Title
Beyond Memory: Goal-Structured Dynamics in Spontaneous Thought

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 48(0)

Author
Li, Yizhi

Publication Date
2026

Beyond Memory:

Goal-Structured Dynamics in Spontaneous Thought

Yizhi Li
Institute of Philosophy II, Ruhr-Universität Bochum, Bochum, Germany

Abstract

A complete theory of spontaneous thought must explain not only content but also dynamics: how the stream unfolds over time. Recent memory-centric accounts characterize these dynamics as fundamentally associative. I argue that such accounts cannot accommodate goal-structured dynamics: sequences in which successor selection is governed by instrumental relevance to a goal rather than by associative strength. Drawing on evidence from spontaneous planning, I show that goal-structured dynamics genuinely occur within mind wandering. I propose a dual-driver model in which memory and cognitive control jointly generate the stream: memory drives associative drift, while control imposes goal-structured organization when an automatically activated goal recruits executive resources. On this view, the spontaneous stream is heterogeneous, shifting fluidly between associative and goal-structured phases.

Keywords: spontaneous thought; mind wandering; cognitive control; memory; planning

Introduction

Spontaneous thought—paradigmatically, mind wandering—is among the most familiar phenomena of mental life. In moments of rest or during undemanding tasks, attention drifts away from the immediate environment, and the mind becomes occupied by self-generated scenes, inner speech, plans, worries, and imagined conversations (Delamillieure et al., 2010; Fox et al., 2015; Killingsworth & Gilbert, 2010; Smallwood & Schooler, 2015). This phenomenon has fascinated thinkers across centuries. William James, in his seminal work on consciousness, famously characterized thought as something that "does not appear to itself chopped up in bits" but rather flows continuously "like a river or a stream" (James, 1890). This metaphor of the stream of consciousness captures an essential feature of spontaneous thought: its temporally extended, dynamic flowing nature.[1]

In recent years, a growing body of work has emphasized the deep connections between mind wandering/spontaneous thought and memory systems (Andreasen et al., 1995; Christoff et al., 2004; Mildner & Tamir, 2019, 2024; O'Callaghan et al., 2021; Wamsley, 2018). The contents of spontaneous thought are typically self-generated rather than perceptually driven, suggesting that memory systems provide much of the raw material for the wandering mind. Neurocognitive research has identified partially overlapping mechanisms and networks implicated in both memory and spontaneous thought, including medial temporal lobe (MTL) structures and the default mode network (DMN) (Andrews-Hanna et al., 2014; Fox et al., 2015). Building on these connections, a family of what I will call memory-centric accounts has been proposed, treating memory not merely as the content-provider from which material of spontaneous thought is drawn, but as the primary "engine" that drives spontaneous thought (Mildner & Tamir, 2019; Mills et al., 2018; Wamsley, 2018).

Memory-centric accounts are theoretically attractive. They promise to explain a puzzling phenomenon by reducing it to better-understood memory processes. If spontaneous thought is a phenomenological reflection of memory consolidation (Wamsley, 2018), or is generated by mechanisms such as pattern completion (Mills et al., 2018) or unconstrained memory retrieval (Mildner & Tamir, 2019, 2024), then the rich body of memory research can be brought to bear on the wandering mind. However, I will argue that these accounts face a fundamental limitation, one that stems from their treatment of cognitive control as external to the generative mechanism.

A complete theory of spontaneous thought must explain not only what we think about when the mind wanders (content), but also how the stream of thought unfolds over time (dynamics). Memory-centric accounts can accommodate the former but struggle with the latter, even though some attempt to address it. A substantial portion of spontaneous thought exhibits what I call goal-structured dynamics: sequences of thought organized around a goal representation, in which transitions are governed by instrumental relevance to that goal rather than by associative strength. Such goal-structured dynamics require cognitive control as a constitutive component of the generative mechanism itself.

The paper proceeds as follows. I first distinguish the content and dynamics dimensions of spontaneous thought. I then review memory-centric accounts, focusing on Mildner and Tamir's (2019) influential framework and its explicit commitment to association-based generation. Next, I introduce the concept of goal-structured dynamics and argue that it is distinct from associative dynamics: whereas the latter selects successors by associative strength, the former

[1] The term "spontaneous thought" covers a range of phenomena (Christoff et al., 2016), including dreaming, creative ideation, and mind wandering. In this paper, unless otherwise specified, I use it to refer specifically to mind wandering.

selects by instrumental relevance to a maintained goal. Using spontaneous planning as a diagnostic case, I present converging evidence that goal-structured dynamics genuinely occur within mind wandering. Finally, I outline a dual-driver model that incorporates cognitive control into the generative architecture and consider the methodological implications for studying spontaneous thought.

Dynamics as Explanandum

According to Christoff et al.'s (2016) dynamic framework, spontaneous thought is a mental state, or sequence of mental states, that arises relatively freely because its contents and transitions are subject to relatively weak constraints. The framework distinguishes two broad sources of constraint: deliberate constraints (cognitive control) and automatic constraints (e.g., sensory salience). Mind wandering occupies an intermediate position: it is more constrained than dreaming but less constrained than fully goal-directed thought.

