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On second thoughts: Testing the underlying mechanisms of spontaneous future thought

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ABSTRACT

The human capacity to imagine possible future events unintentionally, with minimal cognitive effort, is termed spontaneous future thought (SFT). This paper addresses an important theoretical question for cognitive science: What are the possible cognitive mechanisms underlying such SFT experiences? We contrasted three hypotheses present in the literature: the *online construction hypothesis*, the *recasting hypothesis*, and the *memories of future thoughts hypothesis*. Study 1 ($N = 41$) used novel subjective ratings which challenged the recasting mechanism: SFTs were mostly rated as dissimilar to autobiographical memories, suggesting they are not simply past experiences 'recast' as future events. Study 2 ($N = 90$) used a novel experimental paradigm, comparing effects of voluntary episodic future constructions and non-personal narratives upon subsequent spontaneous thought sampling. Results suggested that voluntary future constructions remain accessible to spontaneous retrieval, supporting the memories of future thoughts hypothesis. This finding, and other data presented across the two studies, still indicates a role for online construction processes in SFT, but further empirical work is needed to clarify how and when constructive processes are engaged in SFT. Taken together, these two studies represent initial efforts to elucidate the mechanisms underlying SFT, providing the first proof-of-principle that deliberately envisioned future events can reappear, without intention, in consciousness at some later time, and further supporting the dual process account of future thinking. These methods and findings provide a firm basis for subsequent experimental and longitudinal research on SFT.

1. Introduction

In daily life, humans spend extensive time mentally simulating future scenarios, both mundane and significant, that may or may not transpire. Increased recognition of this fact in the scientific community has heralded a rapid expansion in theoretical, empirical and applied future thinking research (Michaelian et al., 2016; Schacter et al., 2012, 2017). Episodic future thinking is defined as the ability to imagine novel specific events, such as a future trip to a local beach with friends, including sensory-perceptual details (e.g., the smell of the sea) and a subjective sense of 'pre-experiencing' (Addis et al., 2007; D'Argembeau & Van Der Linden, 2004; Schacter et al., 2012). Popular paradigms designed to investigate future thinking typically rely on voluntary or strategic cognitive processes (e.g., Addis et al., 2009; D'Argembeau & Van Der Linden, 2004) to elicit thought reports and thereby investigate commonalities and differences between past and future thought (e.g., Hassabis & Maguire, 2007; Schacter & Addis, 2007; see Cole and Kvavilashvili, 2019, for a review).

Only recently have investigators focused on *spontaneous* cognitive processes in relation to future thoughts. This topic encompasses the spontaneous activation of future thoughts in cue-word tasks (Jeunehomme & D'Argembeau, 2016) and clinically-relevant future projections (Holmes et al., 2016), as well as *spontaneous future thoughts* (SFTs, also termed *involuntary future thoughts* and *involuntary future mental time travel*), or conscious mental simulations of the future that come to mind without intent (Berntsen & Jacobsen, 2008; Cole and Kvavilashvili, 2019). The latter have recently been examined using a specialized method designed to mimic the monotonous contexts in which spontaneous future thoughts occur in daily life (Cole et al., 2016; Plimpton et al., 2015; Vannucci et al., 2017). Humans spend a great deal of time simulating and planning the future (Szpunar et al., 2013), but here we are interested in instances when a 'fully-formed' future thought (including sensory-perceptual details and a sense of pre-experiencing) enters consciousness *spontaneously* (e.g., imagining receiving a speeding fine after driving fast; Berntsen & Jacobsen, 2008).

Specifically, we focus on a critical theoretical question which has

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thus far received scant empirical attention (with some exceptions – Barzykowski et al., 2019; Mazzoni, 2019; Vannucci et al., 2019): What are the possible cognitive mechanisms through which SFTs enter consciousness? Clarifying these mechanisms is essential for understanding the ontological basis of spontaneous future thinking (i.e., what SFT *is* in the context of cognitive science, and where it is placed in relation to other entities; see Cole and Kvavilashvili, 2019). Moreover, it is of substantial applied value, for instance in enhancing understanding of mental health conditions in which spontaneous mental imagery is a component (e.g., PTSD, Berntsen & Nielsen, 2022; depression, Holmes et al., 2016) and informing interventions which rely on spontaneous imagery (see Blackwell et al., 2020).

To this end, we present two complementary studies that examine three hypotheses about the cognitive basis of SFT from different methodological angles. These hypotheses draw upon long-standing theoretical debates around the concept of the 'engram' and the constructive nature of episodic memory (e.g., De Brigard, 2014; Michaelian, 2011; Moscovitch & Melo, 1997; Semon, 1904). Firstly, the *online construction hypothesis* (Berntsen & Jacobsen, 2008) suggests that SFTs arise through rapid constructive processes analogous to involuntary autobiographical remembering (see also Berntsen, 2010). Conversely, the *recasting hypothesis* holds that SFTs involve the re-tagging of stored past experiences as future thoughts – a reactivated 'engram' of a veridical experience, superimposed with a different temporal orientation (Mahr et al., 2021). Finally, the *memories of future thoughts hypothesis*, introduced by Cole et al. (2016), posits that SFT involves the re-emergence of a previous, voluntarily constructed future thought – a reactivated 'engram' of an imagined event (Cole & Kvavilashvili, 2021).

Study 1 examined autobiographical SFTs inside and outside the laboratory, measuring their subjective characteristics (e.g., degree of 'engram' re-emergence), whereas Study 2 introduced a new experimental paradigm (VEST: *Voluntary Encoding / Spontaneous Thought*), based on experimenter-induced future thoughts. To foreshadow our findings, Study 1 challenged the recasting hypothesis and Study 2 provided initial evidence that intentionally encoded future episodes can re-emerge spontaneously as 'memories of the future', with an open question around the extent of online construction processes that may also be involved. Despite recent interest in the characteristics, clinical relevance and developmental origins of SFT (Cole and Kvavilashvili, 2019), this is the first attempt to systematically characterise the mechanisms underlying its occurrence since its emergence as an object of scientific investigation (Berntsen & Jacobsen, 2008).

1.1. Underlying cognitive processes of episodic memory and involuntary autobiographical memory

As future thinking (and particularly SFT) are relatively new concepts, it is important to review the cognitive basis of related and more extensively researched phenomena. Here, we outline key theories of autobiographical episodic memory, and involuntary autobiographical memory, laying the foundations for understanding voluntary and spontaneous episodic future thinking.

Autobiographical episodic memories are mental representations of prior personal experiences that contain some sensory-perceptual detail (e.g., colour of the sky, the sound of someone's voice) and are accompanied by a subjective sense of remembering or recollection (Conway, 2005; Tulving, 2002). This is a relatively consensual definition, but for more than a century, researchers of memory have debated the extent to which autobiographical memory retrieval is a fundamentally *constructive* or *replicative* process. Consistent with key theorists (Conway, 2005; Moscovitch, 1992; Tulving, 2002), we define 'constructive' memory retrieval as a dynamic, conscious or nonconscious process whereby elements or details from past experiences are brought together to form a retrieved memory that meets task demands (e.g., remembering one's previous birthday party). Memory traces are combined at retrieval in ways that might lead to misremembering or false memories, due to scripts and expectancies (De Brigard, 2014). Here we use this more restrictive retrieval-based definition because (re)construction continues to be principally linked with retrieval, in involuntary and voluntary memory research (Berntsen & Nielsen, 2022; Conway & Howe, 2022) and this process directly maps on to the 'construction phase' referred to in future thinking research (Schacter et al., 2012).

In contrast, 'replicative' memory retrieval implies an experienced event returning to consciousness as an intact whole, re-capturing key veridical elements from encoding, as exemplified by Semon's (1904) classic theory. On this view, memories of specific past events exist in the form of an 'engram' – a physical (brain-mediated) representation of an encoded memory which is stored and retrieved as a whole on exposure to (internal or environmental) memory cues (Semon, 1904). Although Semon's ideas fell out of favour (Schacter, 2001), several lines of evidence highlight a resurgence of support in them. In an important study of episodic memory, Horner and Burgess (2014) asked participants to encode simulated episodes consisting of triads (place, person, object/animal), and cued retrieval using one element of the 'episode'. Crucially, findings showed neural reinstatement of the whole triad at retrieval, evidenced by hippocampally-indexed neocortical activity in regions associated with re-experiencing the 'episodic engram' (Horner & Burgess, 2014; see also Johnson & Rugg, 2007).

Additionally, studies have now provided evidence supporting episodic engrams in mice, based on measuring and manipulating subpopulations of neurons supporting particular memory traces (Tonegawa et al., 2018). The possibility that mnemonic content may be retrieved 'fully formed' in this way also receives support from cognitive research on PTSD, which conceives of the disorder's characteristic flashbacks as long-lasting perceptual memory traces that "are not altered in any way but remain intact and may be vividly reexperienced again in the future" (Brewin & Holmes, 2003, p. 355; see also Ehlers & Clark, 2000). One implicit assumption of this approach is that under certain cueing conditions: *memory can be replicative*.

Most contemporary memory researchers implicitly or explicitly view autobiographical memories as being heavily influenced by constructive processes (e.g., Barry & Maguire, 2019; Conway, 2005; Neisser, 1997; Schacter & Addis, 2007). Several lines of evidence support this view: strong effects of schemas on memory retrieval (Bartlett, 1932; Roediger & McDermott, 1995); memory distortion by post-event information (Loftus, 2003); and confidently retrieved false memories (Loftus, 2003; Moscovitch & Melo, 1997). We highlight two prominent theories of episodic memory retrieval which focus on constructive processes: (1) Conway (2005) *Self-Memory System*, whereby episodic retrieval relies on a top-down constructive process that interacts with autobiographical knowledge and current goals; and (2) Schacter and Addis' (2007) *Constructive Episodic Simulation Hypothesis*, whereby an error-prone (re) constructive episodic memory system provides humans with an ability to flexibly combine mnemonic elements into episodic future thoughts (as well as recollecting past events in a similarly flexible manner). However, we acknowledge that the *non-veridicality* of episodic memories, sometimes taken as support for a constructive viewpoint (Berntsen & Nielsen, 2022), does not necessarily imply deliberate (re)construction because retrieved content could fluctuate due to other non-deliberate processes such as attentional limitations at encoding or retrieval.

Next, we turn our attention to autobiographical memories that come to mind unbidden (i.e., without a voluntary retrieval process) – termed *involuntary autobiographical memories* (Berntsen, 2010). If we equate memory construction with a 'retrieval mode' (i.e., adopting a deliberate task set), can involuntary autobiographical memories be considered 'constructions'? There are two main views on this question. Berntsen answers in the affirmative, arguing that involuntary memories are not veridical replications of prior experiences but result from the operation of several constraints at retrieval, such as current goals, the incidental presence of environmental cues and the principle of cue-item discriminability (Berntsen, 2010, 2021). A contrasting view proposes a special mechanism allowing direct access to memory traces under involuntary retrieval conditions. In a voluntary cue-word paradigm, Uzer et al. (2012) found that specific memories occurred frequently *without* intermediate access to autobiographical knowledge, arguing that 'prestored event representations' (or episodic engrams) must underlie rapid retrieval of involuntary memories (see also Conway & Pleydell-Pearce, 2000). Similarly, a group of clinical theories emphasise neuropsychological processes enabling the re-experiencing of sensory-perceptual event details based on a relevant retrieval cue (Brewin & Holmes, 2003; Ehlers & Clark, 2000).

We have so far demonstrated (1) that the modern view of episodic memory arguably relies on an original memory trace or 'engram' that is nonetheless subject to change (and distortion) over time (Cheng et al., 2016; Conway, 2005; Moscovitch, 1992); and (2) that involuntary autobiographical memory can be seen either as a constructive process or as a sensory-perceptual 'replay' of a past experience. These themes are important when considering underlying cognitive mechanisms of SFT.

1.2. Future thinking: shifting from the voluntary to the spontaneous

As with studies of autobiographical memory (Crovitz & Schiffman, 1974), research on future thinking has typically used the cue-word technique (Addis et al., 2009) in which participants are asked to construct future events related to different cue words (e.g., *park*). This has been beneficial in allowing researchers to investigate the neural processes involved in constructing voluntary future thoughts (henceforth VFTs; Schacter & Addis, 2007; Irish & Piguet, 2013; Conway, 2005). However, a by-product of its popularity has been an unintended reduction in the focus on *spontaneous* future thoughts despite their prevalence in daily life (Cole and Kvavilashvili, 2019). Indeed, recent studies have challenged the dominant view that access to future thoughts typically involves voluntary reconstruction, with laboratory studies finding that cue-word paradigms may have substantially underrepresented directly retrieved future thoughts (Jeunehomme & D'Argembeau, 2016).

