Understanding Heterogeneity in the Content of Self-Generated Thought

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Abstract

Self-generated thought is an integral part of our lives. Previous work suggests that our thoughts consist of diverse content that varies across individuals and over time. It is clear from the literature that what, when and how we think have great implications for our behaviour. It is less clear however, what exactly gives rise to the content of our self-generated thoughts. This thesis aims to discuss the cognitive, neural, dispositional and contextual influences on the contents of our self-generated thoughts. Multidimensional experience sampling is used throughout the empirical chapters of this thesis to identify common patterns in the content of self-generated thought. The first empirical chapter (Chapter 2) investigates the neural mechanisms that might support the content of self-generated thought and examines whether patterns of thought are consistent within individuals. The second empirical chapter (Chapter 3) assesses the influence of context and individual differences on self-generated thought. The last empirical chapter (Chapter 4) investigates the relationship between the persistence of thoughts over time and the ongoing influence of context. The findings suggest that: 1) the ventromedial prefrontal cortex might support episodic and social features of thought content, 2) the content of thought can be shaped by context as well as individual differences and 3) individual differences in the expression of some thought content are more consistent across contexts than other thought content. Additionally, these findings demonstrate that multidimensional experience sampling is a reliable tool to capture the heterogeneity of thought content, influence of context, and individual differences. This thesis provides an original contribution to knowledge by investigating the possible cognitive, neural, contextual, and dispositional determinants of the content of self-generated thought.

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Author's Declaration

I, Delali Konu, declare that this thesis is a presentation of original work and I am the sole author, under the supervision of Dr. Cade McCall (Primary Supervisor), Professor Jonathan Smallwood, Professor Steven Tipper and Dr. Harriet Over. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

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Chapter 2

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Chapter 1: Introduction

1.1 Overview

Self-generated thought, also known as mind wandering, is commonly defined as the engagement of internal thought processes that are separate from the immediate external environment (Seli, Carriere, et al., 2015; Smallwood & Schooler, 2015). This form of cognition features heavily in our everyday lives, with studies reporting that people spend a substantial amount of their day engaged in self-generated thought (Kane et al., 2007; Killingsworth & Gilbert, 2010). It is not uncommon, for example, that during routine activities, such as when out for a walk or travelling on the bus to work, one's mind drifts. Self-generated thought can also emerge whilst undertaking apparently externally oriented tasks when attention is disengaged such as whilst watching television or when reading.

Given its prevalence, it seems likely that self-generated thought has a functional role in human cognition. Indeed, research suggests that there are a range of consequences associated with specific forms of self-generated thought. Research suggests that it may facilitate problem solving (Baird et al., 2012; Ruby, Smallwood, Sackur, et al., 2013; Smeekens & Kane, 2016), delaying gratification for maximal reward (Bernhardt et al., 2014; Smallwood, Ruby, et al., 2013) and future planning (Baird et al., 2011; Baumeister & Masicampo, 2010; Cole & Berntsen, 2016; Medea et al., 2018; Stawarczyk, Cassol, et al., 2013). Moreover, potential maladaptive aspects include absent mindedness (McVay & Kane, 2009; Smallwood, McSpadden, et al., 2008; Smallwood et al., 2009) and the exacerbation of psychopathological symptoms, which highlights both the conditions under which this behaviour can be detrimental and its potential functional boundaries (Callard et al., 2012; Cole & Tubbs, 2022; Killingsworth & Gilbert, 2010; Smallwood et al., 2007). The heterogeneity of self-generated thought is reflected, in part, in its varied behavioural consequences. Together, such research indicates that the types of thoughts that we have and when those thoughts occur have great implications for our daily lives and well-being (Mooneyham & Schooler, 2013).

These implications raise key questions regarding the antecedents of self-generated thought. How might the brain be structured to support self-generated content (i.e., what underlying networks and cognitive processes are responsible)? Do specific contexts facilitate specific types of self-generated thought? And how do thoughts change from context to context and within individuals who may be predisposed to specific types of thoughts? These basic questions raise further methodological questions about how self-generated thought and its cognitive underpinnings can be reliably measured using standardised experiments. Conversely, how can standardised experiments better reflect the conditions under which we engage in self-generated thought in real life? Over the course of this thesis, a series of studies will be presented to explore these questions.

This introductory chapter will review research relating to the content of self-generated thought with the aim of contextualising the empirical chapters that follow within the wider self-generated thought literature. This chapter will first discuss the heterogeneous nature of self-generated thought and how this constrains its scientific measurement. Then, the role of different cognitive mechanisms and neural systems that might support this heterogeneity will be discussed. The final section of this chapter will discuss the potential role of both context and individual differences in influencing the content of self-generated thought.

1.2 The Content of Self-Generated Thought

A great deal of previous research has approached self-generated thought as a single construct, with studies simply asking participants whether their thoughts are 'on' or 'off' task. While such research has laid the groundwork for understanding the conditions under which self-generated thought might occur, this singular model of self-generated thought disregards the heterogeneity of its content (Seli, Kane, et al., 2018). Self-generated thought of course varies across time and between individuals. Moreover, it can be viewed as multidimensional, composed of converging features that give rise to its different forms.

Accordingly, recent studies have adopted a multidimensional model of self-generated thought to highlight its underlying features including modality (whether thoughts emerge verbally or visually), emotional valence, temporal focus and immersion (Poerio et al., 2017). In one study by Wang and colleagues (2018), multivariate pattern analysis was used to decompose experience sampling to identify different types of self-generated thought. The analysis revealed differences in participants' experiences of self-generated thought and provides one empirical approach to identifying different types of self-generated thought. Additionally, Andrews-Hanna et al. (2013) applied a novel paradigm where participants reported thoughts that had recently persisted in their minds and categorised the content across various features such as frequency, value, social focus, temporal focus, detail and duration. Findings showed that self-generated thought varied across three key dimensions: construal (temporal and perceptual specificity of thoughts i.e., topic duration, social orientation and imagery), personal significance (self-relevance, frequency and emotional intensity) and outlook (valence and temporal orientation). These studies clearly highlight that self-generated thought is a complex form of cognition with content that varies across multiple dimensions.