Two aspects of this definition matter for present purposes. First, mind wandering is not defined as control-free; it falls within an intermediate region in which control may be present to varying degrees. Both behavioral evidence on central-executive involvement (Teasdale et al., 1995) and neuroscientific evidence of frontoparietal-default network co-activation during mind wandering (Christoff et al., 2009; Fox et al., 2015) converge on the view that control is often involved in spontaneous thought. What this existing work has not yet specified, however, is *how* control shapes the dynamic flow of spontaneous thought, a question this paper takes up.

Second, spontaneous thought is explicitly characterized as a temporally extended phenomenon: a stream of thought that unfolds over time. Contemporary research often emphasizes content-based characterizations of mind wandering: task-unrelated thought, stimulus-independent thought, or thought about goals, the self, the future, or social content. These characterizations are important but incomplete. They specify what mind wandering is about while remaining silent on how it unfolds. I will use the term **thought-transition dynamics** for the way a stream of thought unfolds from one state to the next: how one thought gives rise to a successor, and how sequences maintain coherence or shift topics. Dynamics is not an optional add-on; it is part of the explanandum of spontaneous thought research once we treat spontaneous thought as a temporally extended episode rather than as isolated content.

The importance of dynamics becomes clear when we note that the same content can appear in very different streams. The thought of a colleague's birthday cake might enter consciousness as an associative item, triggered by seeing a chocolate cake in a café, and then rapidly cascade by associative proximity into thoughts about the colleague's work. Or it might arise during planning for the party, embedded in deliberation about what cake to buy and what gift to choose. What differs is not what is thought, but the transition dynamics: how successive thoughts are selected and linked (for example, by associative contiguity versus goal- and plan-constrained successor selection).

To preview what follows, I will argue that a distinctive form of goal-structured dynamics cannot be accounted for by existing memory-based approaches, largely because they under-specify or ignore the role of control in shaping transitions. Yet this kind of goal-structured dynamics does occur within spontaneous thought.

Memory-Centric Accounts: A very brief review

Although memory-centric accounts share the core commitment that certain memory processes or mechanisms are central to the generation of spontaneous thought, closer inspection reveals that they advance importantly different mechanistic claims about how memory and spontaneous thought are related. In brief, they diverge along at least two dimensions: (1) which memory processes or mechanisms they emphasize, and (2) which aspect of spontaneous thought they aim to explain (for example, its onset, occurrence, or dynamics). Once the relevant memory process is specified, it also largely constrains what each account takes to be the function(s) of spontaneous thought. Given space limitations, I can provide only a very brief review of a few major memory-centric accounts and will largely set aside their functional claims (See **Table 1**). Among them, Mildner and Tamir's unconstrained memory framework is the most fully developed memory-centric account and will therefore receive a more detailed discussion; my argument about goal-structured dynamics and the role of control in spontaneous thought will also be developed primarily against this account as background.

Wamsley (Graveline & Wamsley, 2015; Wamsley, 2013, 2018) argued that mind wandering is the phenomenological reflection of memory consolidation during waking rest, though subsequent work suggests that spontaneous thought may interfere with rather than reflect consolidation.

O'Callaghan et al. (2021) proposed that hippocampal sharp-wave ripples (SWRs)—endogenously generated neural events during quiescent states—may trigger some mind-wandering episodes by activating memory traces that propagate to the default network. The hypothesis is explicitly modest in scope and remains speculative because SWRs are difficult to measure in humans. It also faces neuropsychological challenges: McCormick et al. found that patients with selective bilateral hippocampal lesions mind wander as frequently as controls, though with altered content, concluding that the hippocampus is "not necessary for the instigation of spontaneous thought per se (2018, p. 2752)."

Unlike the preceding accounts, Mills et al. (2018) explicitly treat dynamics as part of the explanandum and offer a neurally grounded proposal: hippocampal pattern completion is assumed to produce cascading activations, such that one completed memory cues the next, yielding a self-propagating stream that purportedly supports episodic efficiency and semantic optimization. The account thus targets how spontaneous thought unfolds over time. However, as in Mildner and Tamir's framework discussed below, its dynamics are ultimately characterized as purely association-based, even if the relevant associative links are modulated by contextual factors. The limitations of association-based dynamics will become clearer in the next section's discussion of Mildner and Tamir.

Table 1. Memory-Centric Accounts of Spontaneous Thought

Account	Memory Mechanism	Aspect Explained	Proposed Function
Wamsley (2013, 2018); Graveline & Wamsley (2015)	Memory consolidation; offline replay of recent experiences during waking rest	Occurrence: why mind wandering frequently happens during waking rest	Memory consolidation; strengthening and reorganizing recently encoded information
O'Callaghan et al. (2021)	Hippocampal sharp-wave ripples (SWRs);	Onset: what triggers mind wandering during waking rest;	Memory consolidation; maintaining cognitive maps; etc.
Mills et al. (2018)	Pattern completion; cascading activations where each completed memory cues the next	Dynamics: how one thought gives rise to the next via pattern completion	Episodic efficiency (reducing interference); semantic optimization
Mildner & Tamir (2019)	Associative retrieval via CMR model; drifting context determining which associations are active	Dynamics: how the stream of thought unfolds over time; transition patterns	Memory optimization (implicit); not primary focus

Note. CMR = Context Maintenance and Retrieval model; SWR = sharp-wave ripple.