In contrast to studies of voluntary future thinking, SFT research has largely proceeded within laboratory paradigms that sample mental experiences whilst individuals engage in unrelated simple cognitive tasks (Baird et al., 2011; Cole et al., 2016; McVay & Kane, 2010, 2013; Plimpton et al., 2015; Vannucci et al., 2017). This 'dual-task' setup mimics the contexts in which SFTs naturally occur (i.e., routine daily activities; Berntsen & Jacobsen, 2008). While methods have varied, several consistent findings have emerged: SFTs occur rapidly (average latency = 3.6 s after a self-reported trigger, versus 14 s for VFTs; Cole et al., 2016); they arise in moments of low to moderate task demands (Cole et al., 2016; Smallwood et al., 2009); and are typically related to one's personal concerns and autobiographical planning – sometimes to a greater extent than personal memories (Baird et al., 2011; Cole & Berntsen, 2016; Stawarczyk, Cassol, & D'Argembeau, 2013). They also differ in content from VFTs – for instance, they are more often specific and have greater emotional impact – mirroring differences between involuntary and voluntary autobiographical memories (Cole et al., 2016). In Study 1 (testing SFTs from everyday life *and* the lab versus voluntary future thoughts), these well-known differences from extant research will be analyzed to assess reliability across these wide-ranging studies.

1.3. Underlying mechanisms of SFT: three candidate hypotheses

As outlined above, contemporary theories of autobiographical memory highlight constructive processes, at least when a strategic retrieval mode is engaged (Conway, 2005; Moscovitch, 1992). Similarly, prominent theories of episodic future thinking emphasise constructive processes when mnemonic details are bound together into novel scenarios (Addis, 2020; Hassabis & Maguire, 2007; Irish & Piguet, 2013; Schacter & Addis, 2007). However, a paradox emerges when applying construction processes to spontaneous future thinking: How can SFTs, experienced so rapidly and without intention, involve the operation of constructive mechanisms? One may look for answers in the involuntary memory literature; yet, as the events concerned in SFT have (definitionally) not been experienced, context-dependent mechanisms such as encoding specificity (Conway, 2005; Tulving & Thomson, 1973) and cue-item discriminability (Berntsen et al., 2013) may be insufficient, as they both presume representations originate in the encoding of a veridical event.

Although little prior research has specifically targeted the cognitive mechanisms underlying SFT, including the role of internal / external cues in triggering SFTs, several plausible (and not necessarily mutually exclusive) hypotheses are discernible in the literature. Here we outline three of them: (1) the online construction hypothesis; (2) the recasting hypothesis; and (3) the memories of future thoughts hypothesis. These are summarized in Fig. 1.

According to the online construction hypothesis, constructive processes are involved whenever a future thought is experienced, whether voluntarily or spontaneously (Berntsen, 2019): Elements from memory are recombined to construct novel SFTs (see Fig. 1). After an SFT is constructed and available to consciousness, it is then identified as future-oriented via distinct, semantic categorization processes (Berntsen & Jacobsen, 2008). Although such processes have yet to be outlined in detail, they could involve reference to higher-order autobiographical knowledge (as demonstrated for voluntary constructions; Ben Malek, Berna, & D'Argembeau, 2017) and/or inferences based on phenomenological properties, e.g., level of sensory-perceptual detail. The latter would be consistent with the Reality Monitoring Framework (Johnson & Raye, 1981), which holds that internally and externally generated thoughts are distinguished in this way. SFTs can be considered internally generated thoughts in the sense of lacking a counterpart in past experience (Perrin, 2021); and indeed, show lower levels of specificity and detail than involuntary memories captured via the same method (Cole et al., 2016).

Some support for online construction derives from the proportion of SFTs reported to be completely novel (~30% described as 'never previously experienced'; Cole et al., 2016). We take construction in this context to mean "spreading activation in the same autobiographical memory network as would support the construction of memories for past events" (Berntsen & Jacobsen, 2008, p. 10). This view is consistent with Berntsen (2019), Berntsen, 2021) elaborated theory regarding construction processes underlying involuntary memories. We highlight and empirically test this hypothesis, as it represents a candidate mechanism underlying SFT.

The hypothesis is tested in Study 1 using targeted rating scales assessing SFTs' similarity to a) memories and b) previous future thoughts. The hypothesis will be supported if SFTs are shown to be highly novel, i.e., eliciting low ratings on both similarity scales. SFTs then can consist of combinations of episodic details (i.e., object, place, person, emotion; Levine et al., 2002) that have never occurred together in the past (either in experience or simulation). This would be consistent with the proposed function of spontaneous thoughts in enhancing creativity and generating novel ideas (Smallwood & Schooler, 2015). The difference between this and the memories of future thoughts hypothesis is in essence a question of whether SFTs emerge 'afresh' through the operation of constructive processes (online construction) or are stored as an integrated whole that re-emerges spontaneously in replicative fashion.

According to the recasting hypothesis, SFTs consist of experience-derived memories (i.e., of past events), which are re-tagged at retrieval as future-oriented representations. This view of SFTs is particularly relevant when one considers common events that could reasonably occur in either the past or future (e.g., a dentist check-up). However, recasting would be an inflexible way to imagine the future, reducing its future-oriented planning functions (Suddendorf & Corballis, 2007). Additionally, it has only been shown to be relevant in voluntary future thinking when the semantic system is unavailable (e.g., in

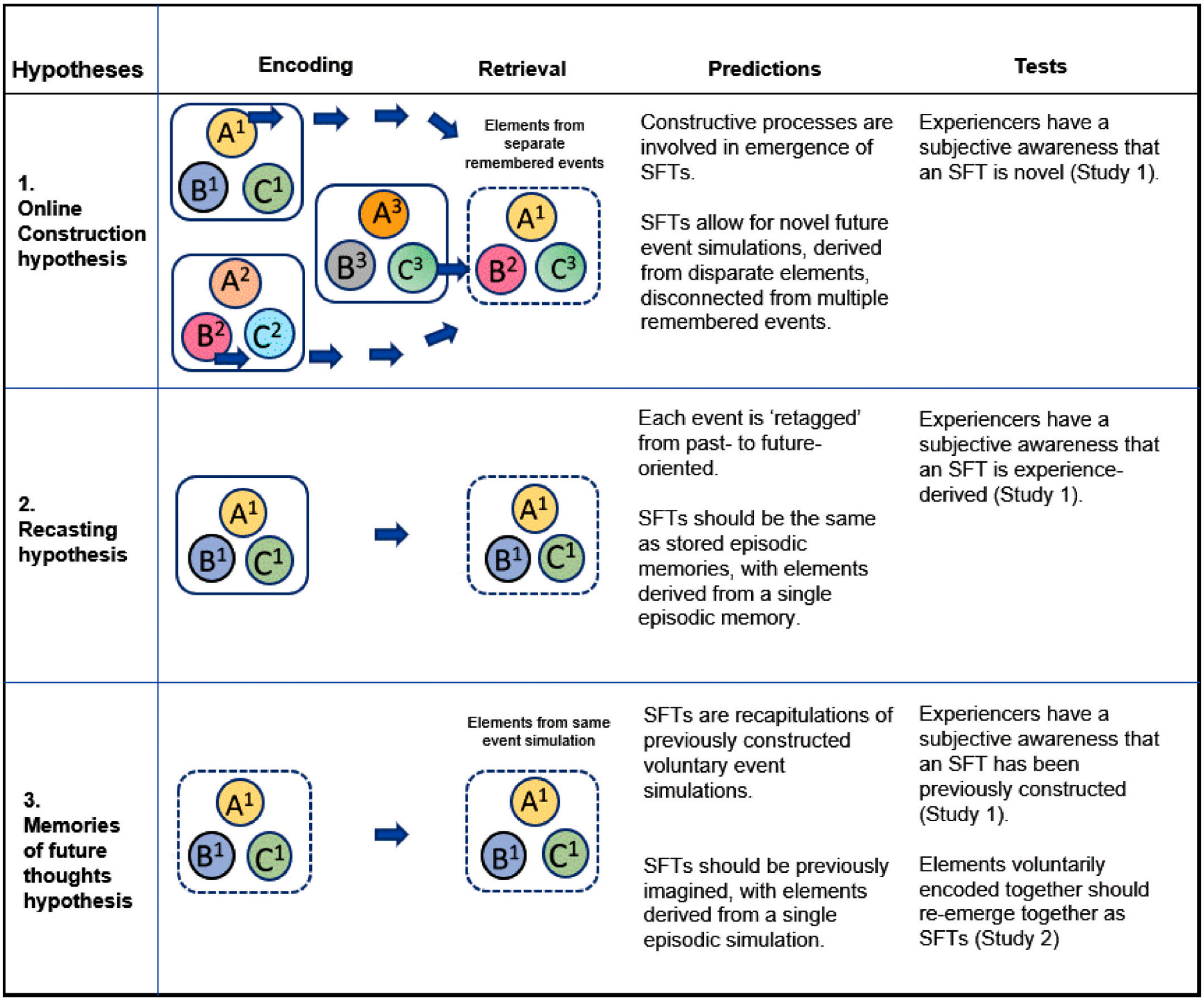

Fig. 1. Schematic of three hypotheses concerning the underlying mechanisms of SFT.
Note. A schematic outline of three hypotheses relevant to underlying mechanisms of spontaneous future thinking [SFT] (left), with relevant predictions and empirical tests (right) [letters A,B,C represent 'episodic elements', squares represent 'episodic complexes' [dotted outline = future-oriented; solid outline = past-oriented/ experience-derived]. Although not the focus of the current paper, we acknowledge the substantial role of semantic memory and related processes in future thinking (Irish & Piguet, 2013).

semantic dementia; Irish et al., 2012). Indeed, within the VFT literature, researchers have used a paradigm that prevents recasting to illustrate the importance of novel recombination of details in future simulations (i.e., the *experimental recombination paradigm*; Addis et al., 2010). The fact that similar effects are observed here as in standard cue-word tasks – for example, age effects (Addis et al., 2008; Addis et al., 2010) – implies that such recombination is representative of VFT processes in general. Nonetheless, recasting could still be relevant in explaining the cognitive basis of SFT given that simple 're-tagging' of past events would be consistent with the rapid and subjectively effortless occurrence of SFTs (Cole et al., 2016). Similar to the memories of future thoughts hypothesis, this invokes the notion of a prestored event representation or 'episodic engram' – yet one relying on experience-derived, as opposed to simulation-derived, material. We note that it may not be necessary to consciously recall a past event for it to be recast in a future direction: It may simply have been experienced previously.

Finally, what we term the memories of future thoughts hypothesis was initially described in Cole et al. (2016) and later outlined in detail in Cole and Kvavilashvili (2021) in their dual process account of voluntary and spontaneous future thinking. Cole and Kvavilashvili (2021) proposed that SFTs are recapitulations of preceding, voluntarily constructed plans or simulations (Szpunar et al., 2013). Therefore, their rapid emergence in consciousness (compared to the extended time course of VFT construction) is explained by positing the existence of *simulation-derived* stored memory representations (cf. 'episodic engram' above). These have been labelled 'memories of the future' (Cole et al., 2016; Cole & Kvavilashvili, 2021; Jeunehomme & D'Argembeau, 2016; Szpunar et al., 2013). The origins of this phrase can be traced to Ingvar (1985), who proposed that action plans (e.g., complex motor sequences) are stored as 'memories of the future'. It has also been used to refer to future thoughts arising under voluntary task instructions that are identified as having been experienced previously (Jeunehomme & D'Argembeau, 2016, 2017). If SFTs can be traced to pre-existing, voluntarily constructed event representations (see Fig. 1), this potentially negates the need for constructive processes at the point of retrieval (see above for similar arguments related to involuntary memory; Uzer et al., 2012).

By this account, VFTs and SFTs are underwritten by qualitatively different cognitive processes, operating on the same content at different points in time.

Evidential support comes from a study of direct and generative processes in future thinking, which found that the likelihood of a cue word directly triggering a future thought (in a voluntary task) was determined by frequency of prior related thoughts (Jeunehomme & D'Argembeau, 2016). More specifically, SFTs arising in a monotonous vigilance task are more likely (compared with VFTs) to be associated with prior related thoughts (Cole et al., 2016). Lastly, when SFTs are thematically coded, three studies have shown a clear prevalence of pre-existing plans among autobiographical SFT content (Mazzoni, 2019; Plimpton et al., 2015; Warden et al., 2019). A direct prediction that follows from this hypothesis is that a high proportion of SFTs should be replications of previous VFTs (Cole & Kvavilashvili, 2021). This possibility will be tested through subjective measures of *similarity to previous voluntary future thoughts* (Study 1) and experimental manipulation of prior VFT encoding (Study 2; see Fig. 1).