Whilst self-generated thought is characterised by its heterogeneity, common patterns of features can arise. For example, studies have shown that we often engage in periods of self-reflection (Marchetti et al., 2013; Shrimpton et al., 2017; Takano & Tanno, 2009; Verhaeghen et al., 2014). Periods of self-generated thought that are occupied by self-reflection are also typically associated with a bias for thinking about future events (Baird et al., 2011; D'Argembeau et al., 2011; Hamilton & Cole, 2017; Rathbone et al., 2011; Smallwood et al., 2009). Such findings support the idea that the mental simulation of future events during periods of self-generated thought supports a sense of continuity of the self and personal goal planning (Cole & Berntsen, 2016; D'Argembeau et al., 2012; Smallwood, Schooler, et al., 2011; Song & Wang, 2012; Stawarczyk, Cassol, et al., 2013). Other studies have found opposite results regarding a prospective bias in self-generated thought. Instead, they report a bias for retrospective thinking, with participants reporting greater experiences of past-focused thoughts (Plimpton et al., 2015). This discrepancy suggests that the temporal focus of self-generated thought is flexible (Miles et al., 2010; Plimpton et al., 2015; Poerio et al., 2013; Vannucci et al., 2019). Researchers have highlighted that differences in these findings are influenced by factors such as task demand and individual differences (Vannucci et al., 2019).

As social beings, it is only natural that our self-generated thoughts will also focus on those with whom we interact. Studies have shown that participants' thoughts are often occupied by those around us, with accounts suggesting that social thoughts potentially facilitate social problem solving (Andrews-Hanna, 2012; Baumeister & Masicampo, 2010; Poerio & Smallwood, 2016; Ruby, Smallwood, Sackur, et al., 2013). Our thoughts are also occupied by events in our lives, both past and those yet to come (Smallwood & Schooler, 2015). Studies have shown that brain areas associated with detailed episodic memory retrieval are activated during periods of self-generated thought (Ellamil et al., 2016; Poerio et al., 2017). Together these findings demonstrate that, despite self-generated thought being varied in content, some of its features are more prominent than others.

The multidimensionality of self-generated thought is central to an ongoing debate within the literature regarding the way that self-generated thought and its various forms are defined (Seli, Kane, et al., 2018). For clarity, in this thesis, *self-generated thought* will be used as an umbrella term to describe heterogeneous conscious experiences that are not solely driven by perceptual input (Smallwood & Schooler, 2015). Individual forms of self-generated thought will be referred to as *patterns of thought*. In places, *ongoing thought* or *thought* will be used interchangeably with self-generated thought. The term *mind wandering* will also be used interchangeably with self-generated thought (although the definition of this term does vary between studies in the literature regarding self-generated task-related thoughts (Smallwood & Schooler, 2015)).

1.3 Capturing the Multidimensionality of Self-Generated Thought

Together the literature regarding the multidimensional nature of the content of thought raises the question as to how such a multifaceted phenomenon can be measured. Self-generated thought is a complex behaviour that is unconstrained and subjective. Consequently, it cannot be directly manipulated or observed. A valid method to assess such an experience is to have participants self-report what thoughts emerge in their minds (Murray et al., 2022; Smallwood & Schooler, 2006). One scientific tool that is used to study ongoing experience is *experience sampling* (Kahneman et al., 2004). Typically, subjective experiences are sampled in real life using mobile devices or computers. Participants are probed to answer questions about their ongoing experience using rating scales or written answers. Due to the introspective nature of self-generated thought, experience sampling is an ideal method to apply to its study, both in real life and within the laboratory.

During experience sampling, participants are probed with questions about their thoughts. Here, two important matters arise for researchers: when to sample their thoughts and what questions to ask them about their thoughts. With regards to when, participants' thoughts can be sampled intermittently during a task in the laboratory or an activity in daily life, using *online sampling*. This approach gives a real-time report of thoughts experienced (Schooler, 2002). One thing to consider with online sampling is that participants will be interrupted and likely to engage in meta-awareness as a consequence (Smallwood & Schooler, 2006; Smallwood & Schooler, 2015). Regardless, there are options for how online sampling is done. One option is *self-caught reporting* where participants indicate (e.g., make a key press) when they notice that they are engaged in self-generated thought. The other option when sampling participants' thoughts online is to use the *probe-caught method* in which participants are interrupted at unpredictable points and asked to respond to specific questions about their thoughts in a given moment (Smallwood & Schooler, 2006).

Instead of online sampling, participants can be sampled retrospectively after completing a task or activity. In *retrospective sampling* the experience of thoughts can occur without the repeated interruption of probes and issue of meta-awareness of the mind wandering experience (Miles et al., 2010). Participants must however rely on their memory of the experience when reporting their thoughts (Barron et al., 2011; Gorgolewski et al., 2014; Schooler, 2002; Smallwood, Brown, Baird, Mrazek, et al., 2012). Despite differences in when participants are sampled, studies have shown strong correlations between the online and retrospective reporting of thoughts (Smallwood, Davies, et al., 2004; Smallwood, O'Connor, et al., 2004; Smallwood et al., 2003; Smallwood & Schooler, 2006). Online experience sampling will be used in Chapter 2 of this thesis, whereas retrospective sampling will be used in Chapters 3 and 4.

The next thing for a researcher to consider is what to ask participants. One form of questioning uses a single item in which participants are asked whether their thoughts are on or off task. This technique has been used as a marker to indicate whether participants' thoughts are engaged in self-generated thought. An alternative approach is the *open-ended method* which requires participants to provide unconstrained written or verbal reports about their experience of self-generated thought (Baird et al., 2011). Themes can be extracted and compared from such data (Smallwood & Schooler, 2015). Somewhere in the middle of these two approaches, lies *multidimensional experience sampling* (Ruby, Smallwood, Engen, et al., 2013). In multidimensional experience sampling participants provide ratings in response to questions about their thoughts. These questions are presented in the form of statements which categorise participants' thoughts across various dimensions such as task focus, spontaneity (i.e., spontaneous/unintentional or intentional/deliberate), emotional valence and diversity (consisting of one or many topics). Participants do multiple instances of these ratings, providing the researcher with rich data that can be reduced into a more easily interpretable form. Such a method is a valuable application to the study of self-generated thought as it goes beyond the practice of initial studies in the field (assessing whether participants thoughts are simply on or off task) and acknowledges that self-generated thought content is composed of multiple features. Multidimensional experience sampling enables researchers to have a better understanding of the different features or dimensions that comprise the many types of self-generated thought that arise. As such, multidimensional experience sampling is implemented in the empirical chapters (Chapters 2, 3 and 4) of this thesis.