Mildner and Tamir's Unconstrained Memory Framework

Mildner and Tamir (2019) propose that spontaneous thought is a relatively unconstrained memory search process. Their framework is built on three observations: both memory search and spontaneous thought exhibit (1) dynamic continuity, (2) associative structure, and (3) state-dependence. To explain how the stream flows, they propose a four-level hierarchical framework. At the foundational level, episodic memory supplies the raw experiential content that populates spontaneous thought. This content is scaffolded by semantic memory, which provides the abstract conceptual structure necessary for constructing novel simulations. To characterize the dynamics of how thought traverses this memory space, Mildner and Tamir invoke computational models from memory research: foraging theory and random walk models explain how retrieval moves through semantic clusters, with foraging determining when to switch between patches and random walks characterizing local exploration within patches.

At the third level, drifting context determines which region of memory space to explore. Drawing on the Context Maintenance and Retrieval (CMR) model from free recall research, Mildner and Tamir propose that multiple contextual factors shape retrieval: semantic associations, temporal context (when events occurred), and source context (the conditions under which information was encoded). These contexts function as "spotlights" that illuminate associated items, with the most strongly illuminated item being retrieved next. Crucially, these contexts drift as each new item is retrieved, continuously updating the associative landscape. At the highest level, current state modulates the weights assigned to different context associations. Current goals, mood, and situational factors can bias the associative landscape, making certain memories more accessible. This allows the framework to accommodate goal-related content: when a goal is active, it can increase the weight on goal-relevant associations.

Crucially, this is an association-based architecture. The computational models characterize retrieval as movement through associative space. Current state can bias which associations are weighted more heavily, but it does not change the fundamental nature of transition dynamics: the stream is shaped entirely by association, albeit weighted association.

While this framework represents a significant advance in explaining the dynamics of spontaneous thought, it faces a fundamental limitation. By treating all thought transitions as ultimately associative, the framework cannot accommodate sequences in which the dynamic principle is not associative strength but instrumental relevance to a goal.

An obvious objection is that goal-structured sequences can be accommodated within the associative framework by treating an active goal as a strong modulatory bias that upweights goal-relevant associations. This objection fails because associative and goal-structured dynamics differ along two connected dimensions.

First, the locality of the constraint. In associative dynamics, even when context or current state introduces persistent influences, their effect at each step is exerted through local associative links: they reweight which neighbor wins the local competition. The modulator persists, but its effect at every step is implemented locally. In goal-structured dynamics, by contrast, a maintained goal representation guides selection across multiple transitions, unifying the sequence under a single organizing constraint rather than relying solely on successive local links.

Second, the selection principle. In associative dynamics, even after modulatory reweighting, transitions are still governed by associative relationships. In goal-structured dynamics, successor selection is governed by instrumental relevance to the goal. Crucially, this can operate across associative gaps: successive thoughts that share no strong pre-existing associative connection in memory space, yet are linked by their roles in advancing a shared goal. Consider mentally planning a meeting: "I need to meet my colleague" leads to "I could suggest lunch on campus," then to "I should send him an email tonight." It is not obvious that "send him an email tonight" is the locally strongest associate of "lunch on campus." A better explanation is that each step is selected by instrumental relevance to the overarching goal, which persists across the full sequence as a non-local organizing constraint. Producing this kind of sequence requires cognitive control.

In the next section, I will show that goal-structured dynamics in fact occur within spontaneous thought, even when the episode is not deliberately initiated.

Goal-Structured Dynamics in Spontaneous Thought

I now introduce a distinction between two modes of thought-transition dynamics.

Associative dynamics refers to a mode in which successor-thought selection is governed primarily by associative structure in memory. The stream advances via the strongest locally available links (for example, semantic similarity, episodic contiguity, or contextual overlap). Modulatory factors such as affect or current concerns can shift which associations are most salient, but they do not change the governing selection principle.

Goal-structured dynamics refers to a mode in which an active goal functions as an organizing constraint on the unfolding sequence. Successor selection is governed primarily by instrumental relevance to realizing the goal, typically exhibiting means–end coherence. Metaphorically, the question guiding the stream of conscious thought is "What is needed next to realize this goal?" rather than "What is the next strongest associative idea?"

A crucial corollary is that goals can figure in spontaneous thought in two distinct ways. A goal can enter consciousness as content as a fleeting reminder, such as "I should call my mom," after which thought drifts associatively elsewhere. This is merely a thought about a goal. Alternatively, a goal can become a control goal that organizes subsequent unfolding into a goal-directed sequence. Only the latter constitutes goal-structured dynamics: it depends on cognitive control that sustains a goal representation and uses it to guide successor selection. Memory-centric accounts can readily explain the former, insofar as an unfinished goal, as part of one's "current state," can modulate associative drift and increase the accessibility of goal-related content during spontaneous thought, but they do not explain the latter.

