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Review

Relating mind-blanking to the content and dynamics of spontaneous thinking

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During wakefulness, the stream of thought is occasionally interrupted by moments when we cannot report any content, termed 'mind-blanking' (MB). As MB is a relatively unexplored mental state, we here examine how it relates to spontaneous thinking, namely, thought content and thought dynamics. By reviewing empirical studies on the neural correlates of MB, we first indicate that MB reports are mediated by variations in cortical and physiological arousal levels. In terms of thought content, we propose to view MB on a dimensional space representing content types, where MB is unrelated to any type of content. In terms of thought dynamics, we suggest conceptualizing MB as a moment during content transitioning or as a failure to transition across contents. Taken together, we suggest that MB has a unique place in the study of spontaneous thinking, and its inclusion can facilitate the isolation of the neural correlates of ongoing cognition.

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Mind-blanking is an ontologically unclear mental state

During wakefulness, we spend approximately half of the time delving into random thoughts that are unrelated to present engagement, highlighting the centrality of spontaneous thoughts [1,2]. The thought-centric approach to cognition suggests that spontaneous thinking can be described as a sequence of discrete cognitive and emotional states that can be decomposed in terms of 'content' (what the state is about) and 'dynamics' (how states transition across each other) [3]. Recently, the study of spontaneous thinking has expanded to account for brief and infrequent moments when people cannot report content, termed mind-blanking (MB) [4].

While the inclusion of 'blank' or 'empty' reports has increased in recent thought-sampling studies, there is no agreement as to what MB refers to. For example, MB has been referred to as 'blank mind' [5], 'not thinking of anything' [6••], 'awareness of absence' [7], or 'no conscious awareness' [8••]. From the diversity of these definitions, we notice a lack of consensus in the phenomenology of MB [9•,10••], which is further evident in the way that MB is described to participants (Table 1).

Importantly, this phenomenological heterogeneity can translate to different psychological interpretations of MB. This means that MB could be the result of (a) attentional lapses [8••], suggesting that there is mental content, but we miss it by not attending to it; (b) thought-silencing [11], where people try to empty their minds by suppressing semantic content; and (c) metacognitive error or failure of metamemory, where people misjudge their immediate past content [7]. Furthermore, it remains unclear whether MB represents a failure of access consciousness, in that there is content, but we are unable to report it, or whether there is no phenomenal experience at all [12•]. Finally, we recently suggested that MB might not represent a unitary experience [10••], as it can manifest with or without meta-awareness and deliberate control [13•].

Here, we aimed at shedding light on the heterogeneity posed by MB by developing an intuition about the relation of MB with spontaneous thinking. The goal is to locate where MB and spontaneous thinking intersect in terms of thought content and thought dynamics. We think that by answering this question we will not only have a better understanding of MB's psychological profile, but also, we will be able to determine the neuronal correlates of thinking in a more precise way. To that end, delineating the neural correlates of MB first is needed.