To reduce the data collected from multidimensional experience sampling, dimensionality reduction techniques such as *Principal Component Analysis* are used to enable the interpretation of the experience sampling data. In Principal Component Analysis, the experience sampling ratings are concatenated and reduced into a low-dimensional representation to identify linear variables which represent meaningful variance in the data (Callard et al., 2013). This approach enables researchers to understand the features that comprise the different types of thought that participants experience in a way that is dependent on the subjective reports of participants' thoughts rather than pre-defined types of self-generated thought. The linear variables or components identified are termed *patterns of thought*. Each pattern of thought is a summary of the different features that characterise a type of thought reported by participants (Konishi et al., 2017). For the purposes of discussion, each pattern of thought is individually named to describe a general type of thought experienced by participants.

Additionally, patterns of thought allow researchers to identify common groupings of features. For example, Ho and colleagues used experience sampling in the lab and daily life to identify general patterns of thought (Ho et al., 2020). Decomposition of experience sampling across both environments showed the extent to which temporal, social, detail and modal features characterised the patterns of self-generated thought that participants engaged in. Across both testing environments four patterns of thought were identified. One pattern, 'vivid, evolving and detailed', characterised thoughts that were highly detailed and changed over time. Another thought pattern, 'off-task and self relevant', represented task unrelated and self focused thought. A 'deliberate and task-relevant emotion' thought pattern characterised thought that was task focused, deliberate and positively valenced. A final thought pattern, 'modality', described thought that was predominately in the form of images instead of words. The features or components comprising each pattern of thought correlated across the lab and daily life environments except for the deliberate and task-relevant emotion pattern. Participants appeared to experience thought that was higher in positive emotion and more deliberate in daily life than when expressed in the lab. Some differences in the off-task and self-relevant thought pattern were found between the lab and daily life with participant thought being more social (less focused on the self but more focused on other people) and less deliberate (more spontaneous) in the lab compared to in daily life. On the other hand, overall broad similarities were seen in the personal, temporal and social features of the thought patterns identified.

Multiple similar studies have implemented multidimensional experience as a means of investigating the heterogeneity of self-generated thought (Ho et al., 2020; Karapanagiotidis et al., 2017; Mckeown et al., 2021; Murphy et al., 2019; Turnbull, Wang, Murphy, et al., 2019; Wang et al., 2018). As a result, there is a need to establish ways of assessing the reliability of the multiple patterns of thought obtained across and within both study and task contexts. Accordingly, reliability analyses will be applied in the empirical chapters of this thesis to assess the consistency of the thought patterns observed within and across studies.

Regardless of their reliability, the thought patterns derived from multidimensional experience sampling are complex. This complexity makes it difficult to pick apart which cognitive processes support the many features that comprise each pattern of thought. Therefore, the inclusion of experience sampling in lab-based testing such as experimental tasks and neuroimaging studies has proved fruitful in enabling closer mapping between patterns of self-generated thought and underlying cognitive processes. Combining experience sampling with a range of objective experimental methods allows researchers to triangulate on a holistic understanding of the phenomenon. Techniques such as neuroimaging (i.e., resting state fMRI scans) and physiological measurements (such as pupillometry) have been used to verify subjective reports of self-generated thought (Franklin et al., 2013; Huijser et al., 2018; Konishi et al., 2017; Pelagatti et al., 2018; Smallwood, Brown, Baird, Mrazek, et al., 2012). Triangulation between these different measures can help identify and verify cognitive processes that underlie self-generated thought in everyday life (Martinon et al., 2019). As such, Chapter 2 will include a task-based neuroimaging study with experience sampling and Chapters 3 and 4 will include different manipulations of task-based studies with experience sampling.

1.4 Mapping Self-Generated Thought to Neural Mechanisms

As the previous section explains, self-generated thought is multidimensional in nature. As a consequence, it is difficult to map patterns of thought to underlying cognitive or neural processes in a one-to-one manner. This section will discuss some of the cognitive processes and neural networks that likely support self-generated thought, as well as the importance of a whole brain approach in neuroimaging to further identify and understand the neural correlates of self-generated thought.

It is likely that the multidimensionality of self-generated thought is supported by multiple cognitive processes. These underlying processes should, in turn, be recruited by higher order or integrative processes (Smallwood & Andrews-Hanna, 2013). If these assumptions hold, the processes involved would need to be flexible and adaptive in manner. The *component processes account* (Smallwood, 2013) provides a model of how this flexibility might work in self-generated thought. This theory proposes that self-generated thought is supported by at least two key cognitive processes: 1) control processes which decouple higher order cognition from the external environment to focus it internally, regulate and maintain it and 2) memory processes which generate the mental content that occupies self-generated thought. In turn, these cognitive processes will be supported by neural networks.

1.4.1 Control Processes Support Self-Generated Thought

One key potential role of control processes in self-generated thought is to facilitate perceptual decoupling, a mechanism by which the brain guides attention internally to maintain trains of thought that are separate from external input (Smallwood, 2013). When we attend to the environment our attention is coupled to the external environment. In this coupled state, attention is focused externally and gives rise to processes such as perception. In the case of self-generated thought, however, attention would need to decouple from the immediate external environment and focus internally on trains of thought. As a consequence of decoupling, performance on externally driven behaviours is necessarily compromised.

This idea is supported by research which has shown that self-generated thought can reduce task performance (McVay & Kane, 2009; Mrazek et al., 2012; Smallwood, McSpadden, et al., 2008; Smallwood & Schooler, 2006). In Smallwood and colleagues' study, participants made a key press in response to frequently presented target stimuli and withheld responding to an infrequent non-target stimulus (Smallwood, Beach, et al., 2008). Participants indicated whether they were engaging in self-generated thought during the task when probed via self-report. The P300 event related potential was also measured as a biological index of attentional focus on the stimuli presented. It was shown to significantly reduce when participants reported engaging in self-generated thought and correlated with poor task performance (when participants failed to correctly withhold a response to the non-target stimulus). This suggests that if externally focused attention is required for good performance in a given task and the brain is in a decoupled state (i.e., engaging in self-generated thought), this can compromise task performance.

