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Mind-wandering as creative thinking: neural, psychological, and theoretical considerations

Kieran CR Fox[1,2] and Roger E Beaty[3]

Creative thinking is understood via a dual-process model involving the generation of creative ideas followed by their subsequent evaluation and refinement. Creative products must also meet a dual-criterion definition requiring that they be both novel and useful. Mind-wandering consists of self-generated thoughts unrelated to a task or the surrounding environment, involving a relatively spontaneous generation stage sometimes (but not always) followed by a more deliberate stage in which thoughts are evaluated and reflected upon. These stages of mind-wandering show brain recruitment similar to the equivalent stages of creative thinking, and moreover, much mind-wandering can be considered novel and useful. We aim to show that there is a profound analogy—perhaps even a direct relationship—between mind-wandering and creative thinking.

Addresses
[1] Department of Neurology and Neurological Sciences, Stanford University, Stanford, CA, 94304, USA
[2] School of Medicine, Stanford University, Stanford, CA, 94304, USA
[3] Department of Psychology, Pennsylvania State University, University Park, PA, 16801 USA

Corresponding author: Fox, Kieran CR (kcrfox@stanford.edu)

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Mind-wandering as creative thinking

Creative thinking is typically described via a *dual-process model* involving the generation of creative ideas or products followed by their subsequent evaluation and refinement [1–3]. Most researchers also require that creative products meet a *dual-criterion definition* including novelty/originality and utility/appropriateness [4]. Anecdotal reports have long suggested that allowing the mind to wander is conducive to creativity [5–7], and questionnaires and personality tests have found tentative relationships between fantasy–proneness and creative ability [8,9]. In-depth exploration of this topic has generally been lacking, however. In this review, we attempt to take some further steps toward an integration of the literature on creative thinking and mind-wandering.

What mind-wandering *is* remains an area of active debate: some researchers privilege thought that is unconstrained and spontaneous [10,11•], while others argue for a broader 'family resemblances' view [12]. In practical terms, mind-wandering is understood by most researchers as thoughts unrelated to the task at hand or unrelated to the surrounding environment [13]. Throughout this review, therefore, we employ the term *mind-wandering* to mean simply what most authors and studies mean by the term [13]: more or less *self-generated* thought [14,15•,16], essentially unrelated to any ongoing tasks or perceptual inputs. The human brain creates tens of millions of such thoughts over an average lifetime—especially when the demands of the external world are low—yet the sheer magnitude of this generative capacity, and the parallels to creative thinking, remain largely unappreciated.

Here we synthesize substantial evidence that the mental content described in empirical research as mind-wandering is, like creative thinking, both novel and useful. The central difference is that mind-wandering tends to be useful or appropriate only for the individual having the thoughts (i.e. the content is overwhelmingly self-referential and has few if any implications beyond the life and immediate social circle of the individual). While some creativity researchers would admit these personally-useful thoughts into the domain of everyday ('little c') creativity [17], others define truly 'creative' products by their utility to society at large; some have gone as far as suggesting that creativity is impossible without a society of peers to judge, appreciate, and make use of the creative product [18]. Similar to dual-process models of creative thinking, mind-wandering can also be conceptualized as involving a relatively spontaneous and unintentional *generation* stage, sometimes (but not always) followed by a more deliberate, intentional *evaluation* stage in which one's thoughts are evaluated, guided, and reflected upon [19]. The central goal of this review is to show that mind-wandering sits quite comfortably alongside current conceptualizations of creativity, both in terms of what creative products *are* (namely, novel and useful) and in terms of how creativity *works* (namely, dual-process models involving generation and evaluation).

A dual-process model of mind-wandering: generation and evaluation

The generation of mind-wandering

When does the human brain self-generate thought?

The mind is most likely to generate its own mental content when the demands of the external world are minimized, for instance during simple or highly-practiced tasks (e.g. [20,21]). If the reduction of external stimulation is carried further, even more intensive and immersive forms of self-generated thought tend to result, for instance during sensory deprivation [22,23] or dreaming [24,25].

How much thought does the human brain generate?

An early study by Klinger [26] found the average duration of thought segments of many kinds was ~5 s. Extrapolating from this number, Klinger estimated that the average person experiences ~4000 thoughts in a typical 16 h day [27]. As people are mind-wandering about half the time in daily life [28], this yields ~2000 self-generated thoughts each day [27]. Very young children likely lack the ability to form the kind of coherent, interiorized streams of thought that would allow for self-generated thought [25], and there is ample evidence that the frequency of self-generated thought declines somewhat in later life (e.g. [29]). But despite these periods at the dawn and dusk of life where self-generated thought is absent or curtailed, the output of the human mind over some 70 years of highly active thought-generation is staggering: some 50,000,000 self-generated thoughts. Self-generated thought in sleep would add considerably to this total [30].

These are back-of-the-envelope calculations, intended to provide an impressionistic picture rather than an accurate estimate. Given this huge volume of mind-wandering, it seems inescapable that the thoughts one generates will shape the very neurophysiological matrix that gave rise to them in the first place: beyond unceasingly creating thoughts, the brain is continually creating *itself*. The creative capacity of the human mind therefore appears to be immense and also immensely wasteful (to judge by the mundane nature of most mind-wandering). Nonetheless, this cognitive quirk is in fact an efficient, indeed brilliant, evolutionary strategy: a single useful thought can conceivably mean the difference between life and death; a single important insight can potentially precipitate a continuous cascade of technological innovation or scientific discovery.