1.4. Summary of studies

The studies presented below use a laboratory paradigm eliciting SFTs during a vigilance task interspersed with cue-word phrases (Cole et al., 2016). In Study 1, we adopted a self-caught method for capturing spontaneous thoughts (see Smallwood & Schooler, 2015), adding novel measures to evaluate evidence for the three hypotheses outlined above. We also sought to further validate the basic method by demonstrating convergence with a naturalistic (diary) measure of SFT. In Study 2, we combined the vigilance task with a voluntary episodic construction task modelled on those of Addis and colleagues (Addis et al., 2007; Addis et al., 2009) to examine the hypothesis that deliberately encoding possible future events would lead to spontaneous retrieval of the simulated events (i.e., simulation-derived memories). It is important to highlight the potential for several alternate 'routes' to experiencing SFTs, which may vary in use depending on psychological or environmental context (see General Discussion). Nevertheless, overall, by systematically evaluating these hypotheses, the paper represents a step-change in understanding SFT's underlying cognitive mechanisms.

2. Study 1

This study assessed SFTs and VFTs under controlled laboratory conditions, alongside everyday SFTs captured via the diary method. There were two lab sessions spaced 6 days apart: SFTs were assessed using a vigilance task in Session 1 and VFTs were assessed using a standard cue-word task in Session 2. In the 5-day interval between sessions, participants recorded SFTs during daily life using a mini diary booklet (Berntsen & Jacobsen, 2008). Everyday SFTs were assessed to establish convergent validity between laboratory and naturalistic measures of SFT (measured via a regression to assess whether the frequency of laboratory SFTs predicts that of everyday SFTs), which has to our knowledge not been examined.

The paradigm used to elicit SFTs in the laboratory was piloted extensively in Cole et al. (2016). This paradigm incorporates minimal ratings at the time of SFT occurrence to avoid undue disruption to the vigilance task and to reduce meta-cognitive effects of monitoring (Smallwood & Schooler, 2006). After participants complete the vigilance task, they revisit each thought and provide more extensive retrospective ratings (see *2.1.4. Procedure*).

The principal aim of Study 1 was to use established experimental tasks (Cole et al., 2016; Crovitz & Schiffman, 1974), augmented by novel subjective measures, to address three hypotheses concerning the underlying mechanisms of SFTS. Specifically, participants reported the extent to which the content of each future thought was similar to previous experience-derived memories (i.e., veridical past events) and similar to previous simulations (i.e., voluntarily constructed future thoughts).

The online construction hypothesis was assessed by examining the degree to which constructive processes may be at play, operationalized as the deviation between the content of SFTs and prior simulations (i.e., putatively allowing more constructive re-integration of episodic details into novel episodes). On this view, such reintegration should be present for both voluntary and spontaneous future thoughts; therefore ratings of similarity to prior simulations should generally be low and should not differ between these two tasks. The same measure was used to examine the memories of future thoughts hypothesis, which would instead predict *high* levels of similarity to prior simulations – indicating substantial overlap in content – for SFTs but not for VFTs (which themselves facilitate novel construction).

The recasting hypothesis was assessed via the extent to which SFTs resemble participants' experience-derived memories: Under this hypothesis, ratings should indicate high correspondence between experience-derived memories and SFTs. However, even if SFTs are recast, we predicted that VFTs would remain novel (not recast memories), based on prior work by Addis et al. (2010). Hence, we should detect a significant difference between SFT and VFT tasks on this measure.

Additionally, we assessed the *information source* of SFT content by asking participants whether their SFTs were derived from episodic memories, general autobiographical knowledge, or media (see Anderson, 2012). Although this was not expected to discriminate directly between hypotheses (all proposed mechanisms rely on episodic memories, in different ways), it was included to further characterise the process of SFT (i.e., whether details are derived from personal experience or other sources).

Participants also rated thoughts on effort (defined as the extent to which they actively brought them to mind), and hence expected to clearly differentiate voluntary from spontaneous thoughts, as found in previous studies (e.g., Cole et al., 2016). Several other constructs were measured: Mood impact, like specificity, allowed us to assess the extent to which our data replicated previous basic findings on SFT whereby SFTs are more impactful and specific (Cole et al., 2016). Emotional valence of future thoughts was measured but not analyzed here as this was not the focus of the present study.

2.1. Method

2.1.1. Design

This study implemented a within-subjects design with three conditions: laboratory SFTs, diary SFTs, and VFTs (see Fig. 2). The study was approved by the [Details omitted for double-anonymized reviewing].

2.1.2. Participants

A target sample size of 40 was determined a priori based on samples used in previous studies with comparable within-subjects designs (e.g., Schlagman & Kvavilashvili, 2008). The study was advertised as a study of concentration, and only those who not had previously taken part in any SFT studies were eligible to participate. We recruited 51 participants at [Details omitted for double-anonymized reviewing], of whom 10 were excluded. Exclusions were due to self-reported significant mental illness, neurological disorder and/or brain injury ($n = 3$); failure to understand one of the tasks ($n = 1$); partial responses ($n = 1$); and dropouts between time 1 and 2 ($n = 5$), leaving data from 41 who completed both laboratory sessions but did not provide the diary ($M_{age} = 26.3$, $SD = 10.1$, range 18–60) and 38 participants who completed all three components ($M_{age} = 26.3$, $SD = 10.4$, range 18–60). All participants who completed the study received a £16 voucher.

2.1.3. Materials

SFT and VFT laboratory tasks are illustrated in Fig. 2. To ensure elicitation of a sufficient number of SFTs, we used an existing paradigm successfully applied in recent studies (Cole et al., 2016; Schlagman &

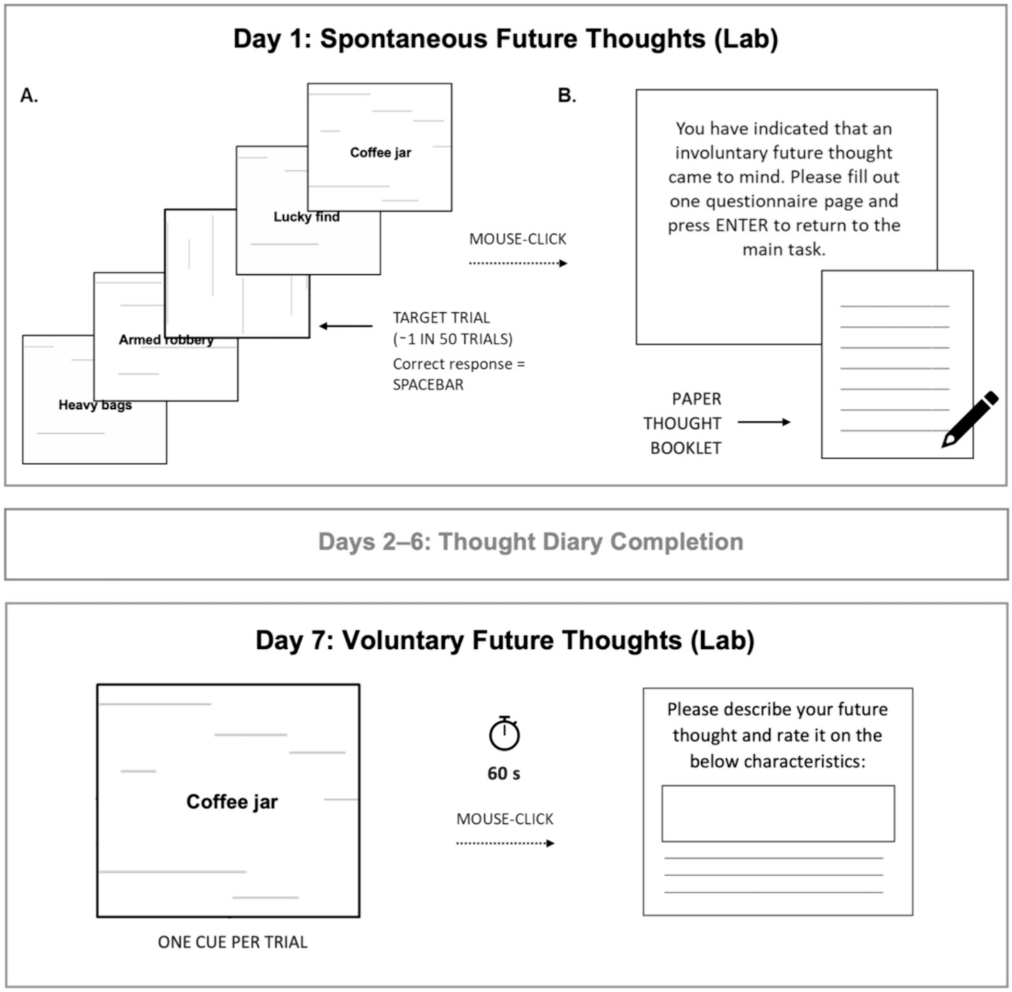

Fig. 2. Schematic diagram of Study 1 procedure (Day 1: A = vigilance task; B = thought reporting).

Kvavilashvili, 2008). This paradigm uses an undemanding vigilance task as a background activity to mimic the situations in which SFTs naturally occur (Berntsen & Jacobsen, 2008). Specifically, the task consisted of 600 slides presented sequentially with no inter-stimulus interval. Each slide contained two elements: line arrays and one cue phrase. Line arrays were presented in black on a white background and varied in the number of lines (4–8) and their spatial arrangement (12 variants). Most arrays were oriented horizontally (589), with 11 vertically oriented target slides appearing pseudo-randomly every 40–60 slides. Cue phrases (e.g., *coffee jar*, *lucky find*) were always presented centrally in 18-point Arial black font and were originally extracted from a database of participant-generated triggers (see Schlagman & Kvavilashvili, 2008, for further details). The list comprised equal proportions of emotionally positive, neutral and negative phrases (200 per category). Cue phrases were presented in a fixed pseudorandom order.

The VFT task resembled that used for SFTs, with the following exceptions (see Fig. 2): Participants had the single aim of generating future thoughts voluntarily in response to cue phrases (i.e., standard cue-word task; Crovitz & Schiffman, 1974); the task contained 12 distinct cue phrases (selected from Schlagman & Kvavilashvili, 2008); and all lines were horizontal as there were no target slides. Voluntary and spontaneous cues were matched on concreteness and imageability (Cole et al., 2016; Schlagman & Kvavilashvili, 2008). Both laboratory tasks were presented on *E*-Prime 2.0 Professional and are available on OSF ([Details omitted for double-anonymized reviewing]). Finally, participants were restricted to reporting a maximum of 12 future thoughts in each laboratory task, to ensure parity and because piloting demonstrated that people varied between 0 and 12 SFTs ($M = 5.70$, $SD = 4.23$) and very rarely exceeded this maximum (Cole et al., 2016).

2.1.4. Procedure

Laboratory sessions ran individually in a quiet location. On arrival, each participant met a research assistant, provided informed consent, and completed an onscreen confidential questionnaire in which they were asked to self-report any significant mental illness, neurological disorder and/or brain injury. Conditions were administered in the following order: Laboratory SFTs were assessed using a vigilance task in session 1 (day 1). In session 2 (day 7) participants returned to the laboratory for an assessment of VFTs. Condition order was not counterbalanced to avoid potential contamination of SFT capture by voluntary processes if the VFT task took place first (Cole et al., 2016; Schlagman & Kvavilashvili, 2008). In the interval between sessions (days 2–6), participants recorded SFTs during daily life using a mini diary booklet.

2.1.4.1. Laboratory SFTs (Day 1). This task was introduced as an attentional vigilance task in which participants must identify infrequent vertical line arrays (targets), by pressing spacebar, in a long sequence of horizontal line arrays. They first completed a practice block of 40 trials (including 3 targets), at a rate of 1.5 s per slide with no inter-stimulus interval. A research assistant was present to check participants' understanding.

Thereafter, onscreen instructions informed participants that because the task is quite monotonous, they might experience spontaneous thoughts about goals, daydreams or memories, and that this was normal.

A detailed explanation of SFT was presented (as per Cole et al., 2016), highlighting that the thoughts must come to mind spontaneously. The following information was given to aid participants' understanding of the nature of SFT: "Involuntary future thoughts may be in the very near future or in the distant future. They may vary in detail and specificity… The only criterion we have is that your future thought came to mind spontaneously without you trying to think of something." Participants were to make a mouse-click every time they experienced an SFT. It was emphasized, however, that their primary task was still to detect vertical line targets (as in the practice block), with the future thought reporting as an adjunct (see Fig. 2, top panel).