Because of results along these lines, research initially supported the idea that self-generated thought is a lapse in attention, a failure in attentional resources to maintain attention towards the external environment when required, known as the *executive failure account* (McVay & Kane, 2010). Executive control processes were thought to only play a role in systems that maintain externally guided attention such as in working memory. A common finding in working memory experiments is that when participants engage in periods of self-generated thought during high-demand working memory conditions, task performance is reduced with participants making more errors (McVay & Kane, 2009). This view that self-generated thought is a lapse in attention has however restricted understanding of the role of self-generated thought in higher order cognition as it assumes that all self-generated thought is the result of an inability to control attention (Smallwood, 2010). Alternatively, it has been suggested that control processes used to focus attention externally may also be involved in guiding it internally during periods of self-generated thought (Smallwood, 2013). This would suggest that executive control processes may play a role in the regulation of self-generated thought, ensuring that its occurrence is relevant to the demands of the external environment. In this case, self-generated thought would need to be adaptive and regulated to occur when there is little risk in affecting ongoing task performance. This is outlined by the *context regulation hypothesis*, an account that suggests that self-generated thought is regulated according to the demands of the environment and as such is limited to situations where continuous external attentional is not required (Smallwood & Andrews-Hanna, 2013). For example, you may be more likely to engage in self-generated thought that is unrelated to your immediate external environment when travelling on the bus or out for a walk than when calculating mental arithmetic during a test.

The functional role that self-generated thought may play generally in higher order cognition is not accounted for in the executive failure account. The observation that self-generated thought reduces task performance during periods of high working memory demand could rather help inform the boundary conditions of this higher order cognition (Callard et al., 2012). For example, this observation could be used to support the idea that the brain is organised so that external processing such as attending to the external environment and more internal processing such as self-generated thought, where attention may be used to support goal planning, self-reflection and creativity (Baird et al., 2012; Smallwood, Schooler, et al., 2011; Stawarczyk, Cassol, et al., 2013), share the same limited resources resulting in competition between them (Smallwood, 2010). This supports the idea that executive resources are shared to support adaptive higher cognitions.

Task-based fMRI provides evidence for this potential role of executive resources in self-generated thought (Konishi et al., 2015; Sormaz et al., 2018). An example of this can be seen in Turnbull and colleagues' study in which participants completed a task during fMRI with online experience sampling (Turnbull, Wang, Murphy, et al., 2019). The task conditions varied in the extent to which participants were required to focus attention externally, similarly to studies used to assess the effects of self-generated thought on task performance (Feng et al., 2013; McVay & Kane, 2009, 2010; Smallwood, McSpadden, et al., 2008; Unsworth & McMillan, 2013). The results showed significant dorsolateral prefrontal cortex (dlpfc) activity when participants engaged in on-task thought, when demand for externally guided attention was high. This same dlpfc activity was also seen when participants engaged in off-task thought during periods where demand for externally guided attention was low. Using transcranial direct current stimulation to the dlpfc researchers were able to increase instances of mind wandering in participants (Axelrod et al., 2015). It could be inferred that the executive control mechanisms used to focus attention externally when external demand is high, are also recruited to support attention when focused internally and external demand is low, such as during periods of self-generated thought. This finding of the flexible regulation of attentional resources lends support to the context regulation hypothesis. Here the use of fMRI in conjunction with experience sampling has enabled the identification of a neural correlate of off and on task thought (Smallwood & Andrews-Hanna, 2013).

These findings have increased empirical support for mechanistic accounts of self-generated thought which suggest that shared executive processing in higher order cognition facilitates perceptual decoupling during periods of self-generated thought. Consequently, this finding also lends itself to refute accounts of self-generated thought (Smallwood, 2010) such as the executive failure account (McVay & Kane, 2010), which suggests that self-generated thought is the product of a lapse in attention occurring only in opposition to control processing.

Further evidence for this idea comes from research on the role of the default mode network (Raichle et al., 2001).The Default Mode Network (DMN) is a group of regions with anatomic connections, a core and two subsystems, seen to activate at rest and deactivate during task periods (Andrews-Hanna et al., 2014). Its disparate structure facilitates its involvement in multiple cognitive functions including self-generated thought. Studies have shown that the default mode network (DMN) activates during conditions associated with self-generated thought (Mason et al., 2007; McKiernan et al., 2006; Stawarczyk et al., 2011). As DMN activity has been associated with multiple internal goal-directed cognitions, the exact role that it plays in self-generated thought as well as cognition in general is a source of debate (Andrews-Hanna, 2012; Buckner et al., 2008; Spreng et al., 2009).

Nevertheless, the DMN had been implicated in playing a role in moments of internally guided attention. If self-generated thought has been shown to be dependent on executive resources, it would be expected that associated brain networks should also support periods of self-generated thought (Teasdale et al., 1995). The Frontoparietal Control Network (FPCN) is typically associated with externally guided attention and anticorrelations with the DMN (Yeo et al., 2011). During periods of self-generated thought however, co-activations between this network and the DMN have been observed (Dixon et al., 2017). Research has also shown connectivity between the DMN and FPCN in supporting both internally and externally goal oriented processing such as autobiographical planning, retrieval of memory representations and metacognition (Ellamil et al., 2016; Fox & Christoff, 2015; Gorgolewski et al., 2014; Konishi et al., 2015; Spreng et al., 2010; Vatansever et al., 2019; Vincent et al., 2008; Wang et al., 2018).

Other large-scale networks such as the Executive Control Network (ECN) have been shown to contribute to periods of self-generated thought. For example, in a study where participants completed tasks in the scanner and answered online sampling thought probes, it was found that in addition to DMN recruitment, prefrontal cortex regions typically associated with the ECN such as, the dorsal lateral prefrontal cortex and dorsal anterior cingulate cortex, were recruited during reports of self-generated thought (Christoff et al., 2009). The co-activation between the DMN and the FPCN as well as ECN suggests that the typically 'externally oriented' networks also play a key role in internally directed cognitions such as self-generated thought (Yin et al., 2022).