Yet the marginal metabolic cost of generating a single thought is infinitesimal. Even demanding cognitive and perceptual tasks rarely lead to more than a 5–10% increase in blood flow to the brain; spontaneous brain activity not directly related to ongoing perception or cognition therefore appears to account for $\geq$ 90% of the human brain's metabolic expenditure [31]. If this sophisticated machinery is lying relatively idle (as it often is, during conditions of low external demands on attention), it can be appropriated to self-generate cognitive content of varying levels of novelty and utility. While the value of any given thought might be minimal, so too is the marginal metabolic cost of creating it.

Neural basis of the generative stage of self-generated thought

Because of its largely spontaneous nature and unpredictable timing [11•], combined with the fact that people are often unaware that it is even taking place [32], studying the brain basis of the initial arising of self-generated thought has proved challenging. Multiple indirect lines of evidence, however, have long pointed to the medial temporal lobe (MTL; especially the hippocampus) as a crucial site of thought generation and/or initiation (reviewed in [15•,33]), as well as an important role for the default network – a set of brain regions associated with mind-wandering and other modes of self-generated thought [34].

First, patients with damage to the MTL are unable to imagine novel plans for and simulations of the future [35]. MTL damage also causes marked decreases in the frequency of dreaming – which we consider an intensified form of mind-wandering [36] – and increased stereotypy (i.e. decreased novelty or originality) in the dreams that remain [37,38]. A recent study that directly investigated the impact of MTL lesions on mind-wandering found that although the *frequency* of mind-wandering was not affected, the content had become largely semantic, verbal, and present-focused. In contrast, controls experienced a wide variety of past- and future-focused thoughts, typically involving visual, episodic scenarios [39••].

Second, intracranial electrophysiology in humans has shown that the spontaneous recall of episodic memories is immediately preceded by elevated firing rates (more action potentials) in single neurons in the MTL, but not elsewhere [40]. And when electrically stimulating the brain with intracranial electrodes, the only area that has reliably been shown to elicit experiences resembling mind-wandering – memories, complex visual imagery, and dream-like experience – is the MTL [15•,33,41].

Finally, a recent fMRI study examined the time-course of thought generation by employing highly-experienced mindfulness meditation practitioners who had spent >3000 h observing the arising of their thoughts during contemplative practice [42••]. Practitioners were asked to engage in periods of focused, thought-free meditation and repeatedly identify the specific moment at which thoughts arose by pressing a button. Brain recruitment just before the button-presses was used as a proxy for the neural basis of thought-generation, and included numerous activation peaks throughout the MTL bilaterally, as well as in the major nodes of the default network (Figure 2; [42••]). This study provided direct evidence for the critical role played by the MTL and the default network.

There are many parallels here to the neural basis of explicitly 'creative' generation [43••]. Damage to MTL structures negatively impacts creative thinking [44,45], and the MTL is recruited during a variety of creative endeavors, including divergent thinking, visual art design, and poetry composition (reviewed in [43••]). Default network recruitment during creative thinking of various kinds is also widely attested, including during creative story generation, fluid analogy formation, remote associate insight problems, poetry composition, and musical improvisation [43••]. Although a detailed comparison is beyond the scope of this review, the evidence to date points strongly toward a largely overlapping neural substrate for the generation of everyday mind-wandering and more explicitly creative forms of cognition, involving especially the MTL and default network.

The evaluation of mind-wandering

In contrast to the spontaneous, unpredictable nature of thought generation, the evaluation stage should in principle be much easier to study, because it is largely a conscious and deliberately-initiated cognitive process. Yet it is the much less studied of the two stages both in the context of self-generated thought generally as well as creativity proper; we know of no studies that have directly asked participants to evaluate their mind-wandering in a brain scanner environment. The few studies that might be relevant have investigated the intentional guidance or conscious awareness of mind-wandering, rather than evaluation *per se*.

Nonetheless, conscious awareness and intentional guidance of one's self-generated thought seem to be prerequisites, or at least close companions, of any serious process of evaluation and selection, and are therefore potentially interesting. Experience sampling studies suggest that we have metacognitive awareness of only about half of our mind-wandering [32], but explicitly focusing metacognitive awareness on self-generated thought leads to increased recruitment in default as well as frontal executive regions [46]. Moreover, recent studies have demonstrated that people are very prone to *intentionally* 'tuning out' and allowing self-generated mental content to take precedence over the task at hand or the surrounding environment – indeed, intentionally-initiated mind-wandering might account for anywhere from ~25-50% of all self-generated thought (reviewed in [47]). Golchert and colleagues [48••] found that individuals who engaged in more intentional mind-wandering had greater cortical thickness within regions of the frontoparietal control network, as well as heightened functional connectivity between executive and default regions. Tentative data also suggest that healthy adults intentionally *direct* (not just *initiate*) the course of their self-generated thoughts as much as one quarter of the time [49].

Meager as this evidence is overall, it aligns well with what little is known about evaluation of explicitly creative ideas. The evaluation and revision (by the artists themselves) of both visual artwork [50] and poetry [51] result in increased recruitment of executive brain networks and/or increased functional coupling between executive regions and the areas initially involved in creative generation (usually, the MTL and default network). This increased recruitment and functional coupling of executive and default regions could reflect metacognitive monitoring or guidance, which might help facilitate the continuing novelty and utility of creative output.

A dual-criterion definition of mind-wandering: novelty and utility

Does the wandering mind generate novel thoughts?