On the participant's mouse-click, the line array sequence was replaced by a screen directing them to a 'future thought characteristics' questionnaire booklet on the table. As in previous research (e.g., Cole et al., 2016), participants were asked to give a description of their future thought, report the trigger (if known), then complete ratings of *effort* (1 = No effort at all, 5 = Extreme effort), *mood impact* (made me feel better, made me feel worse, no impact), and *event specificity* (yes / no). After the vigilance task, they then revisited each SFT report, rating their thoughts on similarity to previous FTs / memories and several other items (listed in Table 1). Experimental materials are available on OSF ([Details omitted for double-anonymized reviewing]).

After each brief thought report, the vigilance task (line arrays) resumed. To measure ongoing task performance, accuracy and RTs at detecting the 11 target slides were recorded. Additionally, the latency between each identified trigger (i.e., cue phrase) and SFT was calculated, where participants identified a cue phrase as a trigger. Although participants' descriptions of SFT triggers were mostly clear-cut, to ensure reliability, a random subset ($n = 106$) of all SFTs was classified by two research assistants as either 'cued by word phrase', 'cued by other' (e.g., concurrent thoughts or perceptions) or 'no identified cue'. Inter-rater reliability was high (Fleiss's kappa = 0.95). Rare disagreements, and instances where participants' cue phrase descriptions were absent / ambiguous, were resolved by one of the authors.

2.1.4.2. Diary phase (Days 2–6). During the interval between Sessions 1 and 2, participants were asked to keep an A7-size mini diary close at hand throughout each day and report every time they experienced an SFT (Berntsen & Jacobsen, 2008). In parity with laboratory measures, participants were asked for a thought description, and completed the same three ratings as in the brief reports (see Table 1). Here, based on prior data on SFTs in daily life (1–10 per day; Berntsen & Jacobsen, 2008), we allowed a maximum of 24 SFTs across the five days. The aim of this part was to establish convergent validity between laboratory and everyday measures of SFT. Diary booklets were returned in the second lab session, on day 7.

2.1.4.3. Voluntary future thoughts (Day 7). In this task, participants were instructed to voluntarily generate future thoughts in response to cue phrases superimposed on line arrays. Participants were given 60 s per trial to generate a future thought and report it via mouse-click (latency between cue presentation and mouse-click was recorded). If participants failed to generate a future scenario within this timeframe (i.e., by not clicking as instructed when one came to mind), the next cue slide was presented automatically. As in Session 1 and the diary phase, participants described and immediately rated each future thought on several characteristics; at the end of the session, they completed retrospective reports for all VFTs.

Table 1
Items used in the future thought characteristics questionnaire (Study 1).

Thought Report	Construct measured	Question	Response options
Brief Report (During Vigilance Task)	*1.Effort*	Please indicate to what extent you actively brought this future thought to mind	No effort at all 1 2 3 4 5 Extreme effort
	2.Mood impact	Did the imagined future thought affect your mood?	(a)Made me feel better (b)Made me feel worse (c)No impact on my mood
	3.Specificity	Does the future thought refer to a particular situation in a particular day in your future?	(a)Yes (b)No
Retrospective Report	*1. Previous future thought similarity*	Is this whole future thought exactly the same as any particular future thought you have imagined previously? Meaning, is the future thought exactly the same in terms of the emotion, details and outcome of the event you previously imagined	Not at all similar 1 2 3 4 5 Exactly the same
	2.Previous memory similarity	Is this whole future thought exactly the same as any particular memory you have? Meaning, is the future thought exactly the same in terms of the emotion, details and outcome of an event you have in memory	Not at all similar 1 2 3 4 5 Exactly the same (if response 2–5, complete question 3. If response 1, skip question 3)
	3. *Type of memory*	If the future thought is similar to a memory, please report whether the memory was	*(a)specific* (i.e., novel and duration of several minutes to a day) or *(b)general* (referring to a category of events containing a number of specific episodes), *(c)extended* (an event that lasted more than a day)
	4. *Content of future thought*	The content of future thoughts can vary. Report the main source of the content of the future thought	*(a)memory involving yourself (*You were personally involved) *(b)a situation you heard about involving another person* *(c)media* (you learnt about it from a media source, e.g., magazine, TV, internet) *(d)none of the above.* Please specify
	5. *Anticipatory emotion*	How do you currently feel when you think about this future thought	very negative −2 -1 0 1 2 very positive
	6. *Anticipated emotion*	How do you think you will feel if and when the event is experienced	very negative −2 -1 0 1 2 very positive

2.2. Results and discussion

2.2.1. Data analysis plan

Given the multilevel nature of the data (level 1 = thoughts, level 2 = participants), subjective rating data were analyzed using linear mixed-effects models, using the open-access software *Jamovi* (2021) which

Note. Questions are exactly as phrased and formatted in the booklets. Emotional valence was not the focus of this study, therefore retrospective variables 5 and 6 are not analyzed in the present manuscript.

implements the *lme4* package from R (Bates et al., 2015). Each model included random intercepts and slopes by participants for the fixed effect of thought condition (lab VFT, lab SFT, diary SFT) in line with recommendations by Barr et al. (2013). Models were of the form outcome ~1 + condition + (1 + condition | ppt), and inference was based on *F*-statistics and *p*-values for fixed effects of condition (Satterthwaite degrees of freedom). Logistic generalized mixed effects models were used for categorical outcomes. Models used restricted likelihood estimation (REML), as recommended by Brauer and Curtin (2018). Each outcome variable (effort, specificity, mood change, latency, similarity-to-memory, similarity-to-simulation) was assessed in a separate model. All post-hoc comparisons were Bonferroni corrected.

This mixed-effects approach allowed us to include participants with few thoughts, thereby retaining more data for the remaining conditions and increasing statistical power. The correspondence between diary and laboratory measures was assessed with standard correlational methods.

2.2.2. *Convergent and divergent validity of laboratory measure of SFT*

In order to assess correspondence between two methods of inducing SFTs we correlated SFTs induced in the laboratory and everyday SFTs captured using the diary method. The frequency of recorded thoughts across conditions varied: Lab VFTs ($M = 6.93$, 95% CI = 4.93–6.92), Lab SFTs ($M = 8.61$, 95% CI = 7.66–9.56), Diary SFTs ($M = 10.30$, 95% CI = 8.36–12.30). Means and 95% confidence intervals for key thought characteristics, across the three conditions, are shown in Table 2.

Concerning correspondence between laboratory and diary measures, SFT frequency estimated by both methods was significantly correlated within individuals ($r_{41} = 0.37$, $p = .02$). The bivariate relationship between SFTs experienced in the laboratory and everyday life is displayed in Fig. 3. Critically, when entered into a multiple linear regression, when laboratory-induced SFTs were entered into a model first, they predicted 14% of variance in diary SFTs (unstandardized $b = 0.72$, standardized $\beta = 0.37$, $F_{(1,36)} = 5.75$, $p = .02$) and entering VFTs in a second model did not improve the variance accounted for (Model comparison, R^2 Change $= 0.025$, $F(1,35) = 1.04$, $p = .32$). The Overall Model, with VFTs added as a predictor, remained significant ($F(2,35) = 3.40$, $p = .045$), accounting for 16% of variance.

Several planned linear mixed models were conducted with a fixed factor of condition (laboratory VFT; laboratory SFT; diary SFT) to confirm whether documented differences between voluntary and spontaneous future thoughts were replicated in our data (see Table 2 for descriptive statistics). The key model information is presented in Table 3. First, it was important to verify whether *subjective effort* differed between VFTs and SFTs elicited either in the laboratory or in everyday life. As expected, results indicated that effort differed across conditions ($F_{(2,32.6} = 17.9$, $p < .001$). Post-hoc comparisons indicated that laboratory SFTs came to mind with less effort than VFTs ($p < .001$), as did diary SFTs ($p = .001$; see Table 2), confirming a key difference between SFTs and VFTs (Cole et al., 2016). On the other hand, there was no difference between lab and diary SFTs ($p = .13$).

Future thought *specificity* also differed significantly by condition ($\chi^2_{(2)} = 14.60$, $p < .001$), with post-hoc comparisons indicating that this effect was driven by a higher degree of specificity among SFTs compared to VFTs, for both lab ($p = .03$) and diary SFTs ($p < .001$). There was no difference between laboratory and diary SFTs on specificity ($p = .84$). Finally, we examined whether SFTs were more likely to elicit a *mood change* than VFTs. There was an overall effect of condition ($\chi^2_{(2)} = 9.25$, $p = .01$); post-hoc comparisons indicated a significantly higher frequency of mood change for diary SFTs ($M = 0.65$) than VFTs ($M = 0.52$, $p = .03$) or lab SFTs ($M = 0.53$, $p = .04$). There was no significant difference in mood change between lab SFTs and VFTs ($p = 1.0$). Differences in degrees of freedom across analyses are partly explained by participant and thought numbers varying across conditions; also, because there is no one-to-one mapping of observations and degrees of freedom when using the Satterthwaite approximation. Nonetheless, all above analyses had a minimum of $N = 40$ participants and $N = 940$ thoughts.

As reaction time data were not available for diary SFTs, a mixed effects model was computed comparing *latency* for spontaneous and voluntary laboratory-elicited future thoughts (time between cue phrase and button press; see Table 2 for means). This confirmed that SFTs came to mind more rapidly than VFTs ($F_{(1,113)} = 41.6$, $p < .001$).

In sum, except for mood impact, these findings are in line with our predictions and replicate cardinal differences between voluntary and involuntary thinking (see also Barzykowski & Staugaard, 2016; Berntsen, 2010; Cole et al., 2016). Additionally, they provide further credence to the convergent validity of the laboratory and diary methods used here for eliciting SFTs. Finally, laboratory SFTs were mostly triggered by cue phrases (64.4%), followed by those with no identifiable cue (25.8%) and those with other external/internal cues (9.8%), in line with Cole et al. (2016). Diary SFTs were either triggered by identifiable internal/external cues (67.2%) or had no identifiable cue (32.8%), in line with previous work (Berntsen & Jacobsen, 2008). All voluntary future thoughts were cued by presented phrases. All subsequent analyses for Study 1 will focus on laboratory-elicited SFTs and VFTs only.

2.2.3. *Examining the three candidate mechanisms*

Similarity to experience-derived memories. This was a subjective measure of the extent to which SFTs resemble participants' experience-derived memories. The recasting hypothesis predicts ratings should indicate high correspondence between experience-derived memories and SFTs. However, voluntary future thoughts should nonetheless remain novel (not recast memories), based on prior work by Addis et al. (2010). Thus, a significant difference is expected between SFTs and VFTs.

Results indicated that, on average, participants rated SFTs and VFTs as moderately similar to previous memories (see means in Table 2). A mixed-effects model demonstrated that ratings on this scale did not differ reliably between SFTs and VFTs ($F_{(1,35.4)} = 3.71$, $p = .062$; Table 3 for model details). Only a minority (12.3% of SFTs and 17.1% of VFTs;

Table 2
Comparing voluntary and spontaneous future thoughts (estimated marginal means with 95% CIs).

	Lab VFTs		Lab SFTs		Diary SFTs	
	M	*95% CI*	*M*	*95% CI*	*M*	*95% CI*
Latency (ms)	11,226	9599–12,853	5192	3607–6777	–	–
Specificity (0–1)	0.50	0.38–0.62	0.67	0.60–0.74	0.73	0.65–0.80
Effort	2.60	2.36–2.83	1.75	1.54–1.96	2.02	1.75–2.29
Mood Change (0–1)	0.52	0.44–0.60	0.53	0.44–0.62	0.65	0.57–0.72
Previous Memory Similarity	2.83	2.51–3.14	2.55	2.33–2.76	–	–
Previous FT Similarity	2.60	2.37–2.84	3.11	2.88–3.34	–	–

Note. FT = Future thought. All characteristics were rated on a 1–5 scale unless specified otherwise. Specificity and mood change are proportional data (0–1). *N* sizes are not equal for Level 1 and Level 2 data across all conditions. In the case of reaction time, this was because we could only analyze those thoughts in the SFT condition cued by a phrase. See data on Open Science Framework for full dataset: [Details omitted for double-anonymized reviewing].