1.4.2 Memory Processes Support Self-Generated Thought

In keeping with the component processes account, episodic and semantic processes have been highlighted as key in supporting the content of self-generated thought. Self-generated thought has been shown to be characterised predominantly by social, episodic and temporal features (Smallwood & Schooler, 2015). Studies show that regions of the brain involved in memory processing are significantly activated when individuals engage in self-generated thought. Ellamil and colleagues (2016) showed that the hippocampus, which has an established role in episodic memory (Burgess et al., 2002), is significantly activated during early stages of self-generated thought. Other studies have also shown that episodic and semantic memory representations are critical for self-generated thought. Poerio and colleagues' (2017) investigated the relationship between individual differences in self-generated thought and performance on episodic, semantic and autobiographical planning tasks. A pattern of behavioural performance characterised by both detailed memory retrieval (increased episodic detail and vivid descriptions from autobiographical memory as well as good performance on semantic association tasks) and poorer performance on external tasks (i.e., encoding tasks) was linked to greater reports off-task future focused self-generated thought. This suggests that self-generated thought may be supported by a distinct ability to retrieve detailed memory-based representations.

Studies have shown that the construction of personal future events is dependent on the autobiographical memory system (Schacter et al., 2007; Spreng & Grady, 2010). Patients with deficits in autobiographical memory often experience difficulty in constructing future focused thoughts (Klein et al., 2002). It has been suggested that autobiographical memory processes are important for processing (by anticipating and planning) personal goals during periods of self-generated thought, particularly future related self-generated thoughts (Baird et al., 2011).

In addition, studies have shown that memory processes are critical for self-generated thought that is focused on the future as well as the past. D'Argembeau and Linden (2004) showed that representations of not-so-distant memories of past events and near future events were more detailed than those of more distant past and future events. Additionally, it has been shown that participants with greater vivid imagery reported greater experience of sensory details when remembering past events and when constructing future events. In comparison, participants that engaged in routine emotion suppression of remembered or imagined events, experienced less sensory details (D'Argembeau & Van der Linden, 2006). Furthermore, brain regions typically associated with remembering the past, have been highlighted as critical for imagining future events (Schacter et al., 2007). Okuda and colleagues (2003) had participants report thoughts that were based on past memories and future events whilst being scanned. It was found that there was shared activation in the prefrontal cortex and medial temporal lobe during participant descriptions of both past and future events. Together, research suggests that memory processes support self-generated thought.

The DMN has also been implicated in supporting memory processes during periods of self-generated thought. The *mnemonic account* suggests that the DMN supports meaning and knowledge processes in cognition (Andrews-Hanna et al., 2014). Support is lent to this account by studies which show that the DMN supports semantic and autobiographical memory processing during reading (Ritchey & Cooper, 2020; Smallwood, Gorgolewski, et al., 2013; Sormaz et al., 2017). The DMN has also been implemented in supporting mental time travel in future focused forms of self-generated thought where brain areas such as the hippocampus, medial prefrontal cortex and posterior cingulate cortex are activated (Addis et al., 2009). In addition, the DMN has been shown to play a role in working memory and autobiographical processing (Spreng et al., 2014; Zhang et al., 2022). In Spreng and colleagues' (2010) study they found that the DMN supported autobiographical memory prospection and theory of mind processing during periods of self-generated thought, highlighting that it is likely that the DMN supports common aspects (potentially memory features) of these processes.

Despite these apparent relationships between the DMN and memory, the precise role that the DMN plays in supporting self-generated thought is still an ongoing debate. Self-generated thought involves multiple features that are linked to the activation of the DMN (Smallwood, Bernhardt, et al., 2021). In addition to being highlighted as supporting perceptual decoupling and a range of memory processes during self-generated thought, it has also been shown that DMN areas, such as the medial orbital frontal cortex, support other cognitive processes such as emotional processing (Tusche et al., 2014). In comparison, other accounts suggest that the DMN plays a role in metacognition and introspection during periods of self-generated thought (Baird et al., 2013).The DMN has also been seen to activate during tasks associated with self-referential processing and personal goal planning (D'Argembeau et al., 2005; D'Argembeau et al., 2007; D'Argembeau et al., 2010; Qin & Northoff, 2011). It has also been suggested that the DMN enables the integration of long-term knowledge to help us to make sense of our surroundings (Ralph et al., 2017). Together these findings show that the DMN, despite being labelled as ‘task negative’ network (Fox et al., 2005), plays a role in goal-directed cognition and is not solely activated during periods of self-generated thought. There is an aim to find a more unifying account of the functional role that encompasses the many processes that the DMN has been identified to support. It must however be noted that memory processes seem to be common to the cognitions highlighted when the DMN is activated during self-generated thought. Considering the many processes that the DMN and its regions are implicated in, it is highly plausible that the DMN plays an integrative role in abstract features across multiple processes that gives rise to higher order cognitions (Smallwood, Bernhardt, et al., 2021). Regardless of this debate, it is clear that the DMN is a key brain network that governs the processes involved in supporting self-generated thought, supporting its heterogeneity. It would therefore be expected that regions that encompass the DMN should be involved in the generation of thought content.

It must be kept in mind however that the exact key processes that underlie the occurrence of self-generated thought and its content, as well as how they interact to give rise to this complex behaviour are still being investigated. It is most probable that more processes than those mentioned above are involved. Nonetheless, a model such as the component processes account can allow for an understanding of how key processes might interact to support self-generated thought. The research discussed supports the idea that self-generated thought is a complex higher order behaviour that is supported by multiple cognitive processes that form the basis for higher order cognitions (Smallwood, Turnbull, et al., 2021).

1.4.3 Whole Brain Analysis is Essential for Understanding Self-Generated Thought

The use of neuroimaging techniques to investigate self-generated thought have led to key findings that self-generated thought is supported by 1) multiple cognitive processes including control and memory processes 2) is largely governed by the DMN and 3) by its co-activations with the FPCN and ECN. Whole-brain approach methods are key in developing a holistic understanding of how the brain is designed to support a heterogeneous cognition such as self-generated thought. For example, in Wang and colleagues' study, they used multi-variate pattern analysis to decode experience sampling and neural functional-connectivity data (Wang et al., 2018). The use of multivariate pattern analysis with experience sampling and functional connectivity data enabled evaluation of the complex relation between patterns of thought and neural systems. The decomposition of the data showed that different types of thought were associated with different neural profiles. Such findings highlight the fact that self-generated thought cannot be mapped to neural systems in a one-to-one manner, the relationship is far more complex.