A critical question remains: can goal-structured dynamics genuinely occur within spontaneous thought? Three considerations frame this inquiry. First, as noted above, an influential research tradition emphasizes a role for cognitive control in spontaneous thought. Second, according to the dynamic framework (Christoff et al., 2016), spontaneous thought is typically less constrained by control than fully goal-directed cognition, not free from it. Third, the relevant "goal" in such cases need not be the product of a conscious decision or explicit intention; it can be automatically and non-deliberately activated, for example, when a current concern (see below) is triggered by an environmental cue or by an internally generated associative cue within the ongoing stream of thought.

Spontaneous Planning

One striking feature of spontaneous thought (ST) is its frequent goal/concern-related content. Fox and Beaty (2019) report that 47.7% of sampled mind-wandering thoughts were related to personal goals; other studies similarly find abundant goal- and concern-related content (Baird et al., 2011; Stawarczyk et al., 2011). This is well captured by current concerns theory, a widely accepted view according to which unfinished goals increase the accessibility of goal-relevant representations and cues, allowing them to enter consciousness without deliberate initiation. A closely related and robust feature is ST's prospective bias: spontaneous thoughts are more often future-oriented than past- or present-oriented (Smallwood et al., 2009; Song & Wang, 2012). These two features jointly motivate a natural bridge: if pending goals are frequently activated, a substantial portion of future-oriented ST should involve considering what to do next about those goals. One specific type of mental activity that links goal-relatedness and future-orientation in exactly this way is planning.

Planning is not merely thinking about a future end-state; it involves constructing or refining the means for reaching it, and is therefore a particularly diagnostic case for whether spontaneous thought can exhibit goal-structured dynamics rather than merely goal-involving associative drift. Association might sometimes be recruited for making a plan, but a stream of thoughts for plan-making involves constructing or refining a sequence of steps toward a workable plan, exhibiting means–end coherence across successive thoughts. This necessarily involves goal-structured dynamics: successor thoughts are selected on the basis of what advances plan construction.

Studies also report that planning is frequently present in mind wandering, for example, around 25% in Stawarczyk et al. (2011). However, the literature exhibits a crucial ambiguity between thoughts about plans and genuine planning. A thought about a plan (e.g., "I should buy milk at the grocery store") can enter consciousness associatively and function as prospective memory. This is not the proper planning that shows goal-structured dynamics. This ambiguity reflects a broader neglect of the dynamic dimension of spontaneous thought. Even the studies most frequently cited as evidence that spontaneous thought involves planning also exhibit this conflation: Baird et al. (2011) argue that mind wandering can involve "detailed, structured trains of thought" about future goals, yet operationalize autobiographical planning largely in content terms (future-, self-, and goal-related). Similarly, current concerns theory explains why goals become activated during spontaneous thought, but is comparatively silent about what happens after activation, namely, whether goal maintenance and stepwise successor selection emerge.

I argue that, although the existing literature does not directly demonstrate genuine planning with goal-structured dynamics in spontaneous thought, largely because goal-structured dynamics have been neglected and dominant methods such as experience sampling are not well suited to capturing the dynamics, multiple converging lines of evidence nevertheless can support its existence in spontaneous thought. Call this the spontaneous planning hypothesis.

Evidence for Spontaneous Planning Hypothesis

Phenomenological signature and structuration Future-oriented mind wandering is reported to be more structured and concrete, and to involve more inner speech than other episodes (Stawarczyk et al., 2013). Inner speech is centrally implicated in planning and self-instruction, including maintaining task sets and ordering action-relevant steps (Morin et al., 2011; Perrone-Bertolotti et al., 2014). This profile is difficult to explain if future-oriented episodes are merely goal-themed associative drift.

Control resource demands Future-oriented mind wandering is more sensitive to cognitive load than past-oriented mind wandering (Smallwood et al., 2009) and correlates with working memory capacity (Baird et al., 2011). This control-resource sensitivity is expected if future-oriented thought involves spontaneous planning, which requires cognitive control and maintaining goal representations.

Neuroscientific evidence Autobiographical planning, defined as the "identification and sequencing of steps toward achieving a goal state," recruits both the default network and the frontoparietal control network (FPCN) (Spreng et al., 2010). Crucially, Gerlach et al. (2014) distinguish process simulation (simulating steps toward a goal) from outcome simulation (simulating goal attainment): only process simulation involves DN-FPCN coupling, whereas outcome simulation involves DN coupling with reward-processing regions. The DN-FPCN co-activation observed during mind wandering is thus consistent with the involvement of genuine planning.

Behavioral evidence First, individuals who report more spontaneous thoughts generate more relevant means in means–end problem solving (Ruby et al., 2013), a signature of stepwise successor selection under an end-state constraint. Second, Medea et al. (2018) found that individuals who engaged in more future-oriented mind wandering refined their goal descriptions toward greater concreteness, including specific actions and tangible means. The authors interpret this as evidence that "we spontaneously refine the steps to achieve personal goals." Taken together, these studies are consistent with the claim that spontaneous thought, especially future-oriented mind wandering, can involve planning-like, stepwise organization or goal-structured dynamics.

The converging lines of evidence reviewed here support the spontaneous planning hypothesis: future-oriented mind wandering often involves genuine planning with goal-structured dynamics, which is based on cognitive control.