Repetitiveness of mind-wandering

Although novelty *per se* has not, to our knowledge, been directly investigated in studies of self-generated thought, a first indication can be gleaned from questions about its repetitiveness. For instance, Diaz and colleagues had participants rate the item "I had similar thoughts throughout the session" during a task-free resting state [52]. 51% of participants endorsed the item above the midpoint of the scale, but 26% strongly disagreed with it, and some novelty and variety could still have been present even among 'similar thoughts.' Another study [53] had participants rate the item "it seems that this thought has been on my mind a great deal"; it was endorsed slightly above the midpoint of the scale, indicating that participants were divided about equally: some had recurrent thoughts, others did not [53]. We know of only one study using experience-sampling in everyday life that explicitly asked participants to rate the novelty of their off-task thoughts, but unfortunately-specific values were not reported [54].

Mind-wandering and memory

Memory recall (in the sense of 'replaying' a past event) can be considered essentially the opposite of cognitive novelty, so establishing how much (or how little) of mind-wandering involves memories is an important clue regarding how novel self-generated might be. Although memory recall undoubtedly represents a significant chunk of mind-wandering, dozens of studies agree that thoughts about the past represent a minority of all self-generated content – even if a substantial one (reviewed in Ref. [55]). While not demonstrating definitively that mind-wandering involves novelty, these findings do at least show that self-generated thought is not *merely* repetitious and derivative of prior experience.

Mind-wandering about the future

Conversely, many studies find that mind-wandering is biased toward the future [55]. Even allowing that people

can certainly think the same or similar thoughts repeatedly about the more distant future, the *immediate* future is an ever-receding horizon that changes day to day. Thinking about and planning for tomorrow requires a perennial flowering of flexible thoughts adapted to ever-changing circumstances; and in fact, mind-wandering about the future tends to focus largely on the upcoming 24 h, with the majority of such thoughts centering on today and tomorrow [56,57].

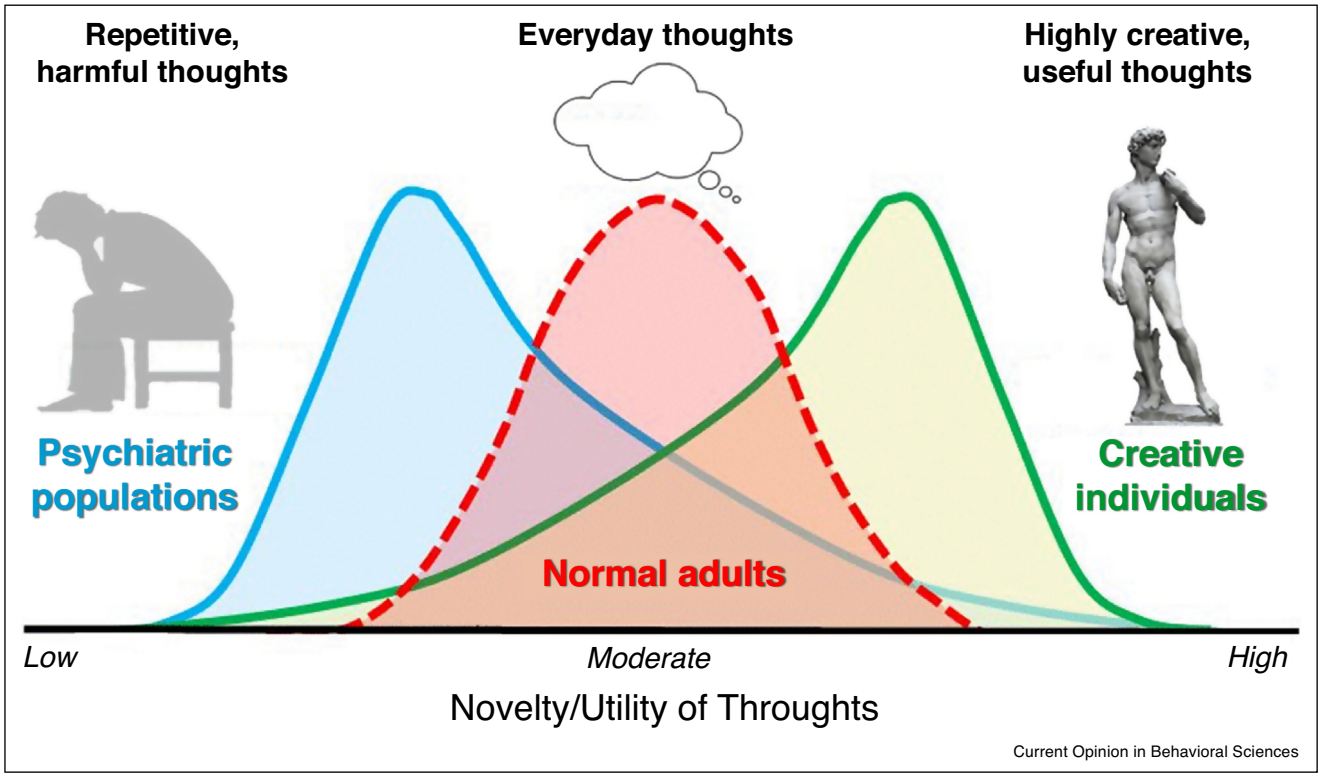
Does the wandering mind generate useful thoughts?