Another whole brain neuroimaging approach that is widely used in the self-generated thought literature is *resting state analysis*. Studies typically include engaging participants in an unconstrained context such as viewing a fixation cross on the screen while undergoing fMRI (Callard & Margulies, 2011). Resting state studies have highlighted that the mind is organised at rest with the activation of a group of regions, i.e., the DMN (Biswal et al., 1995; Fox et al., 2005; Greicius et al., 2003; Morcom & Fletcher, 2007; Raichle et al., 2001). Within the literature, there have been parallel issues with the original conceptualisation of the role of self-generated thought and that of the DMN in cognition, with both being labelled as task negative and passive. The use of resting state and other neuroimaging techniques such as functional connectivity and task-based functional magnetic resonance imaging (fMRI) have enabled the revision of such conceptualisations by investigating the relationship between the DMN and self-generated thought within the context of tasks that target internal representations (rather than externally goal directed tasks). This research shows that the DMN (and other brain networks) support self-generated thought as an active form of cognition with varied functional roles (Andrews-Hanna et al., 2014; Christoff et al., 2009; Mason et al., 2007; McKiernan et al., 2006).

In recent years, there have been further advancements in whole brain analysis with the identification of the *principal gradient* (Margulies et al., 2016) of functional connectivity, showing that the brain is structured to support a functional spectrum that ranges from more concrete cognitive processing such as action and perception, to more abstract cognition such as self-generated thought (Karapanagiotidis et al., 2020; Mckeown et al., 2020; Shao et al., 2022; Turnbull et al., 2020). Whole brain analysis is not limited to fMRI. Kam and colleagues

(2021) used *electroencephalography (EEG)* to investigate the neural correlates of freely moving, dynamic thoughts as participants completed mundane tasks and retrospectively answered questions about their thoughts. Brain activity associated with each thought type was related to the self-report measures of participants' thoughts. The findings showed distinct electrophysiological patterns for different types of thoughts. The use of a whole brain approach in recent studies has led to ground-breaking findings that offer a consensus that the brain is structured to support the heterogeneity of self-generated thought.

Together, the findings in this section highlight that multiple cognitive processes and related neural networks support self-generated thought. As a heterogeneous form of cognition, it is clear from the methodological approaches used to research self-generated thought that a whole brain approach is valuable for encompassing this heterogeneity. Accordingly, in Chapter 2, a whole brain approach, task-based fMRI, is used to investigate the neural correlates of the content of self-generated thought.

1.5 Contextual Influences on Self-Generated Thought

The prior sections demonstrate that the content of self-generated thought is multidimensional in nature. But what determines where our minds go in this multidimensional space at any given moment in time? Intuitively, it seems likely that context is a significant influence on the content of self-generated thought. In other words, even if thought is *self-generated* in the moment, its determinants should include the stuff of our lives and the world around us. Moreover, self-generated thoughts are likely to be stimulated by external as well as internal triggers that relate to our personal goals (Klinger, 2013). Nevertheless, the fact that self-generated thought has been studied in a relatively limited variety of contexts leaves a variety of questions open.

Along these lines, self-generated thought has often been studied within an undemanding task context where participants' minds are free to wander. For example, a variety of studies use the Sustained Attention to Response Task (Robertson et al., 1997) in which participants make single key responses to a frequently presented stimulus but withhold responding to an infrequent stimulus (McVay & Kane, 2009; Mooneyham & Schooler, 2013; Mrazek et al., 2012; Stawarczyk et al., 2014). Alternatively, participants may be given the Choice

Reaction Task (CRT) where they are presented with infrequent target digits which they indicate as either odd or even (Ruby, Smallwood, Sackur, et al., 2013; Smallwood, Brown, et al., 2011; Smallwood et al., 2009). These task conditions are designed to require few working memory resources and, as such, are considered optimal conditions for inducing states of self-generated thought. Indeed, when compared to tasks that require working memory resources (i.e., tasks in which one must remember the previously presented stimuli), participants report more instances of self-generated thought (Konishi et al., 2015; Mason et al., 2007; Smallwood, Ruby, et al., 2013; Teasdale et al., 1995).

Whilst the undemanding task context is ideal for inducing states of self-generated thought, this context is unrepresentative of the many contexts under which we engage in self-generated thought throughout the day (Murray, Krasich, et al., 2020). Consequently, this restricts interpretations of self-generated thought and generalisations of this cognition in daily life. As a consequence of the standardisation implemented in such studies, they lack ecological validity (Martinon et al., 2019). This lack of ecological validity is often justified. In order to identify processes that may underlie behaviours, experiments must be designed to create a controlled environment, but the complexity seen in behaviour in everyday life is consequently removed. It is then unclear if the processes identified under experimental conditions contribute to behaviour in the real world, outside of a controlled environment, particularly when trying to understand higher order cognitions such as self-generated thought (Callard et al., 2012). More to the point, studying self-generated thought in pared-down contexts may obscure the important influences of complex environments on the content of thought.

Research examining self-generated thought across a variety of different situations is limited but hints at contextual influences. For example, Song and Wang (2012) asked participants to report the triggers of their self-generated thoughts in daily life. Participants reported that their thoughts were approximately as equally triggered by external cues as they were by internal cues. Other research has investigated the influence of context on the content of self-generated thought via experimental manipulations. Recent studies have shown that the contextual demands, specifically spatial orientation demands of a task, can influence the temporal focus of participants' self-generated thoughts (Miles et al., 2010; Vannucci et al., 2019). Another study showed that context plays an important role in the temporal focus and frequency of self-generated thought (Plimpton et al., 2015). They found that negative cues were more likely to trigger past memories and positive cues, future thoughts. In addition, participants were more likely to report past memories than future or present focused thoughts. Together, these studies highlight important implications regarding how context can influence self-generated thought.

External cuing is a method that is typically used to investigate involuntary autobiographical memories, memories that are spontaneously elicited (Guesdon, Lejeune, Rotgé, et al., 2020). In such research, irrelevant cues are presented during an undemanding vigilance task to create contextual triggers (Mace & Unlu, 2020; Schlagman & Kvavnashvili, 2008). This paradigm has also been applied to self-generated thought (McClure & Cole, 2020; Plimpton et al., 2015). For example, Vannucci and colleagues (2017) had participants complete a vigilance task during which they were intermittently presented with irrelevant verbal cues (e.g., long hair). Verbal cue presence was manipulated across two participant groups (one group saw cues whereas the other group did not) and participants' thoughts were sampled using online and retrospective thought sampling. It was found that participants who were presented with irrelevant verbal cues (which were temporally neutral) reported more episodes of self-generated thought which were past focused compared to the no cue group. This suggests that external cues can influence the frequency and temporal focus of our self-generated thoughts. Other studies have combined this methodology with pupillometry to show that changes in pupil size are associated with the triggering of self-generated thought via external cues (Pelagatti et al., 2018).