In summary, spontaneous planning inherently involves goal-structured dynamics, which require cognitive control to keep the relevant goal representation active and to guide the flow of conscious thought. In fact, the (automatically activated) goal-directed processes that arise within spontaneous thought may be diverse, with planning serving as a paradigmatic case rather than an exhaustive one. The central point is that cognitive control and goal-structured dynamics are not exclusive to deliberate cognition but can be genuinely operative within spontaneous thought. Therefore, memory-centric accounts, regardless of which memory mechanism they emphasize or whether they explicitly target dynamics, remain incomplete insofar as they neglect control.

A New Model of the Dynamics of Spontaneous Thought and Implications

In this section, I will briefly sketch a new model that explains the dynamics of spontaneous thought, and then consider the methodological implications of the foregoing discussion.

Incorporating Control: A Dual Driver Model

The foregoing analysis leads to a clear conclusion: cognitive control must be incorporated into the generative architecture of spontaneous thought. This represents a significant departure from the theoretical architecture proposed by Mildner and Tamir (2019). On their framework, the generative mechanism is purely associative, leaving control with little role in the generation of the stream.

I propose a dual-driver model of spontaneous thought. On this view, two interacting mechanisms jointly drive the stream of spontaneous thought.

Memory processes are not only content providers; they also generate a distinctive mode of thought dynamics. They supply the raw material of conscious thought, and when the stream unfolds as associative drift, they can function as the primary driver of transitions: successive contents are cued via associative structure, yielding the kind of unconstrained traversal emphasized by Mildner and Tamir.

Control processes impose goal-structured organization by actively maintaining a goal representation that constrains successor selection. Crucially, the goal in question is not explicitly adopted through deliberation; it is automatically and non-deliberately activated (for example, by a current concern cued by perceptual input or internal association) and then locally stabilized by control once it captures attention. Control evaluates candidate thoughts by instrumental relevance and selects those that advance the maintained goal, yielding goal-structured dynamics such as planning sequences and structured imagined interactions. Neither driver reduces to the other; both belong to the generative mechanism.

Yet the control involved here differs from that in deliberate, goal-directed cognition. Because the goal was not deliberately adopted, the resulting control resources are seized by the activated goal rather than intentionally deployed by the subject. In Irving's (2021) terms, such sequences are *motivated* but not fully *guided*: the goal is motivated by salient concerns, but the control it recruits lacks the hallmark of attentional guidance, namely a disposition to notice and correct deviations from the goal. As a result, the goal representations involved are typically less stable than those adopted through explicit intention, and when attention drifts away the subject does not characteristically feel pulled back. The goal-structured process simply dissolves into associative drift, either because the goal representation decays or because competing associative cues take over. Long episodes of mind wandering therefore exhibit recurrent and unintentional alternations between goal-structured and associative phases, rather than instantiating a single stable mode. The spontaneity of an episode lies not in the absence of control, but in this typically unmonitored alternation between the two modes.

The dual-driver model preserves what memory-centric accounts get right: their explanation of content, and their characterization of associatively drifting episodes based on memory processes. What it adds is the recognition that some episodes, and often some phases within episodes, are organized by a different transition principle. These goal-structured phases require control as part of what generates them.

On this view, the flow of different episodes of spontaneous thought, or different phases within a single episode, can be governed by different generative drivers. The spontaneous stream of thought is therefore heterogeneous, and its organizational mode can shift fluidly.

A crucial direction for future research is thus to understand how memory and control mechanisms interact to drive the flow of the spontaneous thought stream. The dual-driver model sketches the architecture, treating memory and control as two independent contributors, but it does not yet fully specify the dynamics of their interaction. When does an associatively cued goal recruit control? How, and under what conditions, does control disengage so that thought returns to associative drift? Addressing these questions is essential for a complete theory of spontaneous thought.

Methodological Implications and Hypotheses

The distinction between associative and goal-structured dynamics has important methodological implications for how we study spontaneous thought. In particular, recent years have seen a growing interest in using associative processes as proxies for spontaneous thought, such as FAST (the Free Association Semantic Task) (Andrews-Hanna et al., 2022; Kim Lux et al., 2022; Shin et al., 2025; See also Kérébel et al., 2024). These approaches were developed in part to overcome a limitation of traditional experience-sampling methods, which often provide content labels but are poorly suited to capturing dynamics of spontaneous thought. However, an exclusive reliance on association-based proxies risks a systematic distortion of the target phenomenon: it operationalizes spontaneous thought primarily in terms of associative drift, thereby downplaying or missing the contribution of cognitive control and goal-structured dynamics that can also organize thought streams during mind wandering.