Whereas the novelty of mind-wandering is little studied, research has made it abundantly clear that self-generated thoughts are *useful* – at least to the persons originating them. Here we use *utility* as shorthand for various questions interrogating how people's thoughts are related to their personal goals, plans, and concerns, or are otherwise considered personally meaningful, significant, or important. The kind of questions and items being asked and endorsed are, for example: "How relevant was what you were thinking about to the current concerns in your life?" [58]; "I thought about solving problems" [52]; and "The topic of this thought is of great value or importance to me" [53].

Defined in this broad way, participants ubiquitously endorse utility-related facets of thought questionnaires [52,56,59] and reliably report useful thoughts in experience-sampling paradigms implemented in controlled laboratory studies [49,53,57,60] and recorded via smartphones in daily life [58]. Preliminary data suggest that, as hypothesized above (Figure 1), healthy adults fall along or more or less normal distribution in terms of how much their mind-wandering centers around their own personal goals, and moreover, that these individual differences might be trait-like and persist over time (Figure 3). Again, the main distinction to be kept in mind is that self-generated thoughts are typically useful only to their thinker, and of little if any direct utility to others or society at large.

Figure 1

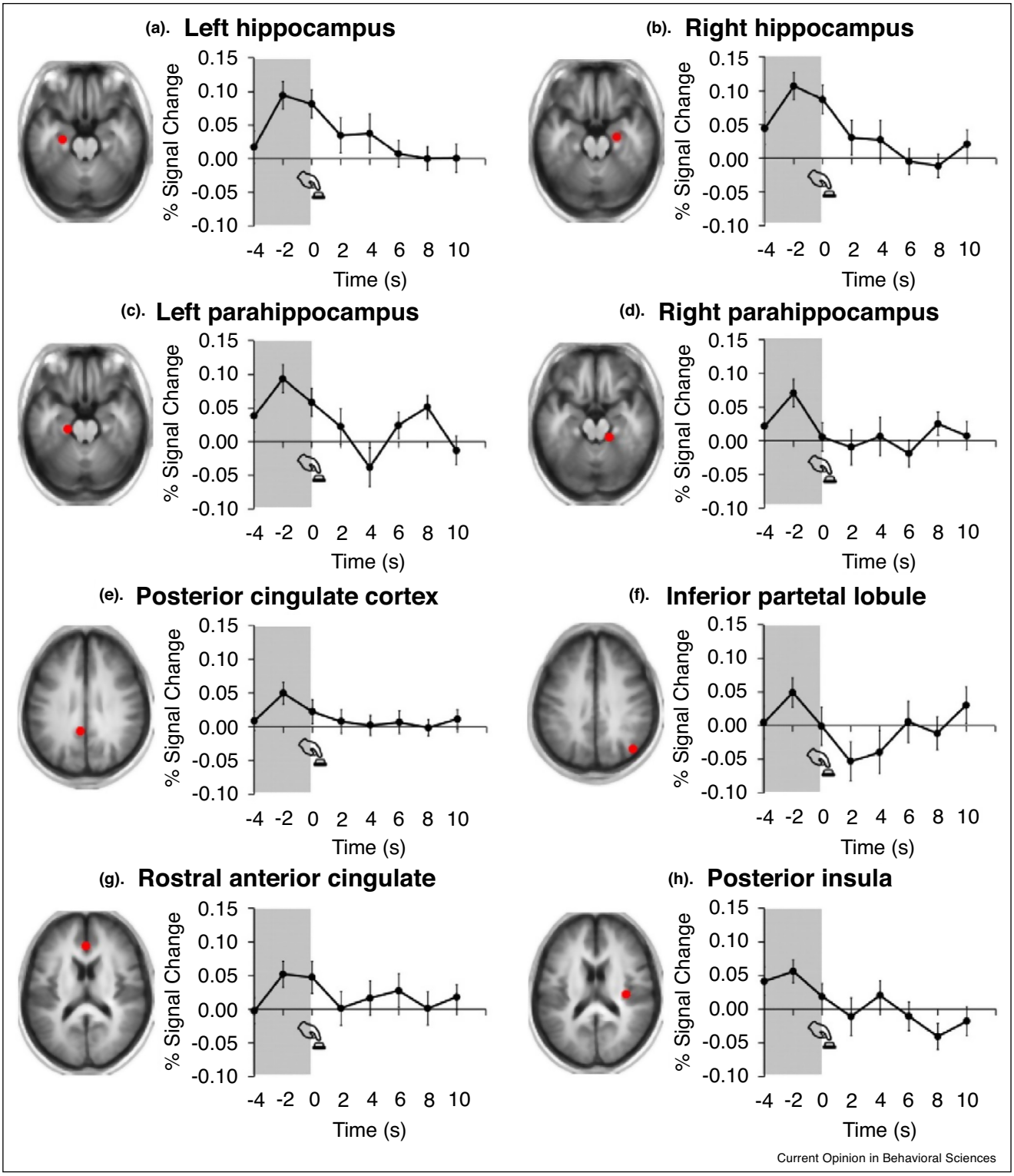
A speculative model of mind-wandering content in clinical, healthy, and exceptional populations.