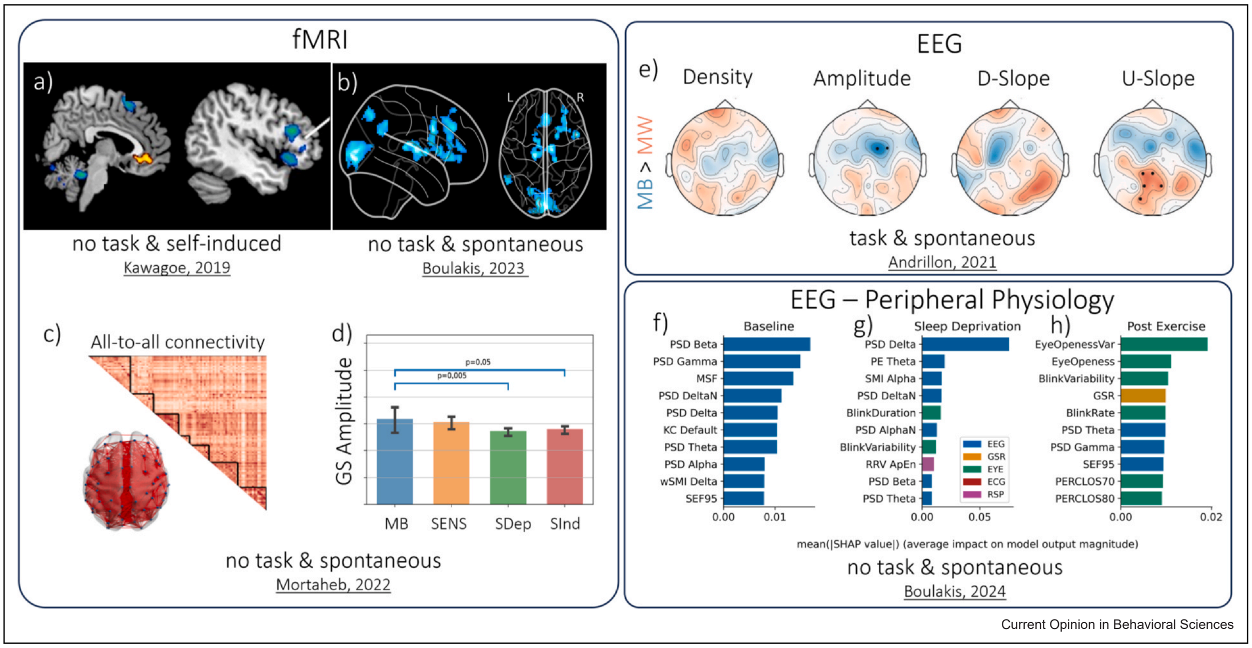
Table 1

Overview of different experimental protocols and analyses of MB.

Descriptions of MB	Task setting	Thought sampling	Modality	Reference
Awareness of no content	Prospective memory	MB questionnaire	Behavior	Efklides & Touroutoglou, 2010 [7]
No conscious awareness Not thinking of anything	Reading comprehension	Probe-catch Self-catch	Behavior	Ward & Wegner, 2013 [4]
Not thinking of anything	SART	Probe-catch	Behavior	Stawarczyk & D'Argembeau, 2016 [14]
Not very alert	Psychomotor vigilance task	Probe-catch	Behavior	Unsworth & Robison, 2016 [15]
No reportable content Not thinking of anything Contentless No thoughts	SART	Probe-catch	Behavior Pharmacology	Van den Driessche et al., 2017 [5]
Absence of content Thinking about nothing Lack of meta-awareness	Rest	Probe-catch	fMRI	Van Calster et al., 2017 [16]
Thinking of nothing	Trying to think of nothing	Post hoc report	fMRI	Kawagoe et al., 2018 [17]
Not very alert	STROOP task Psychomotor vigilance task	Probe-catch	Pupillometry	Unsworth & Robison, 2018 [18]
Thinking of nothing	Trying to think of nothing	Probe-catch	fMRI	Kawagoe et al., 2019 [11]
Not thinking of anything Not attending to task Zone out	SART	Probe-catch	Behavior	Robison et al., 2019 [19]
Not attending to anything Absence of thought	Cohort	Probe-catch	Behavior	Robison et al., 2020 [20]
No conscious awareness Thinking of nothing No recall	SART	Probe-catch	EEG Pupillometry	Andrillon et al., 2021 [8••]
Absence of content Thinking about nothing	Rest	Probe-catch	fMRI	Mortaheb et al., 2022 [6••]
Absence of content Thinking about nothing	Rest	Probe-catch	fMRI	Boulakis et al., 2023 [13•]
Reduced conscious awareness Absence of thought Thinking about nothing No recall	Rest	Probe-catch	Pupillometry	Koroma et al., 2023 [21]
No conscious awareness Not thinking of anything No recall Zone out	Psychometric	MB questionnaire	Behavior	Kawagoe et al., 2024 [22]
Not thinking of anything	Rest	Probe-catch	EEG ECG EDA Respiration Pupillometry	Boulakis et al., 2024 [23••]
No conscious awareness Thinking of nothing No recall	SART	Probe-catch	EEG	Musat et al., 2024 [24]
No conscious awareness Thinking of nothing No recall	SART	Probe-catch	ECG	Corcoran et al., 2024 [25]

ECG = electrocardiography; EDA = electrodermal activity.