Compared with association-based approaches that characterize resting-state spontaneous thought chiefly via semantic similarity and topic drift, the increasingly popular think-aloud paradigm offers a more promising route to capturing both associative and goal-structured dynamics. By eliciting a continuous, time-ordered verbal stream during rest or undemanding contexts, think-aloud protocols preserve temporal adjacency and segmentable "thought units", enabling analyses of higher-order sequential organization rather than only pairwise similarity (Garg et al., 2025; Raffaelli et al., 2021, 2024; Sripada & Taxali, 2020). Recent work combines think-aloud data with computational analyses of thought sequences, for example, transition-based sequence models and semantic-coherence or boundary metrics that track when the stream stabilizes versus shifts (Li et al., 2022; Su et al., 2025; Yu et al., 2025). In principle, such tools could enable a more comprehensive characterization of spontaneous thought by distinguishing associative drift from goal-constrained sequences and, crucially, by clarifying how these two dynamics or drivers interact over time. However, unless goal-structured dynamics are defined as an explicit theoretical and computational target, standard similarity- and transition-based analyses will mostly capture associative structure and may miss goal-structured segments, reducing means–end organization to coherence, topic continuity, or semantic similarity.

If the dual-driver model is correct, then think-aloud resting-state data should reveal not only associative drift but also spontaneous planning and other goal-directed sequences (multi-step, means–end organized) that arise without deliberate initiation. Moreover, topic-centered semantic clumps[2] should be heterogeneous: an association-dominated subtype driven by local semantic proximity (typically higher within-clump semantic similarity) and a goal/control-dominated subtype driven by goal-constrained successor selection (weaker dependence on local semantic proximity, thus typically relatively lower within-clump semantic similarity).

Conclusion

This paper has argued that memory-centric accounts of spontaneous thought, while valuable for explaining content and associative drift, remain fundamentally incomplete. By treating cognitive control as external to the generative mechanism, they cannot accommodate goal-structured dynamics: sequences in which successor selection is governed by instrumental relevance rather than associative strength. Evidence from spontaneous planning demonstrates that such dynamics genuinely occur within mind wandering. The dual-driver model proposed here preserves what memory-centric accounts get right while recognizing that the spontaneous stream of thought is heterogeneous, its organization shifting fluidly between associative and goal-structured phases. Understanding how memory and control interact to shape this shifting stream remains a central challenge for future research.

[2] Topic-centered semantic clumps (Sripada & Taxali, 2020; Garg et al., 2025) refer to temporally contiguous stretches of think-aloud thought units that cluster around a shared semantic topic (high within-cluster semantic relatedness), often separated by discrete "jumps" to a new topic.

Acknowledgments

I am grateful to Prof. Tobias Schlicht for his supervision and guidance. This work was supported by the German Research Foundation (DFG) in the context of funding the Research Training Group "Situated Cognition" (GRK 274877981). Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – Projektnummer GRK 274877981. Parts of this manuscript were edited for clarity and English expression using an AI chatbot. The author takes full responsibility for the content.

References

Andreasen, N. C., O'Leary, D. S., Cizadlo, T., Arndt, S., Rezai, K., Watkins, G. L., Ponto, L. L. B., & Hichwa, R. D. (1995). Remembering the past: Two facets of episodic memory explored with positron emission tomography. *The American Journal of Psychiatry*, *152*(11), 1576–1585. https://doi.org/10.1176/ajp.152.11.1576

Andrews-Hanna, J. R., Smallwood, J., & Spreng, R. N. (2014). The default network and self-generated thought: Component processes, dynamic control, and clinical relevance. *Annals of the New York Academy of Sciences*, *1316*, 29–52. https://doi.org/10.1111/nyas.12360

Andrews-Hanna, J. R., Woo, C.-W., Wilcox, R., Eisenbarth, H., Kim, B., Han, J., Losin, E. A. R., & Wager, T. D. (2022). The conceptual building blocks of everyday thought: Tracking the emergence and dynamics of ruminative and nonruminative thinking. *Journal of Experimental Psychology: General*, *151*(3), 628–642. https://doi.org/10.1037/xge0001096

Baird, B., Smallwood, J., & Schooler, J. W. (2011). Back to the future: Autobiographical planning and the functionality of mind-wandering. *Consciousness and Cognition*, *20*(4), 1604–1611. https://doi.org/10.1016/j.concog.2011.08.007

Christoff, K., Gordon, A. M., Smallwood, J., Smith, R., & Schooler, J. W. (2009). Experience sampling during fMRI reveals default network and executive system contributions to mind wandering. *Proceedings of the National Academy of Sciences*, *106*(21), 8719–8724. https://doi.org/10.1073/pnas.0900234106

Christoff, K., Irving, Z. C., Fox, K. C. R., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews Neuroscience*, *17*(11), 718–731. https://doi.org/10.1038/nrn.2016.113

Christoff, K., Ream, J. M., & Gabrieli, J. D. E. (2004). Neural basis of spontaneous thought processes. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior*, *40*(4–5), 623–630. https://doi.org/10.1016/s0010-9452(08)70158-8

Delamillieure, P., Doucet, G., Mazoyer, B., Turbelin, M.-R., Delcroix, N., Mellet, E., Zago, L., Crivello, F., Petit, L., Tzourio-Mazoyer, N., & Joliot, M. (2010). The resting state questionnaire: An introspective questionnaire for evaluation of inner experience during the conscious resting state. *Brain Research Bulletin*, *81*(6), 565–573. https://doi.org/10.1016/j.brainresbull.2009.11.014