Other researchers have outlined the importance of semantic information in eliciting spontaneous associations with the environment when engaging in semantically rich contexts such as reading or watching a film. Faber and D'Mello (2018) had participants watch a film clip, read a book excerpt and intermittently report when their mind had wandered. Participants were asked to report what they were thinking about, whether any element of the task triggered their thought and if so, what that trigger was. They found that thought relating to memories (autobiographical and semantic) were reported more than introspective and prospective thoughts. Semantic and autobiographical memories were more likely to be triggered by the task stimulus than thoughts relating to introspection and prospection. The content of reported thoughts that related to memory were also semantically related to the triggers reported. The results from this study suggest that thoughts relating to memory may arise from associations with semantically rich information in the environment whereas other types of thoughts may be triggered more internally. Critically, this study suggests that semantic information in the environment is important for understanding how the external world can elicit self-generated thought.

Such studies highlight that while self-generated thought is internal, its stimulation is not independent of the environment. Instead, tasks can guide and shape our self-generated thoughts. But many questions remain. To what extent does context influence the content of self-generated thought? Does the influence of context on self-generated thought content change over time? In turn, can context be used to manipulate self-generated thought?

Whilst there have been recent attempts to empirically investigate the influence of context on self-generated thought, there is a need for research to broaden the contexts under which we study it in order to understand self-generated thought in its entirety (Murray, Krasich, et al., 2020). Such an approach would also be key to understanding how thoughts unfold within and across varying and dynamic contexts over time (Sonkusare et al., 2019; Vanderwal et al., 2019). Directly addressing how context influences or triggers the content of self-generated thought could further contribute to building both mechanistic and ecologically valid accounts of self-generated thought (Smallwood, Turnbull, et al., 2021). Chapter 3 of this thesis addresses this point by sampling participant thought across a range of different task contexts.

1.6 Individual Differences in Self-Generated Thought

Going beyond context, a variety of evidence suggests that individual differences shape the content of self-generated thought across time. For example, studies have shown differences in the frequency and content of mind wandering across age. Younger adults are more likely to engage in self-generated thought that is characterised by negative focus and self-criticism. In comparison, older adults report fewer instances of self-generated thoughts that are more focused and positive (Giambra, 1989; Irish et al., 2019; Jordao et al., 2019; McVay et al., 2013; Seli et al., 2017; Turnbull et al., 2021).

Research has also shown that individual differences in executive control predict the occurrence of self-generated thought. For example, those with higher working memory capacity are more likely to engage in self-generated thought during less demanding contexts (Banks & Welhaf, 2022; Levinson et al., 2012). Furthermore, research suggests that these individual differences also help determine the content of that self-generated thought; individuals with higher working memory capacity are more likely to engage in self-generated thought that is prospective and focused on autobiographical planning (Baird et al., 2011). This suggests that individual differences determine the engagement of self-generated thought that can be constructive in organising everyday life.

The content of self-generated thought is also related to individual differences in mental health and wellbeing. Andrews-Hanna and colleagues (2013) had participants report thoughts that had recently persisted in their minds. Findings showed that the thoughts reported significantly accounted for variance in individual wellbeing. Participants with higher scores on measures of improved psychological wellbeing reported more positive and less personally significant thoughts. In comparison, those with higher scores on measures of poor psychological well-being reported more negative and personally significant thoughts. Other studies show that experiencing states of negative and past-focused self-generated thought is associated with low mood (Killingsworth & Gilbert, 2010; Poerio et al., 2013).

Along these lines, there appears to be an intrinsic association between trait experiences of negative thinking and mental health difficulties. It is well established that individuals that experience self-generated thought as self-critical, intrusive, past-focused and characterised by negative affect, are more likely to experience mental health difficulties (Mooneyham & Schooler, 2013). For example, Hoffman and colleagues (2016) investigated the contents of self-generated thoughts in patients with and without major depressive disorder using experience sampling during an undemanding task. Findings showed that participants with major depressive disorder reported more instances of self-generated thought. Their thought content was more negative, self-related and past-oriented. The extent of negativity and fixation of thoughts correlated with severity of depressive symptoms. Negative and intrusive self-generated thought has been highlighted as a marker of the experience of psychopathological symptoms relating to psychopathological disorders. The perseverance of negative thoughts over time, known as *rumination,* is further related to experiences of a range of psychopathological conditions such as depression, anxiety, bipolar disorder and narcissistic personality disorder (Andrews-Hanna et al., 2014; Beaty et al., 2019; Finnbogadottir & Berntsen, 2013; Hoffmann et al., 2016; Ji et al., 2019; Kanske et al., 2016; Kanske et al., 2017; Nolen-Hoeksema et al., 2008; Plimpton et al., 2015; Smallwood et al., 2005; Stawarczyk, Majerus, et al., 2013; Watts et al., 1988). Together, studies investigating the relationship between the content of self-generated thought and wellbeing lend clear support to the *content regulation hypothesis* which proposes that the contents of an individuals' thoughts relates to both adaptive and maladaptive consequences of self-generated thought (Smallwood & Andrews-Hanna, 2013).

Overall, the aforementioned research demonstrates that individual differences can predict, and possibly determine, the content of thought. As such, individual differences in thought content are integral to understanding the heterogeneity of self-generated thought. Key questions remain, however, regarding the relationship between these individual differences and context. Much of the research discussed reveals significant effects of individual differences via cross-sectional studies or by examining thought content across similar contexts. As a consequence, it is not clear if and when specific relationships between individual differences and thought content emerge across different contexts. In Chapter 3, a combination of experience sampling and measures of individual difference is examined across varying task contexts to investigate this relationship. The influence of individual differences and context over time and across contexts is investigated in Chapter 4.

1.7 The Aim of This Thesis

Together the previous sections raise many questions regarding the determinants of what, how, and when we think. The heterogeneity of self-generated thought implies that it must be supported by multiple cognitive processes, but what are those processes? Moreover, self-generated thought is generally defined as internal processing that is separate from the environment, but we know that the environment must have some influence on our thoughts. So, to what extent does the environment influence our self-generated thoughts? And if the environment does bear influence on self-generated thought, how can we unravel the cognitive, contextual and individual differences that determine our experience of self-generated thought over time and across contexts? The overall aim of this thesis is to further understand how cognitive mechanisms, context and individual differences influence self-generated thought in all its heterogeneity.