Figure 1



The neurophysiological correlates of mind-blanking (MB) indicate a mediation by altered arousal levels. *fMRI.* **(a)** Deliberate MB is linked to cortical deactivations in areas associated with thought-silencing [11]. **(b)** Spontaneous MB is linked to cortical deactivations spanning frontal, parietal, occipital, and thalamic areas, including medial frontal regions [13•]. **(c)** Dynamic functional connectivity around MB reports is characterized by an all-to-all connectivity brain profile [6••]. **(d)** MB is characterized by higher amplitude of the fMRI global signal (GS), an indirect indication of low cortical arousal, compared to reports about direct sensory perceptions (SENS), stimulus-dependent (SDep) and stimulus-independent (SInd) thoughts [6••]. *EEG.* **(e)** MB is preceded by posterior slow-wave-like activity, compared to mind-wandering (MW) [8••]. *EEG-peripheral physiology*. **(f)** During baseline arousal, the most informative features for decoding MB originate from the brain. **(g)** During lowered arousal induced by sleep deprivation, the most informative feature for decoding MB was the power spectrum of the delta EEG band. **(h)** During increased arousal induced by high-intensity exercise, the most informative features for decoding MB originate from eye openness (EYE), electrodermal activity (GSR), and EEG. A SHapley Additive exPlanations (SHAP) analysis indicated that the model relied mostly on features from EEG, electrocardiogram (ECG), and eye openness (EYE) to accurately classify MB reports [23••]. GSR: galvanic skin response, RESP: respiration.

Neurophysiological correlates of mind-blanking

So far, electrophysiological and neuroimaging studies point to the possibility that the brain during MB reports is characterized by reduced activity indicative of reduced arousal levels (Figure 1). One of the first neuroimaging studies using functional magnetic resonance imaging (fMRI) showed that when participants were instructed to actively attempt to empty their minds, MB reports were associated with BOLD deactivations in Broca's area, the left hippocampus, and the supramarginal gyrus and activation of the anterior cingulate cortex [11] (Figure 1a/fMRI). At the time, these deactivations were considered representative of thought silencing. Although this might be the case, the finding that the parallel activation of anterior cingulate areas was not following the general deactivation pattern led to the assumption that the instruction 'to empty the mind' might have indicated task-related activity, where participants were following the instruction to monitor and suppress their thoughts [9•]. Using fMRI with experience sampling where MB was not deliberate, we showed that MB reports correlated with widespread deactivations in frontal, parietal, occipital, and thalamic regions [13•]. Importantly, when contrasting MB with mental states about stimulus-dependent and stimulus-independent thoughts, the deactivations spanned the angular gyrus and medial anterior regions [13•] (Figure 1b/fMRI). In another analysis of the same data set [6••], we showed a brain mode, in which MB was linked to a brain pattern where all regions were covarying in activity the same way (Figure 1c/fMRI). Additionally, this pattern was linked to low amplitude of the fMRI global signal (Figure 1d/fMRI), which was previously linked to reflect vigilance levels [26]. In combination with other studies showing that all-to-all fMRI connectivity patterns are observed also during sleep [27], it is collectively inferred that MB is closely linked to low arousal levels.

Using electroencephalography (EEG), the implication of arousal in MB reports became clearer. When EEG was combined with experience sampling during a sustained attention to response task (SART), attentional lapses (MB and mind-wandering [MW]) were associated with the presence of slow-wave-like activity. The localization of the slow waves further differentiated the two mental reports: slow-wave-like activity in posterior electrodes was associated with MB reports, while slow-wave-like activity in frontal electrodes was associated with MW [8••] (Figure 1e/EEG). A re-analysis of the same data set aiming to characterize the spectral and complexity profile of attentional lapses revealed that MB was associated with higher power in delta and alpha bands, lower power in beta and gamma, and reduced parietal complexity, indicative of a reduced cortical arousal mode [24].