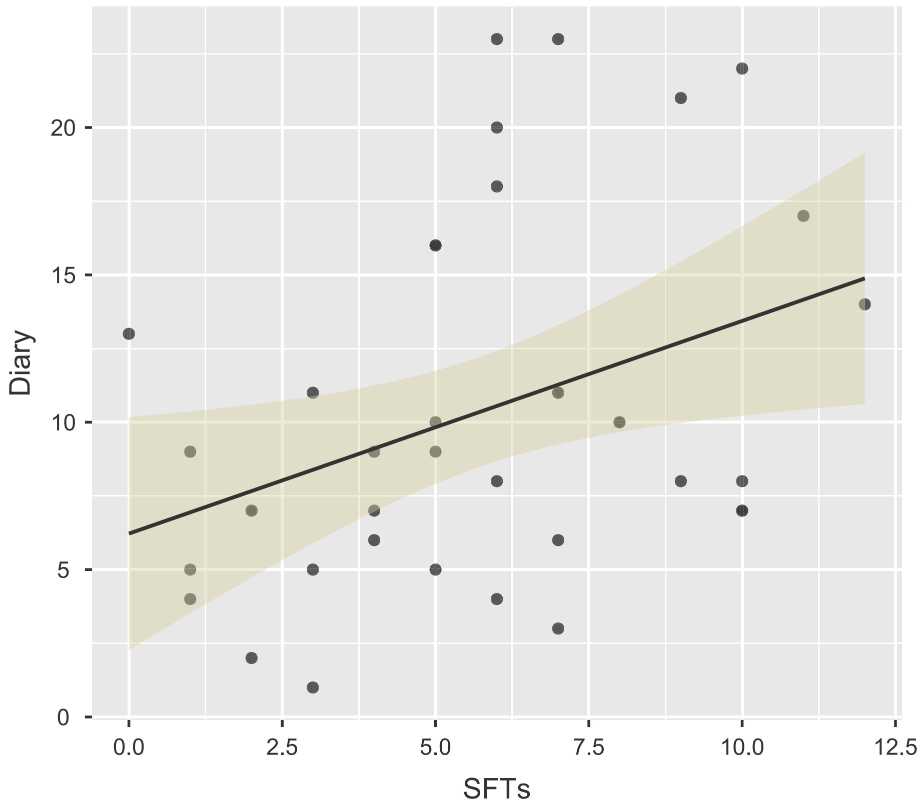

Fig. 3. Scatterplot and regression line showing the positive relationship between SFT frequency in diary and laboratory settings.

see Fig. 4a) were judged to be 'exactly the same' as a particular memory. Conversely, 36.9% of SFTs (and 30.3% of VFTs) were judged 'not at all similar' to a memory, suggesting that in many cases SFTs, like VFTs, did not consist of memories recast as future thoughts. In further conflict with the recasting hypothesis – presumed to entail the recasting of *specific* memories – the memories associated with SFTs were equally likely to be specific or general (42.6% versus 40.6%, with somewhat fewer associated with extended periods, 16.8%). Similar percentages were found for VFTs (48.3% specific, 44.8% general, 6.9% extended).

2.2.3.1. Similarity to previous future thoughts. According to the online construction hypothesis, spontaneous and voluntary future thoughts should not differ on the measure of similarity to previous future thoughts (both should elicit relatively low similarity ratings). In contrast, the memories of future thoughts hypothesis predicts that SFTs should show a significantly higher degree of similarity to previous future thoughts than VFTs.

A mixed-effects model indicated that participants rated SFTs as significantly more similar to previous future thoughts than VFTs $F_{(1,36.6)} = 12.6$, $p = .001$; see Table 3 for model details, and Table 2 for descriptives). As illustrated in Fig. 4b, opposite rating distributions were observed across the two conditions, with the most common rating being 4 for SFTs (35%) versus 1 for VFTs (28%). This indicates that, in general, SFTs were indeed rated as similar to previous future thoughts, whereas VFTs were largely rated as dissimilar. These data offer preliminary support for the memories of future thoughts hypothesis.

Finally, as VFTs and SFTs differed on their frequency of being classed as specific (see above), we repeated the two similarity analyses, with specific thoughts only, and found results comparable to those when including specific and non-specific future thoughts.

2.2.3.2. Information source of SFTs. As shown in Table 4, SFTs were predominantly reported to be drawn from autobiographical content, with far fewer drawn from other individuals or media sources. This showed a clear preference for people to select autobiographical information as the source for their future thoughts, whether spontaneous or voluntary. Chi-square goodness-of-fit tests on thought-level data to explore whether there was an association between condition – VFTs ($n = 290$) and SFTs ($n = 213$) – and source (autobiographical, other, media, misc.) indicated no significant association ($\chi^2_{(3)} = 4.13$, $p = .25$). In sum, both SFTs and VFTs relied heavily upon autobiographical information.

2.2.4. Discussion of study 1

Study 1 aimed to evaluate the merits of three candidate hypotheses in explaining SFT occurrence. Firstly, results suggested that SFTs do not simply reflect memories of previous experiences 'recast' as future-oriented representations; rather, the majority of SFTs (and VFTs) *deviated* from previous experience. This challenges the recasting hypothesis as an explanation for SFT occurrence, reflecting existing evidence on VFTs (Addis et al., 2010). Secondly, the majority of SFTs were rated as highly similar to previously constructed future thoughts (cf. Cole et al., 2016; Jeunehomme & D'Argembeau, 2016), lending support to the memories of future thoughts hypothesis: So-called 'memories of the future' may constitute the rule, rather than the exception, in SFT occurrence (Cole & Kvavilashvili, 2021). Nonetheless, some SFTs were judged as 'not at all similar' to prior simulations, indicating the potential involvement of constructive processes in some instances and leaving the online construction hypothesis a viable possibility (Berntsen & Jacobsen, 2008).

We now review some key aspects of the methodology in Study 1. The core distinction between conditions in Study 1 was the intention-to-construct. This was manipulated by either instructing participants to report spontaneous future thoughts as they occurred (SFT condition, Diary condition) or instructing participants to generate specific FTs in relation to verbal cues (VFT condition). Using this approach, individuals tend to experience more subjective effort in latter than former conditions, which was found here and elsewhere (Cole et al., 2016; see also Barzykowski et al., 2021 for related discussions in relation to memory).

Table 3
Key model information for mixed-effects models (Studies 1 and 2).

	Dependent Variable	Wilkinson-Rogers Formula	Fixed Effect Estimates [95% CI]	Random Effect Variances	Pseudo-R^2
Study 1	*Effort*	effort ~1 + cond + (1 + cond | ppt)	cond(1) = −0.84 [−1.12, −0.56] cond(2) = −0.58 [−0.84, −0.32]	Intercept = 0.266 cond(1) = 0.496 cond(2) = 0.446	0.36
	Specificity	spec ~1 + cond + (1 + cond | ppt)	cond(1) = 2.03 [1.16, 3.54] cond(2) = 2.74 [1.62, 4.64]	Intercept = 0.465 cond(1) = 1.511 cond(2) = 1.276	0.26
	Mood Change	mood ~1 + cond + (1 + cond | ppt)	cond(1) = 1.06 [0.69, 1.63] cond(2) = 1.70 [1.14, 2.54]	Intercept = 0.431 cond(1) = 0.589 cond(2) = 0.500	0.16
	Latency	latency ~1 + cond + (1 + cond | ppt)	cond = −6034 [−7868, −4200]	Intercept = 8.24 × 10^6 cond = 3.31 × 10^6	0.18
	Previous Memory Similarity	simMem ~1 + cond + (1 + cond | ppt)	cond = 0.28 [−0.00, 0.56]	Intercept = 0.385 cond = 0.298	0.23
	Previous FT Similarity	simFT ~1 + cond + (1 + cond | ppt)	cond = −0.51 [−0.79, −0.23]	Intercept = 0.204 cond = 0.363	0.20
Study 2	*Odds of Related Thought*	related ~1 + group + cue type + group*cue type + (1 + cue type | ppt)	group = 1.93 [−1.09, 3.41] cue type = 1.02 [0.58, 1.81] group*cue type = 0.74 [0.24, 2.32]	Intercept <0.001 cue type <0.001	0.03

Note. Effect estimates for generalized mixed models are exp.(B); others are *b*. Cond = condition, spec = specificity, simFT = *Previous FT Similarity*, simMem = *Previous Memory Similarity*.

Furthermore, effort is positively correlated with reaction time to form a future thought (Cole et al., 2016). However, it is important to note a problem with equating effort with construction processes as defined in this paper. We do not conflate these here – rather, effort was used as a manipulation check comparing the extent to which participants actively brought future events to mind.

Additionally, the assessment of whether a spontaneous future thought matched previously constructed future thoughts relied on a subjective judgment from participants. Although we constructed detailed scales, there is a potential issue with relying on participants' meta-awareness that a recently experienced SFT was also envisioned at an earlier time. This is indicative of the detailed experimental work on recursive remindings by Jacoby, Hintzman and others (Hintzman, 2004; Wahlheim & Jacoby, 2013), especially recursive remindings, whereby earlier learnt information is embedded in a more recent memory (Wahlheim & Jacoby, 2013) – however, as this work showed, people can be more or less aware of the earlier (embedded) memory. In Study 1, it is unclear how much our findings are due to participants' understanding of a 'replication' and how people applied their understanding based on introspecting on the content of SFTs and remembering previous VFTs. Also, generally, VFTs could vary considerably in terms of temporal distance and emotion, as they are autobiographical in nature (cf. Berntsen & Jacobsen, 2008).

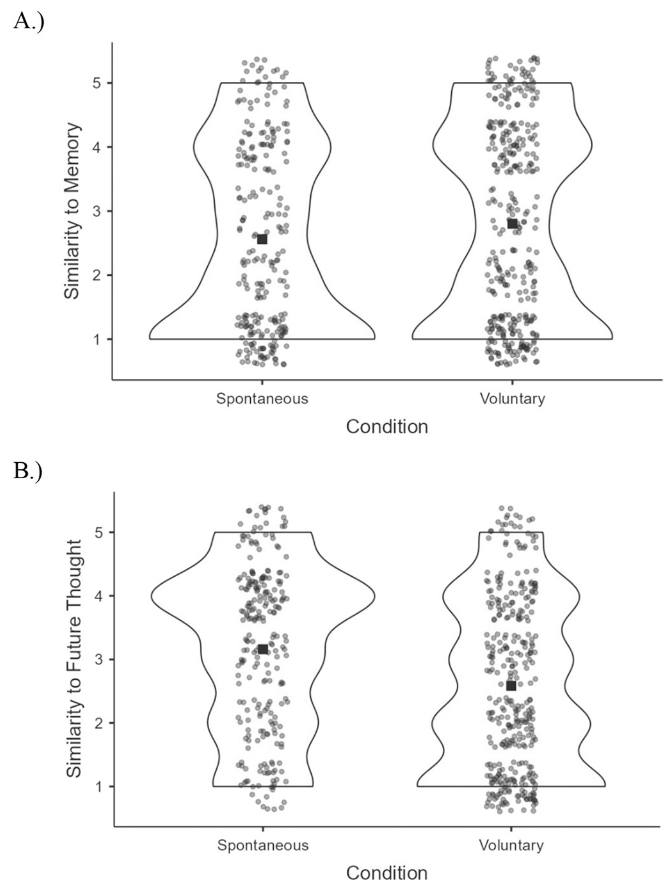

Fig. 4. A. Rating distributions for *similarity to a previous memory/experience* scale (1 = Not at all similar, 5 = Exactly the same) for SFTs and VFTs (SFTs: *n* = 243, VFTs: *n* = 343). **B.** Rating distributions for *similarity to a previously generated future thought* scale (1 = Not at all similar, 5 = Exactly the same) for SFTs and VFTs (SFTs: *n* = 244, VFTs: *n* = 346).

Table 4
Percentages (frequencies) of each information source, for laboratory VFTs and SFTs in Study 1.

Information Source	VFT	SFT
Autobiographical	87.7% (299)	83.5% (202)
Other Individuals	5.0% (17)	9.1% (22)
Media	3.5% (12)	2.9% (7)
Miscellaneous	3.2% (11)	3.7% (9)

Note. Percentages do not sum to 100% due to rare instances where people selected two sources (< 2%).

It is also important to note that similarity-to-memory and similarity-to-previous future thought continuous scales were used because future thoughts were autobiographical and hence heterogeneous and prone to more flexibility than memories. However, a binary decision between 'sameness' of the SFT to a previous future thought was possible in Study 2, whereby voluntary future thoughts were more constrained.

To overcome such limitations requires a methodology that involves experimenter-determined future event constructions, so later reinstatement of each simulation can be measured more objectively. This was the principal rationale for designing Study 2.