Fox, K. C. R., & Beaty, R. E. (2019). Mind-wandering as creative thinking: Neural, psychological, and theoretical considerations. *Current Opinion in Behavioral Sciences, Creativity*, *27*, 123–130. https://doi.org/10.1016/j.cobeha.2018.10.009

Fox, K. C. R., Spreng, R. N., Ellamil, M., Andrews-Hanna, J. R., & Christoff, K. (2015). The wandering brain: Meta-analysis of functional neuroimaging studies of mind-wandering and related spontaneous thought processes. *NeuroImage*, *111*, 611–621. https://doi.org/10.1016/j.neuroimage.2015.02.039

Garg, A., Shelat, S., Gross, M. E., Smallwood, J., Seli, P., Taxali, A., Sripada, C. S., & Schooler, J. W. (2025). Opening the black box: Think Aloud as a method to study the spontaneous stream of consciousness. *Consciousness and Cognition*, *128*, 103815. https://doi.org/10.1016/j.concog.2025.103815

Gerlach, K. D., Spreng, R. N., Madore, K. P., & Schacter, D. L. (2014). Future planning: Default network activity couples with frontoparietal control network and reward-processing regions during process and outcome simulations. Social Cognitive and Affective Neuroscience, 9(12), 1942–1951. https://doi.org/10.1093/scan/nsu001

Graveline, Y. M., & Wamsley, E. J. (2015). Dreaming and waking cognition. *Translational Issues in Psychological Science*, *1*(1), 97–105. https://doi.org/10.1037/tps0000018

Irving, Z. C. (2021). Drifting and Directed Minds: The Significance of Mind-Wandering for Mental Agency. *The Journal of Philosophy*, *118*(11), 614–644. https://doi.org/10.5840/jphil20211181141

James, W. (1890). *The Principles of Psychology*. H. Holt.

Kérébel, A., Caille, J.-A., & Sackur, J. (2024). Dynamics of spontaneous thoughts: Exploration, attentional profile and the segmentation of the stream of thoughts. *Consciousness and Cognition*, *124*, 103735. https://doi.org/10.1016/j.concog.2024.103735

Killingsworth, M. A., & Gilbert, D. T. (2010). A Wandering Mind Is an Unhappy Mind. *Science*, *330*(6006), 932–932. https://doi.org/10.1126/science.1192439

Kim Lux, B., Andrews-Hanna, J. R., Han, J., Lee, E., & Woo, C.-W. (2022). When self comes to a wandering mind: Brain representations and dynamics of self-generated concepts in spontaneous thought. *Science Advances*, *8*(35), eabn8616. https://doi.org/10.1126/sciadv.abn8616

Li, H.-X., Lu, B., Chen, X., Li, X.-Y., Castellanos, F. X., & Yan, C.-G. (2022). Exploring self-generated thoughts in a resting state with natural language processing. *Behavior Research Methods*, *54*(4), 1725–1743. https://doi.org/10.3758/s13428-021-01710-6

McCormick, C., Rosenthal, C. R., Miller, T. D., & Maguire, E. A. (2018). Mind-Wandering in People with Hippocampal Damage. *The Journal of Neuroscience*, *38*(11), 2745–2754. https://doi.org/10.1523/JNEUROSCI.1812-17.2018

Medea, B., Karapanagiotidis, T., Konishi, M., Ottaviani, C., Margulies, D., Bernasconi, A., Bernasconi, N., Bernhardt, B. C., Jefferies, E., & Smallwood, J. (2018). How do we decide what to do? Resting-state connectivity patterns and components of self-generated thought linked to the development of more concrete personal goals. *Experimental Brain Research*, *236*(9), 2469–2481. https://doi.org/10.1007/s00221-016-4729-y

Mildner, J. N., & Tamir, D. I. (2019). Spontaneous Thought as an Unconstrained Memory Process. *Trends in Neurosciences*, *42*(11), 763–777. https://doi.org/10.1016/j.tins.2019.09.001

Mildner, J. N., & Tamir, D. I. (2024). Why do we think? The dynamics of spontaneous thought reveal its functions. *PNAS Nexus*, *3*(6), pgae230. https://doi.org/10.1093/pnasnexus/pgae230

Mills, C., Herrera-Bennett, A., Faber, M., & Christoff, K. (2018). Why the mind wanders: How spontaneous thought's default variability may support episodic efficiency and semantic optimization. In The Oxford Handbook of Spontaneous Thought: Mind-Wandering, Creativity, and Dreaming (pp. 11–22). https://doi.org/10.1093/oxfordhb/9780190464745.013.42

Morin, A., Uttl, B., & Hamper, B. (2011). Self-Reported Frequency, Content, and Functions of Inner Speech. *Procedia - Social and Behavioral Sciences, 2nd World Conference on Psychology, Counselling and Guidance - 2011*, *30*, 1714–1718. https://doi.org/10.1016/j.sbspro.2011.10.331

O'Callaghan, C., Walpola, I. C., & Shine, J. M. (2021). Neuromodulation of the mind-wandering brain state: The interaction between neuromodulatory tone, sharp wave-ripples and spontaneous thought. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *376*(1817), 20190699. https://doi.org/10.1098/rstb.2019.0699