More recently, we tested the hypothesis that MB is mediated by arousal levels more directly by quantifying MB frequency not only when arousal was reduced (after sleep deprivation) but also when it was increased (after intense physical exercise) [23••]. Using experience sampling and multimodal brain–body physiology recordings, we showed that MB occurred more frequently in low and high arousal, compared to baseline levels. Additionally, a decoder trained on both brain and physiological features outperformed chance-level classification, as well as the classification performance of decoders trained solely on brain or body features. Critically, classification was arousal dependent, as different levels of arousal were associated with different patterns of brain–body feature importance (Figure 1f–h/EEG-peripheral physiology).

Collectively, these results show that fluctuations of arousal are a critical mediator in MB, such that optimal cortical and physiological arousal leads to reportable content [10••]. Apart from this neurophysiological substrate, how can MB be further accounted in the context of spontaneous thinking?

Mind-blanking as an origin point in the multidimensional content space

Research on spontaneous thinking has proposed to view thought content as having two main clusters: one where thoughts are guided by external demands and one where thoughts are episodic and self-generated [28•]. In the absence of strong deliberate external constraints, self-referential or autobiographical content acts as an attractor, pulling related thoughts and memories into a tendency to generate spontaneous thoughts about the self. As thoughts flow, content tends to settle into these autobiographical attractors, guiding spontaneous thinking toward reflections on personal history, self-identity, and related emotions [29•]. This internal–external dipole is further supported by neuroimaging evidence pointing to antagonistic cortical network activity: an intrinsic or 'default mode' network (DMN) [30–33], and an extrinsic or 'task-positive' network [34–36]. The DMN includes the medial prefrontal cortex (mPFC), the posterior cingulate cortex, the hippocampus, the medial temporal lobules, and the angular gyrus and has been associated with ongoing thinking [37], internal dialog [38], daydreaming [39], rumination [40], and unrelated thoughts from ongoing task activity [39]. The 'task-positive' network includes primarily lateral frontoparietal areas [36,37], and it is theorized to support the perception of the environment. By considering the underlying neural mechanism (neural inhibition), which supports anticorrelations to rise, this antagonistic activity was proposed to account not only for spontaneous thinking but also to provide the necessary substrate for conscious experience in general to happen [41].

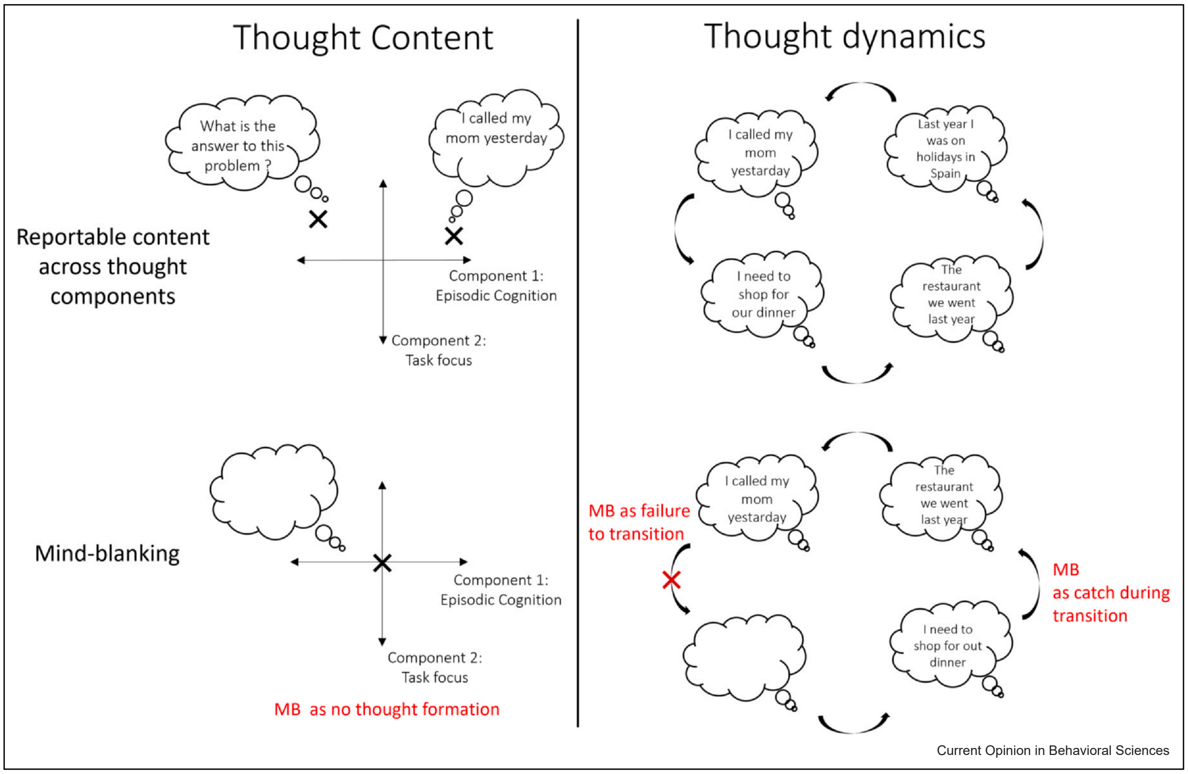
To account for all potential content (beyond the external–internal dipole), a novel approach attempted to uncover how different types of content may appear together. This approach has utilized extensive questionnaires to group covarying content into representative clusters through dimensionality reduction techniques. Identified patterns include self-related processing, episodic social cognition, and task relatedness [42–44*], both during task and naturalistic settings [45,46]. The utility of the multidimensional space is the robust organization of how thoughts covary, allowing us to map similarities across all thought content. What is of interest is that these patterns seem to appear consistently across data sets and experimental settings, which points to their universality [28*]. Neuronally, these thought patterns translate to discrete neuronal substrates. Task-related patterns link to frontal and parietal regions [42,47], and patterns related to the self to the ventromedial prefrontal cortex [43].