3. Study 2

Study 2 specifically targeted the memories of future thoughts hypothesis within a novel experimental paradigm combining voluntary and spontaneous processes (Cole & Kvavilashvili, 2021). We term this the *Voluntary Encoding / Spontaneous Thought* (VEST) paradigm. The procedure combines, in a single experimental session, a voluntary future thinking task in which participants deliberately envision possible future events in response to verbal cues (Addis et al., 2009) and a vigilance task sampling subsequent spontaneous thoughts (Cole et al., 2016; present Study 1). This formulation makes it possible to standardise and control the *encoding* of future-oriented episodic representations in the first task (Klein et al., 2012; Szpunar et al., 2013) before testing for their spontaneous reoccurrence in the second (as predicted by the memories of future thoughts hypothesis). The VEST paradigm thereby mimics the progression from deliberate construction to spontaneous retrieval presumed to underlie everyday instances of SFT, while providing an objective reference point for classifying some spontaneous thoughts as potential *repeats* of previously constructed representations.

We also included a control group, who instead of producing plausible future event constructions in the first task, constructed non-future narratives or "mini stories" in response to the same cues. We then hypothesized that the frequency of spontaneous repetitions should be higher for future event constructions. Potential repetitions were operationalized, for both groups, as thoughts showing a clear thematic relation with at least one event construction from the first task (established through content coding). The subsequent vigilance task featured a combination of "seen" cues (those encountered in the future event / mini story task) and "unseen" cues (those not previously encountered). All cues were familiar locations drawn from a separately validated list (e.g., *bus stop*, *museum*; see supplementary materials), which, by default, should be equally capable of triggering spontaneous thoughts (Jeunehomme & D'Argembeau, 2016; Schlagman & Kvavilashvili, 2008). However, the distinctive associative links created between the *seen* cues and specific event representations in the encoding task should render these more effective than the unseen cues in triggering later spontaneous retrieval of said representations (cf. Berntsen et al., 2013).

To minimise the potential for demand characteristics, and the need to maintain a high level of meta-awareness of one's ongoing thoughts (Schooler et al., 2011), the *probe-caught* method of thought sampling was used (Smallwood & Schooler, 2006, 2015). At unpredictable intervals, participants were stopped and asked if anything was going through their mind other than the task of detecting vertical lines. They then described and rated their thoughts in a similar manner to Study 1. The reappearance of cues from the first task therefore aimed to maximise the chances of detecting repeat spontaneous thoughts by means of the probes.

In summary, Study 2 aimed to establish whether, in the presence of relevant cues, voluntary future event constructions would spontaneously reoccur more frequently than non-future narratives (thus supporting the memories of future thoughts hypothesis). This was done by administering a voluntary future thought task, or non-future narrative control task, followed by a vigilance task capturing spontaneous thoughts in response to previously seen and unseen cues. The key outcome measure was the odds that any captured spontaneous thought would be coded as a potential repetition of (one or more of) a participant's initial voluntary constructions.

3.1. Method

3.1.1. Design

The study used a 2 × 2 mixed factorial design with a between-subjects factor of participant group (future event construction, non-future narrative) and a within-subjects factor of cue type (seen, unseen). The key dependent variable was a binary measure of potential thought repetition derived by content-coding each participant's spontaneous thought descriptions against their prior writing task responses (1 = related, 0 = unrelated). The study was approved by the [Details omitted for double-anonymized reviewing] and preregistered via the Open Science Framework in advance of data collection ([Details omitted for double-anonymized reviewing]).

3.1.2. Participants

Calculations in *G*Power 3* (Faul et al., 2007) for logistic regression with base probability $p_1 = 0.2$, odds ratio = 1.5, and $\alpha = 0.05$ indicated that at least 308 observations would be required to achieve power of 0.80. In other words, assuming a low (20%) overall incidence of related thoughts, detecting a 50% increase in the relative odds of related thoughts in the future construction group, after a seen cue, would require at least 308 thoughts to be sampled. For an odds ratio of 2, 113 observations would be required for power of 0.80, and a sample of 308 would give power of >0.99. We therefore sought to recruit sufficient participants to obtain a sample of at least 308 spontaneous thoughts across the 12 thought probes (see 3.1.3. Materials).

Ninety students at [Details omitted for double-anonymized reviewing] were recruited (73 females, 16 males, one unspecified; $M_{age} = 21.3$, $SD = 5.2$ years). Participants were randomly allocated to either the future construction ($n = 44$) or the non-future narrative group ($n = 46$). The two groups were equivalent in terms of age ($M_{diff} = 0.03$, $t_{(88)} = 0.03$, $p > .90$) and gender ($X^2_{(2)} = 1.08$, $p > .50$). Participation was rewarded either with course credit ($n = 80$) or a £10 retail voucher ($n = 10$), at students' discretion.

3.1.3. Materials

3.1.3.1. Future construction and non-future narrative tasks. Depending on group assignment, participants completed either a voluntary future event construction task or a non-future narrative task. In the future event construction task, participants were asked to "…imagine yourself in each of the following locations, providing one or two sentences of detail to describe the imagined experience". The task resembled those commonly used in voluntary future thinking studies (e.g., Addis et al., 2007; review by Schacter et al., 2012). Participants were presented with 15 prompts, each consisting of a location phrase (e.g., *bus stop*, *museum*) and a future time point (1 week / 1 year / 5 years from now; 5 trials at each time point in pseudorandom order). Specifying time points was intended to standardise event representations within the experimental group, given that temporal distance has known effects on future thought characteristics (D'Argembeau & Van Der Linden, 2004).

In the non-future narrative group, participants were asked to write a "mini story", one or two sentences long, based on a given location and verb (e.g., *bus stop* and show): "Please write a mini story set in each of the following locations, providing one or two sentences of detail and including the given verb. Ensure your story is plausible (could actually happen) and focussed on the location and action in question." This was designed to closely mimic the future construction task in terms of stimuli (locations), response format, and duration, without eliciting personal, future-oriented events. Verbs were included to balance task complexity, given the inclusion of time points in the experimental condition. An example response was given for both tasks to aid understanding; in the experimental task, this was explicitly future-oriented; in the control task, it was written in the past tense to reduce likelihood of future event simulation (full materials available at [Details omitted for double-anonymized reviewing]).

Both writing tasks used the same list of 30 location phrases (available at [Details omitted for double-anonymized reviewing]), randomly divided into two lists of 15. Items in the two lists were compared, where possible, on psycholinguistic attributes to ensure a high level of experimental control relative to previous studies. In terms of basic lexical properties, they did not differ in terms of length ($t_{(28)} = 0.15$, $p = .88$) or frequency ($t_{(25)} = -1.36$, $p = .19$; SUBTLEX database, Brysbaert & New, 2009). Semantic characteristics were checked with reference to standard word norms (Clark & Paivio, 2004) where the relevant word(s) or synonyms were available (e.g., *market* for *marketplace*); the two cue lists did not differ in concreteness ($t_{(12)} = -0.43$, $p = .68$), context availability

($t_{(12)} = 0.82$, $p = .43$), or imageability ($t_{(13)} = 1.68$, $p = .12$). Mean semantic similarity – expressing the vector distance between words or texts in multidimensional semantic space (Landauer & Dumais, 1997) – also did not differ between the lists ($t(28) = 0.47$, $p = .64$). The 15 verbs used in the control task were moderately common (e.g., *show*, *move*; Brysbaert & New, 2009). Finally, the two cue lists were counterbalanced so that half of the future construction group and half of the narrative control group received each list of location phrases in the writing task.

3.1.3.2. Vigilance task. The vigilance task was similar to that used in Study 1, with two key differences. Firstly, in Study 2 we used a probe-caught, rather than self-caught, method for capturing spontaneous thoughts (Smallwood & Schooler, 2015). Secondly, the verbal cues in this study were the location phrases described above, presented four times for every participant (i.e., appearing on 120 trials, or 20%, a 'moderate' presentation rate as prescribed by Vannucci, Pelagatti, Hanczakowski, Mazzoni, & Rossi Paccani, 2015). Hence, each participant was exposed to the full list of 15 cues they received in the writing task, plus the other 15 cues, four times in total. Cue order was determined by randomly ordering the cues and then adjusting using latent semantic analysis (LSA; Landauer & Dumais, 1997) to minimise similarity between consecutive and near-consecutive cues. This process was intended to make successive cues more distinctive, reducing the chance of multiple phrases interacting to trigger SFTs (identified as a possible pitfall in pilot work).

3.1.4. Procedure

The experimental procedure is summarized in Fig. 5. After providing informed consent, each participant completed the experiment in an individual lab room equipped with a PC and iPad. First, the writing task (both versions) was introduced as a 'verbal processing task' for which participants would have a maximum of 20 min and should therefore spend about one minute on each response (time limit = 80 *s*).

As in Study 1, the vigilance task was introduced as an attentional task in which the sole aim was to respond to vertical line targets as quickly and accurately as possible. After the practice block (40 trials including three targets and eight cues not appearing subsequently), participants were informed that their concentration level would be monitored by occasional probes occurring at random intervals; at each probe stop, they should switch to the iPad to rate their concentration level and answer a few brief questions via Qualtrics.

Twelve thought probes occurred at fixed intervals of 24–70 trials throughout the task (average interval = 47 trials). Six probes were programmed to occur shortly after a seen cue and six after an unseen cue (cue-probe latency = 1–3 trials / 1.5–4.5 s).[1] Each time, participants were first asked to rate their current concentration level using a 1–5 Likert scale (Jordão et al., 2019; Plimpton et al., 2015). This was followed by the binary question "Did you have any thoughts at the moment when you were stopped?". Whenever participants responded 'no', the probe terminated and instructed them to continue the attention task. Whenever they responded 'yes', they were asked to provide a short description of the thought; whether there was a trigger ("Was there anything that triggered the thought – in your mind or in the environment?"); a brief description of the trigger if applicable; whether they had previously experienced the thought ("Have you ever thought about this before today's session?"); and a spontaneity rating on a 1–5 Likert scale (1 = Spontaneous / out of the blue; 3 = Somewhat spontaneous / not sure; 5 = Voluntary / actively chose to think about it).

At the end, participants revisited their writing task responses using the 'piped text' feature in Qualtrics to provide vividness ratings for each imagined scenario or narrative (1–7 Likert, 1 = Not at all vivid, 7 = Extremely vivid). This was to ensure that any group differences were not confounded by individual differences in visual imagery ability (D'Argembeau & Van der Linden, 2006). Trait measures of everyday spontaneous and deliberate mind-wandering (MW-S and MW-D, respectively; Carriere et al., 2013) were also included to account for individual variation in habitual mind-wandering, which is known to impact laboratory thought sampling (Kane et al., 2017). Finally, participants were debriefed and reminded of their right to withdraw.

3.1.5. Data coding and processing

Two trained research assistants, blind to study hypotheses (including the existence of two experimental groups), coded each thought report as related (1) or not related (0) to any of the participant's writing task responses. Given the typically succinct format of thought-probe reports (see Jordão and St. Jacques, 2022), the raters were instructed that related thoughts did not have to explicitly restate the imagined scenario. However, in some instances participants made explicit that they had experienced a repetition, reinforcing the assumption that related thoughts reflect potential repetitions (e.g., "Thinking about my imaginary [scenario] with a fox that I wrote earlier"; "My *service station* response on the written task"). Present task-related thoughts (TRTs, e.g., "thinking about the horizontal lines") were coded as unrelated to prior constructions. The coding process showed acceptable interrater reliability ($\kappa = 0.664$); disagreements were resolved by the first author, yielding 86 (17.8%) related and 398 (82.2%) unrelated thoughts. As a general principle, we took an inclusive approach to coding (on thematic relatedness rather than exact replicas), yet comparisons between conditions should be unbiased because hypothesis and condition-blind research assistants classified each thought purely based on thematic relatedness to any of the participant's earlier constructions.

Prior to analysis, coded thought data were filtered by spontaneity, retaining those rated 1–3 out of 5 (326 thoughts, 18.7% related). Nine participants were excluded due to having zero remaining (i.e., spontaneous) thoughts; two of these had reported zero thoughts in total. The following results therefore pertain to 81 participants (39 future construction, 42 non-future narrative).

3.2. Results and discussion

3.2.1. Writing task

An independent samples *t*-test indicated that an equivalent amount of time was spent on the future (M = 871 s, SD = 186 s) and control tasks (M = 816 s, SD = 220 s; $t_{(88)} = 1.29$, $p = .20$). Future construction responses were somewhat longer on average (word count: M = 21.1, SD = 5.28) than narrative control responses (M = 18.6, SD = 4.05; $t_{(88)} = 2.54$, $p = .013$, $d = 0.54$). Post-test vividness ratings suggested that both future (M = 4.30, SD = 0.87) and narrative control responses (M = 4.04, SD = 1.18) were imagined in an equivalent level of detail ($t_{(88)} = 1.17$, $p = .25$). Furthermore, visual checking of all thought data by the first author confirmed that participants created mini-stories as instructed (only 2.9% of responses were future-tensed). When tensed, they were anchored in the past (e.g., 55% contained at least one word ending *-ed*).