Perrone-Bertolotti, M., Rapin, L., Lachaux, J.-P., Baciu, M., & Lœvenbruck, H. (2014). What is that little voice inside my head? Inner speech phenomenology, its role in cognitive performance, and its relation to self-monitoring. *Behavioural Brain Research*, *261*, 220–239. https://doi.org/10.1016/j.bbr.2013.12.034

Raffaelli, Q., Malusa, R., de Stefano, N.-A., Andrews, E., Grilli, M. D., Mills, C., Zabelina, D. L., & Andrews-Hanna, J. R. (2024). Creative Minds at Rest: Creative Individuals are More Associative and Engaged with Their Idle Thoughts. *Creativity Research Journal*, *36*(3), 396–412. https://doi.org/10.1080/10400419.2023.2227477

Raffaelli, Q., Mills, C., de Stefano, N.-A., Mehl, M. R., Chambers, K., Fitzgerald, S. A., Wilcox, R., Christoff, K., Andrews, E. S., Grilli, M. D., O'Connor, M.-F., & Andrews-Hanna, J. R. (2021). The think aloud paradigm reveals differences in the content, dynamics and conceptual scope of resting state thought in trait brooding. *Scientific Reports*, *11*(1), 19362. https://doi.org/10.1038/s41598-021-98138-x

Ruby, F. J. M., Smallwood, J., Sackur, J., & Singer, T. (2013). Is self-generated thought a means of social problem solving? *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00962

Shin, W.-G., Ahn, J., Choe, K. W., Lee, H., Han, J., Lee, E., Lux, B. K., Woo, C.-W., Choi, I., & Sul, S. (2025). Happier individuals generate more spontaneous thoughts about friends and value relationships over money. *Communications Psychology*, *3*(1), 162. https://doi.org/10.1038/s44271-025-00341-3

Smallwood, J., Nind, L., & O'Connor, R. C. (2009). When is your head at? An exploration of the factors associated with the temporal focus of the wandering mind. *Consciousness and Cognition*, *18*(1), 118–125. https://doi.org/10.1016/j.concog.2008.11.004

Smallwood, J., & Schooler, J. W. (2015). The Science of Mind Wandering: Empirically Navigating the Stream of Consciousness. *Annual Review of Psychology*, *66*(1), 487–518. https://doi.org/10.1146/annurev-psych-010814-015331

Song, X., & Wang, X. (2012). Mind Wandering in Chinese Daily Lives – An Experience Sampling Study. *PLOS ONE*, *7*(9), e44423. https://doi.org/10.1371/journal.pone.0044423

Spreng, R. N., Stevens, W. D., Chamberlain, J. P., Gilmore, A. W., & Schacter, D. L. (2010). Default network activity, coupled with the frontoparietal control network, supports goal-directed cognition. *NeuroImage*, *53*(1), 303–317. https://doi.org/10.1016/j.neuroimage.2010.06.016

Sripada, C., & Taxali, A. (2020). Structure in the stream of consciousness: Evidence from a verbalized thought protocol and automated text analytic methods. *Consciousness and Cognition*, *85*, 103007. https://doi.org/10.1016/j.concog.2020.103007

Stawarczyk, D., Cassol, H., & D'Argembeau, A. (2013). Phenomenology of future-oriented mind-wandering episodes. *Frontiers in Psychology*, *4*, 425. https://doi.org/10.3389/fpsyg.2013.00425

Stawarczyk, D., Majerus, S., Maj, M., Van der Linden, M., & D'Argembeau, A. (2011). Mind-wandering: Phenomenology and function as assessed with a novel experience sampling method. *Acta Psychologica*, *136*(3), 370–381. https://doi.org/10.1016/j.actpsy.2011.01.002

Su, H., Li, X., Born, S., Honey, C. J., Chen, J., & Lee, H. (2025). Neural dynamics of spontaneous memory recall and future thinking in the continuous flow of thoughts. *Nature Communications*, *16*(1), 6433. https://doi.org/10.1038/s41467-025-61807-w

Teasdale, J. D., Dritschel, B. H., Taylor, M. J., Proctor, L., Lloyd, C. A., Nimmo-Smith, I., & Baddeley, A. D. (1995). Stimulus-independent thought depends on central executive resources. *Memory & Cognition*, *23*(5), 551–559. https://doi.org/10.3758/BF03197257

Wamsley, E. J. (2013). Dreaming, waking conscious experience, and the resting brain: Report of subjective experience as a tool in the cognitive neurosciences. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00637

Wamsley, E. J. (2018). Dreaming and waking thought as a reflection of memory consolidation. In *The Oxford Handbook of Spontaneous Thought: Mind-Wandering, Creativity, and Dreaming* (pp. 457–468). https://doi.org/10.1093/oxfordhb/9780190464745.013.23

Yu, Y., Raffaelli, Q., Freveletti, D., Brossart, J. J., Andrews, E., Wilcox, R. R., Grilli, M. D., & Andrews-Hanna, J. R. (2025). Mapping content and dynamics in the stream of consciousness through latent brain state analysis. *iScience*, *28*(11), 113755. https://doi.org/10.1016/j.isci.2025.113755