We recently speculated that, in such a multidimensional coordinate space, in which various content types can be represented as distant points, MB could be placed at the origin point. This would imply that MB is of undifferentiated content, and as we move away from the origin point, it dissolves, and content becomes more representative of the axis on which it varies (Figure 2). Starting from the deactivations profile of MB, at the origin point, thoughts along a specific axis would neuronally translate to neuronal activations exclusive to that thought content. At the same time, content closer to the origin access would be related to mental states where content is progressively less clear and reportable. In support of this hypothesis, Mullholand et al. [44*] found that thoughts during mundane automated tasks, such as eating and chores, are closer to the origin axis. Taken together, in the dimensional space representing content types, MB is reported as such because it does not seem to relate to any type of content.

Mind-blanking as the result of transition catch or failure

The dynamic components of thinking emphasize the presence of bottom-up automatic constraints (such as

Figure 2

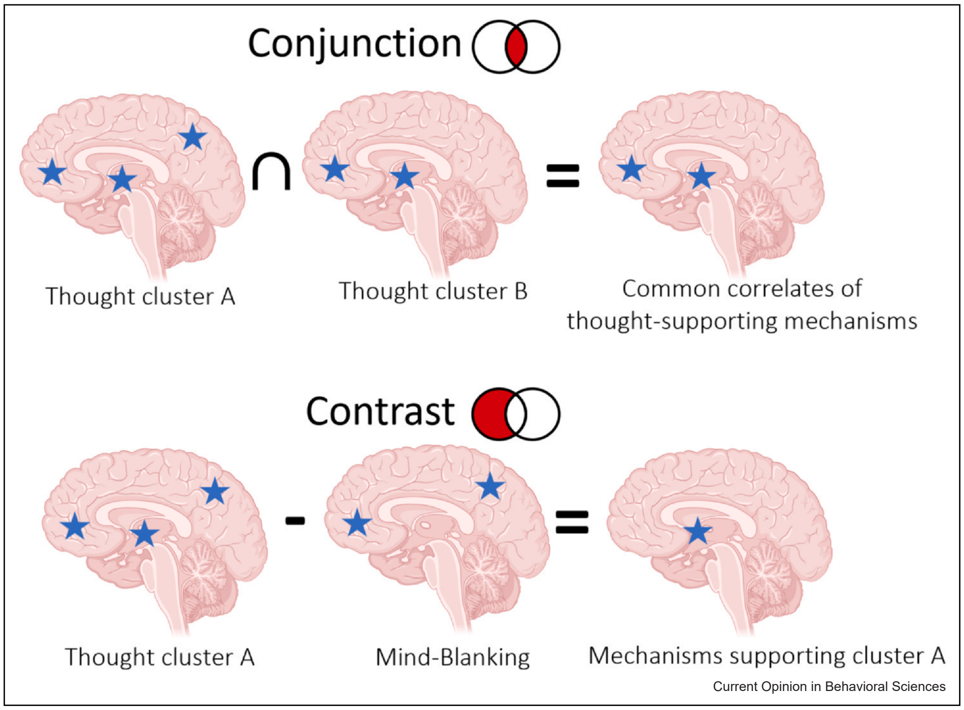


On the way to understand mind-blanking (MB), we can conceptualize it in terms of key aspects of spontaneous thinking, namely thought content and thought dynamics. *Left column*: Specific thoughts can be represented as points in a multidimensional space, where each dimension reflects key patterns of variation (thought components) in thought content. MB can be considered as resting at the origin point of each dimension to indicate that it does not relate to any other content. *Right column*: Thought dynamics can be represented as transitions from one content to another. An individual can report a train of thoughts because they can navigate across variant content. In that respect, MB can be considered as the instances happening during content transitions or as the inability to transition at all.

sensory salience), as well as top-down cognitive control constraints of thought (such as motivational factors) [3]. This approach stresses that there are mechanisms that generate and propagate thoughts and indicate how these mechanisms alternate based on the presence of such constraints. For instance, generative accounts of thought initiation and propagation have focused on the role of subcomponents of the DMN, specifically the mPFC [48], the medial temporal lobe (MTL) [49] and the hippocampus [50]. The mPFC was postulated to bind semantically adjacent concepts to propagate the stream of consciousness [51,52] by appropriately retrieving associated concepts [51,53]. The hippocampus was shown to assist in the propagation of ongoing