3.2.2. Vigilance task

Vigilance task performance did not differ between groups, either in terms of accuracy ($t_{(88)} = -0.270$, $p = .79$) or RTs ($t_{(88)} = 1.47$, $p = .15$), and was therefore unaffected by the prior manipulation. Average concentration ratings, captured at the probe stops, were also equivalent between the future (M = 3.39, SD = 0.67) and non-future narrative groups (M = 3.37, SD = 0.70; $t_{(88)} = 0.142$, $p = .89$); as was the total number of thoughts reported (future M = 4.91, SD = 2.92; control M = 5.80, SD = 2.83; $t_{(88)} = -1.48$, $p = .14$). Thus, participants in both groups engaged with the primary task in a similar manner.

[1] For 41 of 90 participants, vigilance task trials were randomly (rather than pseudorandomly) presented due to a systematic technical error. In these cases, cue type for each thought probe was determined by examining the preceding cues in experiment output files.

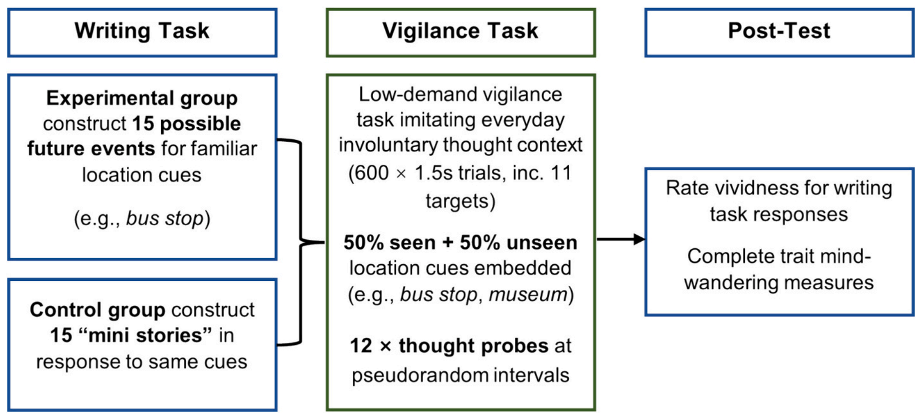

Fig. 5. Outline of Voluntary Encoding / Spontaneous Thought (VEST) paradigm used in Study 2.

3.2.3. Control measures (mind-wandering)

No differences in trait mind-wandering were detected between groups: MW-S scores were similar in the future (M = 20.4, SD = 4.31) and non-future narrative groups (M = 21.5, SD = 3.99; $t_{(88)} = -1.22$, $p = .23$); as were MW-D scores (future M = 17.9, SD = 5.50; control M = 19.5, SD = 4.72; $t_{(88)} = -1.45$, $p = .15$). Descriptive statistics for all tasks are summarized in the Appendix (Table A.1). Since none of the control variables (event vividness, MW-S, MW-D) were found to differ between groups, these were omitted from subsequent analysis.

3.2.4. Confirmatory analysis: Spontaneous thoughts reflecting prior future constructions

A generalized mixed model (i.e., mixed logistic regression) was computed in *Jamovi* (2021) to evaluate the hypothesis that future-group participants would be more likely to experience spontaneous repeats of their pre-constructed events (or variations thereon) in the presence of relevant cues. Specifically, we expected to find an interaction between the factors of group and cue type upon the odds ratio of related versus unrelated thoughts. In fact, the model ($k = 5$, $df_{\text{residual}} = 319$, $-2LL = 308.98$) showed a main effect of group ($\chi^2_{(1)} = 5.08$, odds ratio exp.(B) = 1.93, $z = 2.25$, $p = .024$), while the main effect of cue type and Group × Cue Type interaction were non-significant ($\chi^2_{(1)} < 0.3$, $|z| < 0.6$, $p > .50$; see Table 3 for the model details). Thus, future construction group participants were significantly more likely to experience spontaneous thoughts resembling their prior constructions, irrespective of the type of cue immediately preceding the thought probe. Fig. 6 presents estimated marginal means and 95% confidence intervals for the observed probability of related thoughts in the future construction and non-future narrative groups.

These results suggest that voluntarily constructed, plausible future events remain highly accessible to retrieval after a short temporal interval, relative to non-future constructions equal in subjective vividness. This is consistent with the documented retrieval advantage for future-oriented encoding of episodic memory contents (Jeunehomme & D'Argembeau, 2017, 2021; Klein et al., 2012; Szpunar et al., 2013), and with recent theory and evidence suggesting that many, if not all, SFTs constitute simulation-derived memories or 'memories of the future' (Cole & Kvavilashvili, 2021; Study 1, present paper). Nonetheless, we did not find the expected interaction between group and cue type, suggesting that the increased accessibility of future events in long-term memory may not be dependent on exposure to highly specific retrieval cues (i.e., *cue specificity*; Berntsen et al., 2013). This can be interpreted in line with existing evidence that SFTs are less cue-dependent than (past) autobiographical memories (Plimpton et al., 2015; Vannucci et al., 2017), despite their putative status as mnemonic representations. This argument is further elaborated in General Discussion.

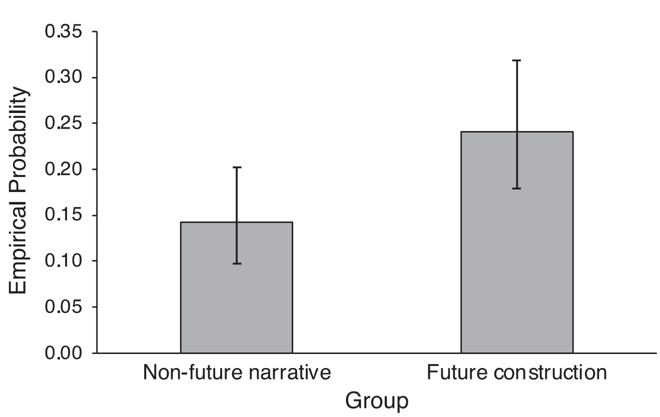

Fig. 6. Mean Probability of Related Spontaneous Thoughts by Group (Study 2).

(Error bars represent 95% confidence intervals)

3.2.5. Conclusions

Study 2 used a novel method (the VEST paradigm) to establish whether voluntary future event constructions, encoded under controlled conditions, would reoccur spontaneously in a subsequent task upon exposure to relevant cues. Potential repetitions were operationalized as those showing a thematic relation with the participant's earlier voluntary constructions. As expected, related thoughts were found to be more prevalent following a future construction task (24%) than a control task (14%); yet this difference was insensitive to the presence of highly relevant cues. Results support the memories of future thoughts account, by which spontaneous access to imagined future events is preceded by deliberate episodic simulation (Cole & Kvavilashvili, 2021).

4. General discussion

Although substantial progress has been made on theory development in episodic memory (Dere et al., 2008), voluntary future thinking (e.g., Schacter & Addis, 2007), spontaneous thought (Fazekas et al., 2020) and involuntary autobiographical memory (e.g., Berntsen, 2010), theoretical work on spontaneous future thought is very recent and as such has been sparse and unsystematic (see Cole & Kvavilashvili, 2021, and Berntsen, 2019, for exceptions). This paper therefore focussed on an important theoretical question: What are the possible cognitive mechanisms through which SFTs enter consciousness? Three hypotheses were extrapolated from previous literature (Berntsen & Jacobsen, 2008; Cole et al., 2016; Plimpton et al., 2015; Vannucci et al., 2017) and systematically tested in two studies. The candidate hypotheses are not necessarily mutually exclusive; indeed, given the heterogeneous nature of SFTs (Mazzoni, 2019), we anticipated that the evidence might support the existence of several alternate 'routes' to experiencing such mental contents. Nonetheless, these two studies represent the first attempt to empirically test the viability of different possible mechanisms underlying spontaneous future thinking.

A summary of findings and conclusions from these studies is provided in Table 5. First, it is important to note that Study 1 revealed differences in the characteristics of spontaneous and voluntary future thoughts which aligned with previous work on these phenomena (e.g., event specificity, mood impact; Cole et al., 2016; Cole & Kvavilashvili, 2021). In particular, the clear difference found in subjective effort ratings indicates that the 'spontaneous' and 'voluntary' methods used in the two lab sessions reliably elicited the respective types of future thoughts. Study 1 also provided novel evidence of convergent validity between the structured daily diary method (Berntsen & Hall, 2004; Berntsen & Jacobsen, 2008) and laboratory vigilance task (Cole et al., 2016; Schlagman & Kvavilashvili, 2008) as alternate methodological approaches for capturing SFTs. By showing that the controlled (albeit artificial) conditions of the vigilance task approximate the more naturalistic diary setting, both in terms of SFT frequency and certain key characteristics, we strengthen the validity/generalisability of claims about SFT's underlying cognitive mechanisms drawn from lab experiments.

Moving, then, to our key theoretical aim, the novel measures of similarity and information source incorporated into the laboratory SFT procedure in Study 1 provided evidence against one of the three candidate hypotheses (the recasting hypothesis). Although the vast majority of SFTs were constructed from direct autobiographical experience rather than other sources (see Anderson, 2012), low ratings of similarity to experience-derived memories implied that SFTs were not simply copies of veridical past experiences, 're-tagged' as future-oriented events (Addis et al., 2010). Although a priori arguments and previous data cast doubt on the plausibility of the recasting hypothesis (e.g., Plimpton et al., 2015), it was important to eliminate it methodically before examining more plausible candidates.

In Study 2, given the limited capability of 'retrieval-only' experiments to elucidate questions about SFTs' underlying representational nature (Study 1; see also Diamond et al., 2020, who attempt to resolve similar limitations in autobiographical memory research), we devised a new approach termed the Voluntary Encoding / Spontaneous Thought (VEST) paradigm. The rationale here was founded on the theoretical proposition that SFTs may have their origins in voluntary future thoughts constructed at some previous time (Cole & Kvavilashvili, 2021). The VEST procedure therefore induced future event construction, in a standard voluntary episodic future thinking task (Addis et al., 2009), before testing for VFTs' reoccurrence in a subsequent vigilance task. A control group wrote 'mini stories' detached from their own autobiographical timeline (Conway, 2005; Conway et al., 2019). A higher rate

Table 5
Hypotheses, study findings and conclusions.

	Research Questions	Evidence	Conclusions
Study 1 (N = 41)	Subjective ratings of SFTs (versus VFTs) were used to assess three hypotheses: *online construction, recasting, simulation-derived memory*	Subjective ratings on memory and VFT similarity showed SFTs were not replications of experience-derived memories but were similar to previous VFTs.	Recasting hypothesis challenged; some evidence to support memories of future thoughts hypothesis. Online construction hypothesis still viable.
Study 2 (N = 90)	Voluntary Encoding / Spontaneous Thought (VEST) paradigm was employed to establish whether VFTs (versus nonpersonal 'mini stories') reoccur as SFTs when controlling for encoding	More frequent potential reoccurrence during a vigilance task sampling spontaneous thoughts after VFTs than non-future narratives, both for previously seen and unseen cues.	First experimental support (across encoding and retrieval) for the memories of future thoughts hypothesis of SFT occurrence.

of *spontaneous repetitions* of pre-constructed scenarios in the future-event group would suggest an encoding advantage for future events consistent with the memories of future thoughts hypothesis (Cole & Kvavilashvili, 2021; Szpunar et al., 2013). Given that a diverse range of spontaneous mental content was likely to emerge during the vigilance task (Smallwood & Schooler, 2015), the likelihood of repetition was estimated by predicting the odds of a related versus an unrelated thought, accounting for individual differences in baseline probability.

Analysis found a clear increase in related thoughts in the future construction group compared to the control group, from 14% to 24% of total spontaneous thought content. This result suggests that voluntarily constructed future scenarios may re-emerge without intention at a later point in time, and hence lends experimental support to the memories of future thoughts hypothesis (previously supported by retrieval-only measures; Mazzoni, 2019; Plimpton et al., 2015; Study 1, present paper).