Three distributions illustrating a speculative model of how the novelty and utility of mind-wandering content might be distributed throughout the general population. A significant proportion of 'normal' individuals fall at the center of the spectrum (red curve), with most self-generated thoughts being moderately useful and novel, and the occasional instance of highly novel or deeply repetitive thought at the tails of the distribution. Certain psychiatric populations (blue curve)—for example those suffering from rumination due to major depression [63] or intrusive repetitive thoughts due to post-traumatic stress disorder [64] or obsessive-compulsive disorder [65]—exhibit a distribution skewed toward low novelty and utility. Such patterns of thought can be conceived of as simultaneously cause and symptom of such psychiatric conditions, and can be decidedly harmful. Finally, exceptionally creative and inventive individuals (green curve) are skewed in the opposite direction, showing a disproportionately high frequency of novel and useful (i.e. creative) thoughts, ultimately resulting in creative products such as artworks.

Figure 2

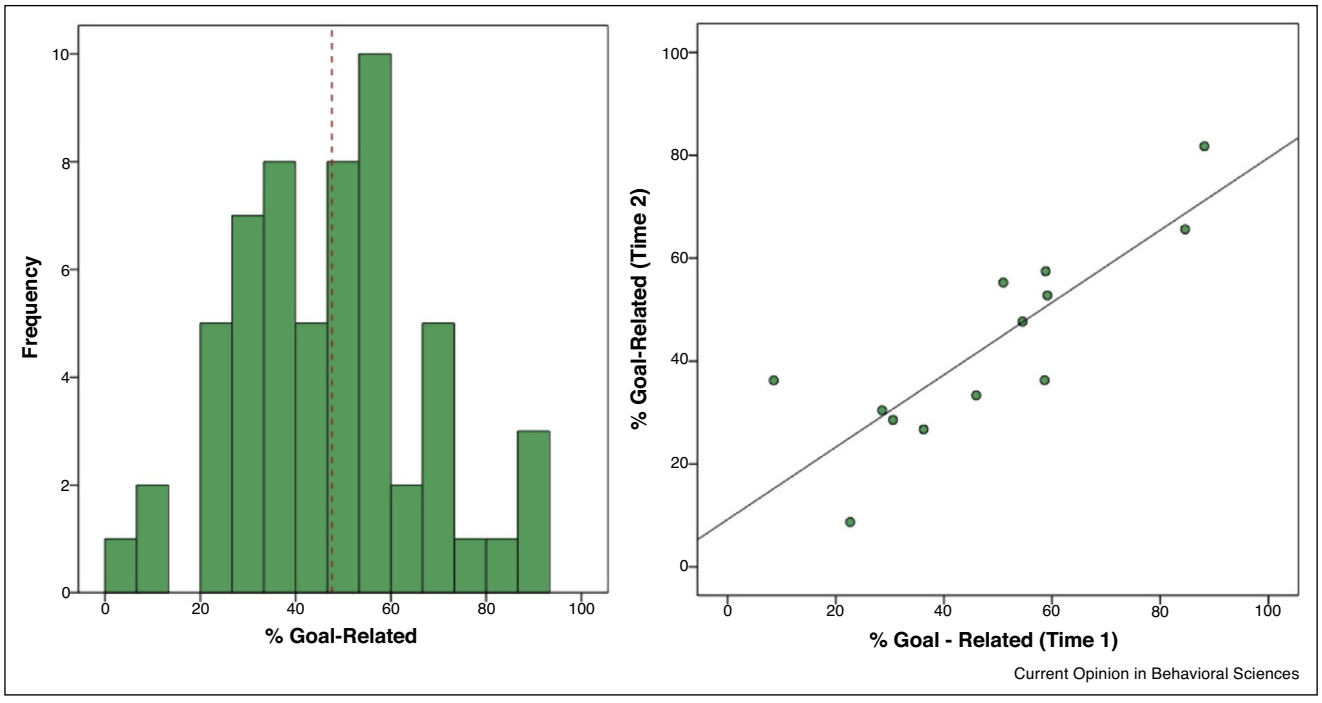
Timecourse of brain regions where activation peaks just before awareness of spontaneously arising thoughts.



Brain regions where activation peaked before the conscious awareness of a spontaneous thought arising (as indicated by the button-press icon). The results suggest a crucial role for the MTL (hippocampus and parahippocampus recruitment bilaterally), but the temporal resolution of fMRI could not distinguish these early activations from those in various default network regions, such as the posterior cingulate cortex and rostral anterior cingulate. Reproduced with permission from Ellamil *et al.* [42••].

Figure 3

Interindividual differences and intraindividual consistency in goal-related stimulus-independent thoughts.



Histogram: Individuals fall along an approximately normal distribution in terms of the percentage of their thoughts that are related to their goals and current concerns. Red dotted line indicates mean (47.7%) of thoughts that were goal-related across all participants. Scatterplot: Individual patterns appear to be trait-like, in that the percentage of thoughts focused on goals is highly stable when re-tested up to two weeks later (test-retest correlation of $r = .84$, based on a subset of $n = 13$ participants who underwent the same thought-sampling paradigm twice). Figures are based on unpublished data from $n = 58$ participants, expanded from published findings from $n = 32$ participants reported in [49].

Conclusion: the creativity of the wandering mind

We have endeavored to show that the accepted conceptualizations of creative thinking can be applied with only minor modifications to mind-wandering. On this view, creativity is not a special faculty possessed only by artists and inventors, but is instead the birthright of every brain [17]. A truly creative *thought* is simply one falling toward the far right of the distribution (Figure 1), novel and useful not merely to the individual, but to society – or even the species as a whole. *A truly creative individual is able to repeatedly generate such highly novel and useful thoughts*: someone who has harnessed the default generative capacity of the mind for their own particular purposes—or alternatively, someone simply born with their distribution skewed toward the more novel and useful end of the cognitive spectrum.

