s proposal overlooks the two critical problems associated with adopting a necessary-features approach: Adopting any exclusive definition of mind-wandering without independent argument is problematic because (i) such a definition excludes numerous thought types that others commonly consider mind-wandering, and (ii) neither logic nor empirical evidence can adjudicate among proposed definitions [2].

First, as with all definition approaches, the dynamic framework requires that other experiences frequently referred to as 'mind-wandering' no longer qualify, as it 'privileges the lack of strong constraints on thought as a necessary feature of mind-wandering.' For instance, even though, in 2016, 94.5% of researchers defined mind-wandering as 'task-unrelated thought' [4], constrained task-unrelated thoughts would not meet the mind-wandering definition and hence could not be considered as mind-wandering. Moreover, in our opinion, adopting the dynamic framework would mean that no previous empirical research on mind-wandering, excepting one article from Christoff's group [4], could directly inform research on the topic because the thoughts under investigation may not have met the necessary 'lack-of-constraint' criterion.

Second, suppose another research group advocated a conflicting definition (e.g., [5–8]). How should a field taking a necessary-features definition approach, which requires one and only one reductive definition, proceed? Christoff *et al*. [1] provide no solution to this fundamental problem, other than suggesting that we leave the issue 'open for debate.' We reiterate that debating arbitrarily generated definitions cannot adjudicate among them (indeed, one might interpret authoritative calls to adopt any exclusive definition to preclude debate). Any promised future 'empirical efforts' will likewise fail to specify an inherently idiosyncratic and arbitrary definition of mind-wandering: The empirical identification and characterization of unconstrained thought no more licenses it as the definition (or the necessary feature) than does the empirical identification and characterization of task-unrelated, stimulus-independent, or unintentional thought. No powerful experimental manipulation, nor any robust correlation with external behavior or with neurocognitive markers, can support or falsify the claim that any one dimension of thought properly or singularly reflects 'mind-wandering'.

Christoff *et al*. [1] do not address either of these crucial problems with definition approaches, both of which prompted us to adopt the family-resemblances framework in the first place. Fortunately, as we argued, an exclusive definition is not required for scientific inquiry into mind-wandering. Researchers can empirically investigate, and propose scientific accounts of, any of its many varieties, from task-unrelated thought to relatively unconstrainted thought (in the same way we can discuss and create 'games' and 'chairs', which lack necessary and sufficient defining features).

Clarifications of Our Framework

(i) We re-emphasize the critical role of protoypicality in the family-resemblances framework. Christoff *et al*. [1] argue that it 'groups together different and sometimes conflicting definitions of mind-wandering.' Not so. Within the family-resemblances framework, concepts do not dissolve into each other but are distinguished by constellations of graded prototypicality. As we previously argued, we can determine which varieties of mind-wandering are more versus less prototypical by polling laypeople and researchers. We might, further, empirically assess which varieties of thought are most frequent, or most frequently co-occur, under commonplace environmental conditions. Scientific fields can thus quantify graded membership in their constructs without 'grouping together' different varieties of mind-wandering.

(ii) Christoff *et al*. [1] suggest that the family-resemblances framework seeks to remedy the problem of grouping different varieties of mind-wandering by

grouping different varieties of mind-wandering. Instead, we argued that by adopting a family-resemblances framework, whereby mind-wandering is a graded, heterogeneous construct, researchers must commit to clearly specifying the dimension(s) of mind-wandering under investigation. Furthermore, we entreated researchers to include in their articles an explanation of how they conceptualized and operationalized mind-wandering. We therefore argued that the field must mindfully distinguish, not lump together, different varieties of mind-wandering, and we provided a method for doing so.

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Spotlight

Using Anesthesia to Reveal the Elements of Consciousness

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General anesthesia provides an invaluable experimental tool to probe the essential neural circuits that underlie consciousness. A new study reports that cholinergic stimulation of the prefrontal cortex restores wake-like behaviors in anesthetized rodents, suggesting that cholinergic inputs to the prefrontal cortex play a fundamental role in modulating consciousness.

The essential neural circuits that generate consciousness are unknown. There are multiple subcortical pathways that promote arousal, but the cortical areas that modulate arousal states are not well understood. In a recently published study, Pal and colleagues [1] reported that cholinergic stimulation of the prefrontal cortex (PFC), but not the parietal cortex, restores wake-like behaviors in rats anesthetized with sevoflurane. The authors also found that noradrenergic stimulation of these areas was insufficient to induce wake-like behaviors under the same anesthetic regimen. These results suggest that cholinergic inputs to the PFC are critically important in regulating levels of consciousness.

In the context of natural sleep, numerous subcortical arousal pathways in the brain have been identified. Cholinergic neurons in the brainstem and basal forebrain, noradrenergic neurons in the locus coeruleus, histaminergic neurons in the tuberomammillary nucleus, and others are known to decrease sleep and increase wakefulness. However, it has become increasingly evident that not all arousal circuits are capable of inducing emergence from the anesthetized state. Dopamine reuptake inhibitors such as methylphenidate and dextroamphetamine, as well as optogenetic stimulation of ventral tegmental area dopamine neurons [2], have been shown to induce wake-like behaviors in anesthetized rodents, while reuptake inhibitors that are selective for norepinephrine are ineffective [3]. The latter finding is consistent with the report by Pal *et al*. that norepinephrine administration in neither the PFC nor parietal cortex promotes wake-like behaviors during sevoflurane anesthesia. While noradrenergic neurotransmission is thought to be important for the transition to wakefulness from natural sleep, noradrenergic stimulation appears insufficient to induce wake-like behaviors during continuous general anesthesia.

Despite the notable lack of behavioral changes, the authors found that noradrenergic stimulation of the PFC and parietal cortex nevertheless produced wake-like changes in the electroencephalogram that were similar to those observed with cholinergic stimulation of the same areas. This result is also consistent with the finding that intravenous administration of a norepinephrine reuptake inhibitor during sevoflurane anesthesia produces wake-like electroencephalogram changes without behavioral changes indicative of wakefulness [3]. This dissociation has important implications for the future design of neurophysiological monitors that utilize the cortical electroencephalogram to determine anesthetic depth in surgical patients.

General anesthetics have been used clinically for more than 170 years, and their molecular sites of action have been largely established. Unconsciousness is the *sine qua non* of general anesthesia, but it is now apparent that different