Although Study 2's findings are broadly in line with the concept of thought reoccurrence as anticipated previously (Cole & Kvavilashvili, 2021), we did not find the expected interaction between group and cue type when predicting the likelihood of related thoughts (whereby cues presented at encoding, providing a high degree of associative overlap with future event content, should elicit more repetitions; see Berntsen et al., 2013). Instead, increased related thoughts following a future construction task were detected equally in the presence of seen and unseen location cues. This challenges our presumption that the high level of cue specificity observed in involuntary memory retrieval (Berntsen et al., 2013; Mace, 2004) extends to SFT occurrence. Importantly, however, we argue that it does not preclude an important role for external cues in the occurrence of SFTs; rather, it suggests that cueing dynamics may differ in the context of experience-derived versus memories of future thoughtsretrieval. We will now flesh out this argument with reference to the existing involuntary memory and SFT literature and relevant theoretical considerations.

First, we must revisit the *cue-item discriminability theory* of Berntsen and colleagues (Berntsen et al., 2013), which explains involuntary memory retrieval in terms of cue-memory interactions. Specifically, these authors provided experimental evidence across four studies that the likelihood of experiencing an involuntary (experienced-derived) memory is greatest when a retrieval cue encountered once (e.g., 'a seal's call') *uniquely* relates to the originally encoded memory. This is in contrast with the situation where a particular retrieval cue (e.g., 'a cat's call') maps on to multiple memories – making involuntary retrieval less likely due to low distinctiveness/discriminability (Berntsen et al., 2013). This explanation builds upon the classic *encoding specificity principle* (Tulving & Thomson, 1973) that posits memories are more likely to be recalled when there is an overlap between the retrieval cue and the stored memory engram. To what extent can these same principles be applied to the occurrence of SFTs, viewed as simulation-derived memories?

On the one hand, there is much existing evidence to suggest that most SFTs *are* linked to specific environmental cues that show semantic or thematic overlap with the reported thought content (Berntsen & Jacobsen, 2008; Cole et al., 2016; Mazzoni, 2019; Plimpton et al., 2015). This may be taken to imply the existence of one-to-one mappings (at least in content) from cue to thought, as per involuntary (experience-derived) memories (see Berntsen & Jacobsen, 2008). Yet simultaneously, studies comparing the characteristics of past and future spontaneous thoughts have concluded that future representations are *less sensitive* to verbal cues, often arising with no apparent trigger (Plimpton et al., 2015; Vannucci et al., 2017). Perhaps, given our characterisation of SFTs as simulation-derived memories, we can offer a speculative resolution to this apparent contradiction.

Given that much of the extant research has used generic cues (e.g., 'friendly boss', 'missed opportunity'; see Schlagman & Kvavilashvili, 2008) – displaying limited cue-item discriminability (Berntsen et al., 2013) – one might expect a *low* incidence of involuntary (experience-derived) memories relative to other types of spontaneous thought. Yet the presence of verbal cues has been shown to boost involuntary memory retrieval relative to SFT occurrence (Vannucci et al., 2017). Importantly, possible future events are, by definition, less fully determined due to their basis in simulation rather than veridical past experience (Perrin, 2021). This has adaptive value, since the utility of future simulations for predicting and planning forthcoming events/actions depends on their flexibility (Seligman et al., 2016; Suddendorf & Corballis, 2007). Conversely, past events (despite their well-known susceptibility to inaccuracy and distortion; Conway & Howe, 2022) are 'closed' representations with a finite, though potentially numerous, range of component features based on what was encoded at the time (Dijkstra & Misirlisoy, 2006). If experience-derived memories are more fixed, yet also more detailed, it is understandable that they would be more sensitive to the presence of verbal cues even where distinctive one-to-one mappings do not exist. Simulation-derived events, on the other hand, may depend more heavily on other aspects of the retrieval context, such as momentary activation of an individual's internal goal representations (Klinger & Cox, 2011).

In contrast to remembering the past, imagining the future involves more extensive semantic processing (Irish & Piguet, 2013). Consonant with this, the occurrence of SFTs may be more reliant on current goal activation than on the thematic content of external cues per se (for a review see Jordão & St. Jacques, 2022). This is supported by the observation that future thinking (voluntary and spontaneous) is driven and constrained by a person's current goals (Cole & Berntsen, 2016; D'Argembeau & Mathy, 2011; Michaelian et al., 2016); and by evidence that priming people's goals before thought sampling increases the number of SFTs experienced, regardless of cue words (Jordão et al., 2019; see also Stawarczyk et al., 2011). Hence, without ruling out a role for meaningfully linked verbal cues (which are often endorsed by participants as the source of their SFTs; Cole et al., 2016; Plimpton et al., 2015), future research should specifically target the possibility that activation of personal goal representations – at or before retrieval – boosts the rate at which SFTs, or simulation-derived memories, are experienced (Jordão et al., 2019; Klinger & Cox, 2011). This could be achieved by using specifically goal-related verbal cues (see McVay & Kane, 2013, for a relevant application of this method).

Finally, while the present results generally support the dual-process account proposed by Cole and Kvavilashvili (2021), in which (effortful) construction is held to be a hallmark of *voluntary* future thinking, we cannot rule out a role for online construction in the occurrence of spontaneous future thoughts. In Study 1, a small proportion (~14%) of SFTs were judged to be 'not at all similar' to previous thoughts and hence, presumably, were constructed anew in the moments preceding their report. Likewise, Study 2 found a large proportion of spontaneous thoughts not related to the preceding deliberate constructions, in both the future (76%) and control (86%) conditions. While the aim was not to comprehensively classify all naturally occurring thought content, this leaves open the possibility that some SFTs were constructed online alongside those that originated as prior voluntary constructions.

Without undermining the broader utility of a dual-process account distinguishing voluntary and spontaneous modes (Cole & Kvavilashvili, 2021; see also Evans & Stanovich, 2013), we endorse the notion of a 'fuzzy' boundary between the two, whereby a variable degree of online construction can be involved in SFT occurrence despite the impression that a thought has come unbidden to consciousness (cf. Berntsen, 2019). Although the precise details of how these constructive processes may operate is beyond the present scope, our findings open opportunities for future research to examine how and under what circumstances reported SFT content differs from scenarios already imagined in the past.

4.1. Limitations and future directions

Study 1, in its reliance on subjective reports at the retrieval stage only, was limited in its potential to draw strong conclusions about the underlying mechanisms involved. Also, although sampling naturally-occurring spontaneous thought offers unique insights into uncontrolled cognitive processes, it presents unique challenges to code thoughts as "episodic" (see Jordão & St. Jacques, 2022 for informative discussions). The VEST paradigm, used in Study 2, was devised to address these problems. Nonetheless, several limitations in Study 2 can still be identified.

Firstly, the criterion used to infer links between the content constructed in the first task, and that retrieved spontaneously in the second, was liberal (i.e., thematic relatedness, but not detailed overlap). This was thought necessary for a first iteration of the new method, in view of the documented difficulty of meaningful content analysis of brief, probed spontaneous thought reports (see Jordão and St. Jacques, 2022). However, in further developing the VEST paradigm, it will be important to gauge reoccurrence of future event representations at a more fine-grained level of analysis. This would enable direct assessment of the degree of online (re)construction that we have speculated may co-occur with each retrieval of a previously simulated event (for a relevant discussion of variability in repeated autobiographical memory retrieval, see Drivdahl & Hyman, 2014).

Secondly, experimenter-generated future event construction was compared to a single, non-autobiographical control task involving 'mini stories' (cf. Addis et al., 2007). To broaden our understanding of the relevant mechanisms under different encoding conditions, different instructions could be used in the future construction task (e.g., simulate goal-related scenarios). In a similar vein, a different control condition could be used – such as an episodic memory condition enabling us to compare spontaneous SFT reoccurrence with involuntary memories (Berntsen & Jacobsen, 2008; Cole et al., 2016). Cue content in the spontaneous retrieval phase could also be modified based on details of participants' responses (persons, objects, actions, etc.; Dijkstra & Misirlisoy, 2006). One could thereby test the hypothesis that current personal goals exert a moderating influence on the effectiveness of external cues in triggering SFTs (Clayton McClure, 2022; Klinger & Cox, 2011).

Finally, the single-session VEST paradigm only assessed future thought reoccurrence over a short interval (i.e., within an hour). Another important priority is therefore to examine the durability of simulation-derived memories over longer timescales. Since involuntary memories can reflect events that occurred weeks, months or years prior to the present moment (Berntsen & Jacobsen, 2008), it is plausible that pre-existing future representations should remain accessible over a similar timescale. Thus, SFTs captured in 'retrieval-only' experiments (e.g., Cole et al., 2016) might be traceable to voluntary constructions encoded weeks or months before. Knowing that future events can be encoded, stored and retrieved – all cardinal properties of memory (Craik, 2007, 2020) – we should now seek to document their longer-term mnemonic properties, e.g., susceptibility to offline consolidation, interference, and forgetting. This could be achieved either with multiple lab sessions, spaced days or weeks apart (as in Study 1); or with remote experience sampling (Hurlburt & Akhter, 2006), a flexible method offering high ecological validity that has recently been applied to involuntary memories (Laughland & Kvavilashvili, 2018). The VEST paradigm introduced here gives a blueprint that can be modified to investigate such questions.

A final priority for SFT research is to further elucidate its functional value (Cole & Kvavilashvili, 2021; Smallwood & Andrews-Hanna, 2013). Duffy and Cole (2021) found, using multiple self-report measures of thought function, that SFTs frequently serve *directive* functions including planning, goal setting and decision making (especially those perceived as relating to specific current goals). However, several questions remain: Can we increase the accessibility of positive, spontaneous future mental imagery, to reduce low mood (Blackwell et al., 2020)? What types of SFT content (Plimpton et al., 2015; Warden et al., 2019) appear to be most functional in predicting goal attainment? To further these lines of enquiry, future studies could combine sensitive SFT capture with objective assessment of specific goal-directed behaviours (see naturalistic studies on prospective memory, e.g., Mason & Reinholtz, 2015; and Clayton McClure, 2022).

5. Conclusions

Despite theoretical advances in related fields (e.g., episodic memory), little research has examined how spontaneous future thoughts come to mind. Out of three candidate explanations, Study 1 challenged the recasting of past events hypothesis, while also providing novel evidence of convergent validity between naturalistic/diary and laboratory-based methodological approaches. In Study 2, we employed a new paradigm (VEST) enabling control over memories of future thoughts encoding. As expected, this revealed a higher incidence of related spontaneous thoughts after a voluntary future construction than after a control task, suggesting that future events remain highly accessible to long-term memory retrieval and supporting the memories of future thoughts hypothesis (Cole & Kvavilashvili, 2021). Although we provide the first direct experimental evidence of this mechanism in operation, some data remains compatible with a role for online construction processes, which may be implicated to varying degrees in SFT.

Taken together, the present studies support the view that deliberately envisioned possible future events can reappear unintentionally in consciousness; and conversely, that many of the SFTs captured in existing paradigms (including in Study 1) constitute 'simulation-derived memories' retrieved by means of a largely *replicative* (as opposed to constructive) mnemonic process. Several promising new lines of investigation stem from this, notably around the timescales and functional value of SFT reoccurrence.

CRediT authorship contribution statement

J. Helgi Clayton McClure: Writing – original draft, Project administration, Investigation, Formal analysis, Conceptualization. **Charlotte Elwell:** Writing – review & editing, Resources, Project administration, Formal analysis. **Theo Jones:** Writing – review & editing, Project administration, Methodology, Investigation. **Jelena Mirković:** Writing – review & editing, Supervision, Data curation. **Scott N. Cole:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Formal analysis, Conceptualization.

Declaration of competing interest

None.

Data availability

Data for both studies will be accessible on OSF (links removed on paper for anonymization)

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Appendix A. Descriptive statistics for study 2

Table A.1
Study 2: Descriptive statistics for all measures (means with SDs in parentheses).

Task	Measure (unit/range)	Future Construction Group	Non-Future Narrative Group	Total
Writing task	Duration (mm:ss)	14:31 (03:06)	13:36 (03:40)	14:03 (03:25)
	Word count	21.1 (5.28)	18.6 (4.05)	19.8 (4.83)
	Vividness (1–7)	4.30 (0.87)	4.04 (1.18)	4.17 (1.04)
Vigilance task	Proportion correct	0.97 (0.06)	0.97 (0.06)	0.97 (0.06)
	Reaction time (ms)	602 (99)	631 (88)	616 (95)
	Concentration (1–5)	3.39 (0.67)	3.37 (0.70)	3.38 (0.68)
	Total thoughts (0–12)	4.91 (2.92)	5.80 (2.83)	5.37 (2.89)
MW scales	MW-S (4–28)	20.4 (4.31)	21.5 (3.99)	21.0 (4.16)
	MW-D (4–28)	17.9 (5.50)	19.5 (4.72)	18.7 (5.15)

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cognition.2024.105863.

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