The fecundity of the human brain provides a compelling source of raw material for so-called 'Darwinian' or 'selectionist' theories of creativity. These models posit a largely unconscious, quasi-random generation of ideas and insights, some of which end up actually being novel and useful and then 'selected' for by largely conscious, top-down processes of evaluation [2,61]. Our proposal is consistent with such models, and amounts to the claim that the difference between carefully composing a symphony and spontaneously conceiving a shopping list is one of degree, not of kind. This hypothesis might offend more Romantic notions of inspiration and creativity, and to be sure, at the far reaches of creative genius the analogy is strained to the breaking point (cf. [62]). Yet it should not be surprising if the complex and beautiful are built upon simple and perhaps inelegant foundations. Indeed, it is difficult to see how it could be any other way; great creativity without a simpler generative fountainhead would be *even more* mysterious than creative thinking already is. Moreover, the proposed similarity between humdrum mind-wandering and more definitively 'creative' products leads directly to the testable hypothesis that the two should share a common neural substrate – which available data suggest is indeed the case (e.g. Figure 2; [43••]). Our hope is that the evidence laid out here will complement the anecdotal reports [5,7], personality measures [8,9], and empirical research [6] suggesting a link between these two intriguing forms of cognition by further demonstrating that there is a profound analogy—perhaps even a direct relationship—between mind-wandering and creative thinking.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. Basadur M, Graen GB, Green SG: **Training in creative problem solving: effects on ideation and problem finding and solving in an industrial research organization**. *Organ Behav Hum Perform* 1982, **30**:41-70.
2. Campbell DT: **Blind variation and selective retention in creative thought as in other knowledge processes**. *Psychol Rev* 1960, **67**:380-400.
3. Finke RA, Ward TB, Smith SM: *Creative Cognition: Theory, Research, and Applications*. Cambridge MA: MIT Press; 1992.
4. Sternberg RJ: **Implicit theories of intelligence, creativity, and wisdom**. *J Pers Soc Psychol* 1985, **49**:607.
5. Roberts RM: *Serendipity: Accidental Discoveries in Science*. Wiley; 1989.
6. Baird B, Smallwood J, Mrazek MD, Kam JWY, Franklin MS, Schooler JW: **Inspired by distraction: mind wandering facilitates creative incubation**. *Psychol Sci* 2012, **23**:1117-1122.
7. Sawyer K: **The cognitive neuroscience of creativity: a critical review**. *Creat Res J* 2011, **23**:137-154.
8. Singer JL, Schonbar RA: **Correlates of daydreaming: a dimension of self-awareness**. *J Consult Psychol* 1961, **25**:1.
9. Singer JL, Antrobus JS: **A factor-analytic study of daydreaming and conceptually-related cognitive and personality variables**. *Percept Motor Skills* 1963, **17**:187-209.
10. Christoff K, Mills C, Andrews-Hanna JR, Irving ZC, Thompson E, Fox KC, Kam JW: **Mind-wandering as a scientific concept: cutting through the definitional haze**. *Trends Cogn Sci* 2018.
11. • Christoff K, Irving ZC, Fox KCR, Spreng RN, Andrews-Hanna JR: **Mind-wandering as spontaneous thought: a dynamic framework**. *Nat Rev Neurosci* 2016, **17**:718-731.

This article puts forward a detailed neurocognitive framework in which mind-wandering and creative thinking are closely associated in a single cognitive state space encompassing many forms of self-generated thought.

12. Seli P, Kane MJ, Smallwood J, Schacter DL, Maillet D, Schooler JW, Smilek D: **Mind-wandering as a natural kind: a family-resemblances view**. *Trends Cogn Sci* 2018, **22**:479-490.
13. Mills C, Rafaelli Q, Irving ZC, Stan D, Christoff K: **Is an off-task mind a freely moving mind? Examining the relationship between different dimensions of thought**. *Conscious Cogn* 2018, **58**:20-33.
14. Andrews-Hanna JR, Smallwood J, Spreng RN: **The default network and self-generated thought: component processes and dynamic control**. *Ann N Y Acad Sci* 2014, **1316**:29-52.
15. • Fox KCR, Andrews-Hanna JR, Christoff K: **The neurobiology of self-generated thought from cells to systems: integrating evidence from lesion studies, human intracranial electrophysiology, neurochemistry, and neuroendocrinology**. *Neuroscience* 2016, **335**:134-150.

This article comprehensively reviews the evidence for the involvement of the medial temporal lobe in self-generated thought and relates this work to research on creativity.