thought by memory retrieval functions that reactivate memory traces relevant to ongoing experiences [54], potentially binding content under context similarity [3]. Finally, the MTL has been implicated both in thought initiation and in associative processes that bind sequential thoughts: ongoing MTL BOLD activity has been observed preceding ongoing thoughts [55], while MTL lesions have been associated with reduced variability of content during MW [56]. This decrease was explained as reduced conceptual variability due to impaired associative processing [57].

Accounting for the dynamic aspect of thinking, we observe that thoughts with reportable content can lead toward other content-full mental states thanks to semantic associations, hence creating the perception of a stream of thought (Figure 2). Since MB is not semantically associated with any particular thought content, we previously considered that MB might represent the moments during which we transition across different contents, which get to be phenomenologically translated as MB [6**]. This view is supported by behavioral findings showing that MB has a low chance of being reported when reporting a content-oriented state before and that rereporting MB is also of low likelihood [6**]. It can also be that transitions happen too fast, like in certain cognitive phenotypes, such as ADHD, which are characterized by mental restlessness and fast thought pacing. In that scenario, MB events are also reported more frequently [5], potentially due to more frequent

Figure 3



Mind-blanking can help to isolate the neural correlates of thinking. The isolation of the neural correlates of thinking can be approached via the conjunction of brain activity, which supports common content clusters, or by contrasting the activity of brain areas, which support specific clusters of thought and no-thought. The *conjunction* approach can be used by identifying brain areas, the activity of which supports different content and by examining their neural overlap between them, leading to a common mechanism that supports thought content. The *contrast* approach can be achieved by subtracting the neural correlates of MB from brain activity supporting states with reportable content, leading to the neural correlates of that specific content. *Note*: the stars represent brain activity associated with different thought clusters and MB.

thought transitions. Another scenario stresses that MB might be the result of unsuccessful transitions across states in the first place. Evidence for this explanation comes from activation studies showing reduced activity in the hippocampus [11] and ventromedial prefrontal areas [13*], potentially reflecting a failure in generating and binding sequential thought content altogether (Figure 2).