16. Fox KCR, Andrews-Hanna JR, Mills C, Dixon ML, Markovic J, Thompson E, Christoff K: **Affective neuroscience of self-generated thought**. *Ann N Y Acad Sci* 2018. Special Issue: The Year in Cognitive Neuroscience.
17. Kaufman JC, Beghetto RA: **Beyond big and little: the four c model of creativity**. *Rev Gen Psychol* 2009, **13**:1.
18. Csikszentmihalyi M: *Creativity: Flow and the Psychology of Discovery and Invention*. New York: Harper Perennial; 1996.
19. Fox KCR, Christoff K: **Metacognitive facilitation of spontaneous thought processes: when metacognition helps the wandering mind find its way**. *The Cognitive Neuroscience of Metacognition*. Springer; 2014:293-319.
20. Antrobus JS, Singer JL, Greenberg S: **Studies in the stream of consciousness: experimental enhancement and suppression of spontaneous cognitive processes**. *Percept Motor Skills* 1966, **23**:399-417.
21. Mason MF, Norton MI, Van Horn JD, Wegner DM, Grafton ST, Macrae CN: **Wandering minds: the default network and stimulus-independent thought**. *Science* 2007, **315**:393-395.
22. Lilly JC: **Mental effects of reduction of ordinary levels of physical stimuli on intact, healthy persons**. *Psychiatr Res Rep* 1956.
23. Lilly JC: *The deep self*. New York: Simon & Schuster; 1977.
24. Hobson JA, Pace-Schott EF, Stickgold R: **Dreaming and the brain: toward a cognitive neuroscience of conscious states**. *Behav Brain Sci* 2000, **23**:793-842.
25. Domhoff GW: *The Emergence of Dreaming: Mind-Wandering, Embodied Simulation, and the Default Network*. Oxford University Press; 2017.
26. Klinger E: **Modes of normal conscious flow.**. *The Stream of Consciousness*. Springer; 1978:225-258.
27. Klinger E: **Daydreaming and fantasizing: thought flow and motivation**. In *Handbook of Imagination and Mental Simulation*. Edited by Markman KD, Klein WMP, Suhr JA. Psychology Press; 2008:225-239.
28. Killingsworth MA, Gilbert DT: **A wandering mind is an unhappy mind**. *Science* 2010, **330**:932.
29. Shake MC, Shulley LJ, Soto-Freita AM: **Effects of individual differences and situational features on age differences in mindless reading**. *J Gerontol Series B: Psychol Sci Soc Sci* 2015, **71**:808-820.
30. Fox KCR, Girn M: **Neural correlates of self-generated imagery and cognition throughout the sleep cycle**. In *The Oxford Handbook of Spontaneous Thought: Mind-wandering, Creativity, and Dreaming*. Edited by Fox KCR, Christoff K. Oxford University Press; 2018:371-384.
31. Raichle ME, Mintun MA: **Brain work and brain imaging**. *Annu Rev Neurosci* 2006, **29**:449-476.
32. Christoff K, Gordon AM, Smallwood J, Smith R, Schooler JW: **Experience sampling during fMRI reveals default network and executive system contributions to mind wandering**. *Proc Natl Acad Sci U S A* 2009, **106**:8719-8724.
33. Fox KCR: **Neural origins of self-generated thought: insights from intracranial electrical stimulation and recordings in humans**. In *The Oxford Handbook of Spontaneous Thought: Mind-wandering, Creativity, and Dreaming*. Edited by Fox KCR, Christoff K. Oxford University Press; 2018:165-179.
34. Fox KCR, Spreng RN, Ellamil M, Andrews-Hanna JR, Christoff K: **The wandering brain: meta-analysis of functional neuroimaging studies of mind-wandering and related spontaneous thought processes**. *NeuroImage* 2015, **111**:611-621.
35. Hassabis D, Kumaran D, Vann SD, Maguire EA: **Patients with hippocampal amnesia cannot imagine new experiences**. *Proc Nat Acad Sci* 2007, **104**:1726-1731.
36. Fox KCR, Nijeboer S, Solomonova E, Domhoff GW, Christoff K: **Dreaming as mind wandering: evidence from functional neuroimaging and first-person content reports**. *Front Hum Neurosci* 2013, **7**:412.
37. Greenberg R, Pearlman C, Brooks R, Mayer R, Hartmann E: **Dreaming and Korsakoff's psychosis**. *Arch Gen Psychiatry* 1968, **18**:203-209.
38. Torda C: **Dreams of subjects with bilateral hippocampal lesions**. *Acta Psychiatr Scand* 1969, **45**:277-288.
39. •• McCormick C, Rosenthal CR, Miller TD, Maguire EA: **Mind-wandering in people with hippocampal damage**. *J Neurosci* 2018:1812-1817.

The first study to directly investigate the impact of hippocampal lesions on mind-wandering, showing that self-generated thought in these patients is severely impoverished.

40. Gelbard-Sagiv H, Mukamel R, Harel M, Malach R, Fried I: **Internally generated reactivation of single neurons in human hippocampus during free recall**. *Science* 2008, **322**:96-101.

41. Curot J, Busigny T, Valton L, Denuelle M, Vignal J-P, Maillard L, Chauvel P, Pariente J, Trebuchon A, Bartolomei F: **Memory scrutinized through electrical brain stimulation: a review of 80 years of experiential phenomena**. *Neurosci Biobehav Rev* 2017, **78**:161-177.

42. •• Ellamil M, Fox KCR, Dixon ML, Pritchard S, Todd RM, Thompson E, Christoff K: **Dynamics of neural recruitment surrounding the spontaneous arising of thoughts in experienced mindfulness practitioners**. *NeuroImage* 2016, **136**:186-196.

The first neuroimaging study to carefully investigate the neural correlates of spontaneously arising thoughts. The authors found clear evidence for the critical role of the medial temporal lobe, as well as the default network more broadly– findings consonant with the neural basis of creative thinking.

43. •• Beaty RE, Benedek M, Silvia PJ, Schacter DL: **Creative cognition and brain network dynamics**. *Trends Cogn Sci* 2016, **20**:87-95.

A detailed review of the emerging understanding of the brain networks involved in creative generation and evaluation. The review highlights default and executive network interaction as a consistent neural signature across studies of creative cognition and artistic performance. The authors propose that default-executive interaction may reflect a mode of goal-directed self-generated thought, similar to directed forms of mind-wandering.