Using mind-blanking to uncover the neural correlates supporting spontaneous thinking

Having examined how the neuronal substrate of MB can be incorporated into the study of spontaneous thinking, we can examine how we can leverage it to uncover the neuronal correlates of thought. As MB represents a rough dissociative line between reportable and non-reportable moments, it can be of value in uncovering the neural correlates of spontaneous thinking more comprehensively. Current research in spontaneous thinking examines how neural activity correlates with content and does not examine content-invariant mechanisms that facilitate thought content presence and thought dynamics [28*,58,59]. Based on this, we suggest that the neural correlates of thinking can be defined as the minimal neural mechanisms jointly necessary for thought to be manifest. To elaborate on this, we can draw a parallel from the research on the minimal neural prerequisites of consciousness: the neural mechanisms that are prerequisites for conscious experience are discrete from the content of the experience. For example, the neural correlates of a visual experience differ from mechanistic prerequisites, such as global brain states of desynchronized activity. The isolation of mechanisms that support specific conscious experience can then be uncovered in two ways: (a) with a *conjunctive* approach, where neural correlates of different clusters of content are taken as a union and (b) with a *contrastive* approach, where neural correlates during the absence of consciousness are subtracted from the neural correlates during consciousness presence. Using the *conjunctive* approach, we can sample multiple thought content clusters and examine the neural overall, isolating common content-supporting mechanisms. On the other end, using the *contrastive* approach, we can subtract neural activity of MB reports from moments of reportable content or moments where thought transitions are successful, isolating mechanisms that support these specific phenomena (Figure 3). Overall, MB reports can serve as a point of self-reported no thought during wakefulness and provide an adequate contrast for eliminating brain activity that is not associated with thought.

Discussion and conclusions

We here attempted to get insights into the current heterogeneity of MB by developing a proposal about the relation between MB and spontaneous thinking. We first notice that MB is associated with altered arousal, raising the issue of whether something can be reported under such a neuronal background [10**].

The role of arousal in MB can be contextualized within the broader discussion regarding conscious content and consciousness states [60]. Typically, conscious content (what we are conscious of) refers to the phenomenal character of our experience [61]. Research on content-specific properties aims to separate how distinct items of experience are differentially represented neurally, like delineating the role of the fusiform gyrus during face processing [62]. At the same time, consciousness states refer to 'global' states or 'modes' of consciousness that provide specific background conditions for any content to appear [60]. These states are content invariant and describe how brain anatomy, functional connectivity, or cortical arousal creates the background conditions for content to manifest. As MB is heavily driven by cortical and bodily arousal, it may hence be more akin to a conscious state, similar to that of NREM sleep or absence seizures, rather than to a specific content. It is important to mention that state and content as presented are not necessarily orthogonal; to be conscious is to be conscious of something. However, this distinction raises the issue of whether the neuronal correlates of MB can support content or not [10**].

Jumping off that point, we attempted to position MB within the context of spontaneous thinking by connecting it to two key aspects: content and dynamics. In both cases, MB can represent the absence of key components necessary for uninterrupted spontaneous thinking. Subsequently, by contrasting MB to thoughts with reportable content, we can get further insights into the neuronal mechanisms that make content reportable.

Moving forward, a key issue in the study of MB is the standardization of how MB is defined in experimental settings. We here propose to define MB as a "mental state where people have nothing to report or are unable to report anything about their immediate experience". We find that this definition respects the phenomenological experience of 'having no content' without being rigid about whether MB reflects no content or no access to content. Furthermore, this definition remains agnostic as to the psychological underpinnings of MB, that is, whether people fail to attend to something or forget what they were thinking.

Overall, we aimed to examine how MB relates to current conceptions of spontaneous thinking. As the study of MB is regaining attetion and current research on MB has utilized heterogeneous definitions, we advocate for the inclusion of MB as an additional mental state in empirical future protocols, such that the multiplicity of conscious experience can be fully represented.

CRediT authorship contribution statement

PAB: Conceptualization, Writing – original draft, Visualization. **AD**: Conceptualization**,** Writing – original draft, Visualization, Supervision.

Data Availability

No data were used for the research described in the article.

Declaration of Competing Interest

Regarding our manuscript "What's the blank about? Relating mind-blanking to aspects of ongoing thinking", we would like to declare we hold no competing interests.

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