44. Rubin RD, Watson PD, Duff MC, Cohen NJ: **The role of the hippocampus in flexible cognition and social behavior**. *Front Hum Neurosci* 2014, **8**.

45. Duff MC, Kurczek J, Rubin R, Cohen NJ, Tranel D: **Hippocampal amnesia disrupts creative thinking**. *Hippocampus* 2013, **23**:1143-1149.

46. McCaig RG, Dixon M, Keramatian K, Liu I, Christoff K: **Improved modulation of rostrolateral prefrontal cortex using real-time fMRI training and meta-cognitive awareness**. *Neuroimage* 2011, **55**:1298-1305.

47. Seli P, Risko EF, Smilek D, Schacter DL: **Mind-wandering with and without intention**. *Trends Cogn Sci* 2016.

48. •• Golchert J, Smallwood J, Jefferies E, Seli P, Huntenburg JM, Liem F, Lauckner ME, Oligschläger S, Bernhardt BC, Villringer A: **Individual variation in intentionality in the mind-wandering state is reflected in the integration of the default-mode, fronto-parietal, and limbic networks**. *Neuroimage* 2017, **146**:226-235.

The first study to investigate the neural correlates of intentionally-initiated mind-wandering. The authors found that individuals who deliberately mind-wander more often showed increased cortical thickness in, and increased functional connectivity between, executive and default regions. An important step toward understanding the 'evaluation' stage of creative thinking with respect to self-generated thought.

49. Fox KCR: **Functional neuroanatomy of self-generated thought: investigating general brain recruitment, specific neural correlates, and neural origins using functional magnetic resonance imaging and diffusion tensor imaging**. *Psychology*. Vancouver, Canada: University of British Columbia; 2016. PhD Thesis.

50. Ellamil M, Dobson C, Beeman M, Christoff K: **Evaluative and generative modes of thought during the creative process**. *Neuroimage* 2012, **59**:1783-1794.

51. Liu S, Erkkinen MG, Healey ML, Xu Y, Swett KE, Chow HM, Braun AR: **Brain activity and connectivity during poetry composition: toward a multidimensional model of the creative process**. *Hum Brain Mapp* 2015.

52. Diaz BA, Van Der Sluis S, Moens S, Benjamins JS, Migliorati F, Stoffers D, Den Braber A, Poil S-S, Hardstone R, Van't Ent D: **The Amsterdam resting-state questionnaire reveals multiple phenotypes of resting-state cognition**. *Front Hum Neurosci* 2013, **7**.

53. Andrews-Hanna JR, Kaiser RH, Turner AEJ, Reineberg A, Godinez D, Dimidjian S, Banich M: **A penny for your thoughts: dimensions of thought content and relationships with individual differences in emotional well-being**. *Front Percept Sci* 2013.

54. Franklin MS, Mrazek MD, Anderson CL, Smallwood J, Kingstone A, Schooler JW: **The silver lining of a mind in the clouds: interesting musings are associated with positive mood while mind-wandering**. *Front Psychol* 2013, **4**.

55. Stawarczyk D: **Phenomenological properties of mind-wandering and daydreams**. In *The Oxford Handbook of Spontaneous Thought: Mind-wandering, Creativity, and Dreaming*. Edited by Fox KCR, Christoff K. Oxford University Press; 2018:193-214.

56. Andrews-Hanna JR, Reidler JS, Huang C, Buckner RL: **Evidence for the default network's role in spontaneous cognition**. *J Neurophysiol* 2010, **104**:322-335.

57. Stawarczyk D, Majerus S, Maj M, Van der Linden M, D'Argembeau A: **Mind-wandering: phenomenology and function as assessed with a novel experience sampling method**. *Acta Psychol (Amst)* 2011, **136**:370-381.

58. Poerio GL, Totterdell P, Miles E: **Mind-wandering and negative mood: does one thing really lead to another?** *Conscious Cogn* 2013, **22**:1412-1421.

59. Gorgolewski KJ, Lurie D, Urchs S, Kipping JA, Craddock RC, Milham MP, Margulies DS, Smallwood J: **A correspondence between individual differences in the brain's intrinsic functional architecture and the content and form of self-generated thoughts**. *PLoS One* 2014, **9** e97176.

60. Stawarczyk D, Cassol H, D'Argembeau A: **Phenomenology of future-oriented mind-wandering episodes**. *Front Psychol* 2013, **4**.

61. Simonton DK: **Creativity as blind variation and selective retention: Is the creative process Darwinian?** *Psychol Inq* 1999, **10**:309-328.

62. McMahon D: *Divine Fury: a History of Genius*. Basic Books; 2013.

63. DuPre E, Spreng RN: **Rumination is a sticky form of spontaneous thought**. In *The Oxford Handbook of Spontaneous Thought: Mind-wandering, Creativity, and Dreaming*. Edited by Fox KCR, Christoff K. Oxford University Press; 2018:509-520.

64. Ehlers A, Hackmann A, Michael T: **Intrusive re-experiencing in post-traumatic stress disorder: Phenomenology, theory, and therapy**. *Memory Cogn* 2004, **12**:403-415.

65. Seli P, Risko EF, Purdon C, Smilek D: **Intrusive thoughts: linking spontaneous mind wandering and OCD symptomatology**. *Psychol Res* 2017, **81**:392-398.