This thesis addresses these aims in three chapters, each of which presents an empirical study. Chapter Two uses neuroimaging to examine the neural correlates of the content of self-generated thought. Chapter Three investigates the influence of context on self-generated thought by examining the content of thought across a range of contexts. This chapter also addresses how individual differences are associated with the effect of context on self-generated thought. Chapter Four explores the influence of the persistence of thought patterns across time, examining the influence of context as well as individual differences on thought. All chapters consider how self-generated thought can be investigated using different experimental manipulations, how the ecological validity of laboratory experiments can be improved and discuss the reliability of the experience sampling method in measuring self-generated thought.

Chapter 2: A Role for the Ventromedial Prefrontal Cortex in Self-Generated Episodic Social Cognition

This chapter is adapted from:

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Abstract

The human mind is equally fluent in thoughts that involve self-generated mental content as it is with information in the immediate environment. Previous research has shown that neural systems linked to executive control (i.e. the dorsolateral prefrontal cortex) are recruited when perceptual and self-generated thoughts are balanced in line with the demands imposed by the external world. Contemporary theories (Smallwood and Schooler, 2015) assume that differentiable processes are important for self-generated mental content than for its regulation. The current study used functional magnetic resonance imaging in combination with multidimensional experience sampling to address this possibility. We used a task with minimal demands to maximise our power at identifying correlates of self-generated states. Principal component analysis showed consistent patterns of self-generated thought when participants performed the task in either the lab or in the scanner (ICC ranged from .68 to .86). In a whole brain analyses we found that neural activity in the ventromedial prefrontal cortex (vMPFC) increases when participants are engaged in experiences which emphasise episodic and socio-cognitive features. Our study suggests that neural activity in the vMPFC is linked to patterns of ongoing thought, particularly those with episodic or social features.

2.1 Introduction

Human cognition is not always tethered to events taking place in the real world. Often, particularly when external demands are low (Giambra, 1995; Smallwood et al., 2003; Teasdale et al., 1993), we engage in thoughts with few links to events in the “here-and-now”, a phenomena often studied under the umbrella term of mind-wandering (Smallwood & Schooler, 2006, 2015). These patterns of self-generated thoughts have links to both beneficial aspects of cognition, such as creativity (Baird et al., 2012; Gable et al., 2019) and goal-planning (Medea et al., 2018). Self-generated states also have links to detrimental aspects of cognition such as affective disturbance (Poerio et al., 2013; Smallwood et al., 2007) or lapses in attention (McVay & Kane, 2009; Smallwood, Beach, et al., 2008). Since self-generated thought has an important influence on well-being (Mooneyham & Schooler, 2013), over the last decade understanding the neural mechanisms underlying different aspects of ongoing thought has emerged as an important question in the field of cognitive neuroscience (Christoff et al., 2016; Smallwood & Schooler, 2015).

Contemporary accounts of self-generated thought (Smallwood, 2013) hypothesise that the emergence of self-generated states depend on both processes that support the representations on which the mental content is based, as well as more general systems that are linked to regulating the occurrence of these states. This enables the thoughts to be maximally aligned to the current environmental demands (Andrews-Hanna et al., 2014; Smallwood, 2013; Smallwood & Andrews-Hanna, 2013). Consistent with this perspective Turnbull and colleagues used a paradigm which alternated between a demanding and non-demanding task context, a design which optimises the chance to identify the neural systems involved in the contextual control of patterns of ongoing thought (Turnbull, Wang, Murphy, et al., 2019). This study used a paradigm that switched between a simple choice reaction time with a more difficult 1-back decision that relied on working memory, and this routinely leads to reductions in off-task thought in the easy task (Smallwood et al., 2009). Turnbull and colleagues found a region of dorsolateral prefrontal cortex was linked to the facilitation of on-task thoughts during the more difficult working memory task, and the expression of off-task thoughts when task demands reduced. This result highlights that brain regions linked to executive control are recruited when attention is regulated in line with contextual demands, however, it does not directly contribute to our understanding of the processes that differentiate between different types of experience.

In our prior study we found evidence that regions of lateral parietal cortex were important for maintaining attention on the task in hand (Turnbull, Wang, Murphy, et al., 2019). Although this pattern demonstrates the neural systems recruited during a focus on external goals, it leaves open which systems support mental content that is self-generated. It is often hypothesised that memory systems which play an important role in self-generating mental content may be linked to episodic or mnemonic features since these thoughts often have temporal and/or self-relevant features (Smallwood & Schooler, 2015). Consistent with this perspective, individuals who are better at tasks relying on memory tend to report more off-task thoughts (Poerio et al., 2017; Wang et al., 2019), while the functional architecture/activity of neural regions linked to memorial processes are predictive of individual differences in patterns of ongoing thought (Ellamil et al., 2016; Ho et al., 2019; Smallwood et al., 2016). Furthermore, studies of dementia / lesions that target regions that are hypothesised to play a role in memorial or episodic processes impacts on the ability to self-generate mental content, including the hippocampus (McCormick et al., 2018), parahippocampus (O'Callaghan et al., 2019), ventromedial prefrontal cortex (Bertossi et al., 2016), and the temporal pole (Irish et al., 2012; Irish & Piguet, 2013).

It is possible that in our prior study (Turnbull, Wang, Murphy, et al., 2019) we failed to find evidence for neural systems linked to the expression of self-generated thought in a whole brain search because our design was optimised to identify how individuals regulate their experiences in line with external demands, necessitating a within-participant manipulation of task demands. In the current study, we assessed the neural basis behind different types of experience in a similar sized sample of participants as in our prior study (Turnbull, Wang, Murphy, et al., 2019). Unlike our prior study, we focused only on a single task with minimal attentional demands and used a comparable number of experience sampling probes. We hoped this would produce more sensitive estimates of both the different patterns of ongoing thoughts that individuals focus on when task demands are low, and that it would increase our chance of detecting the involvement of regions implicated in self-generated mental content. The task design is summarised in Figure 2.1. In order to provide an empirical constraint to our interpretation of the result, we examined the functional properties of any clusters revealed by our analysis by performing a formal meta-analysis using Neurosynth (Yarkoni et al., 2011).

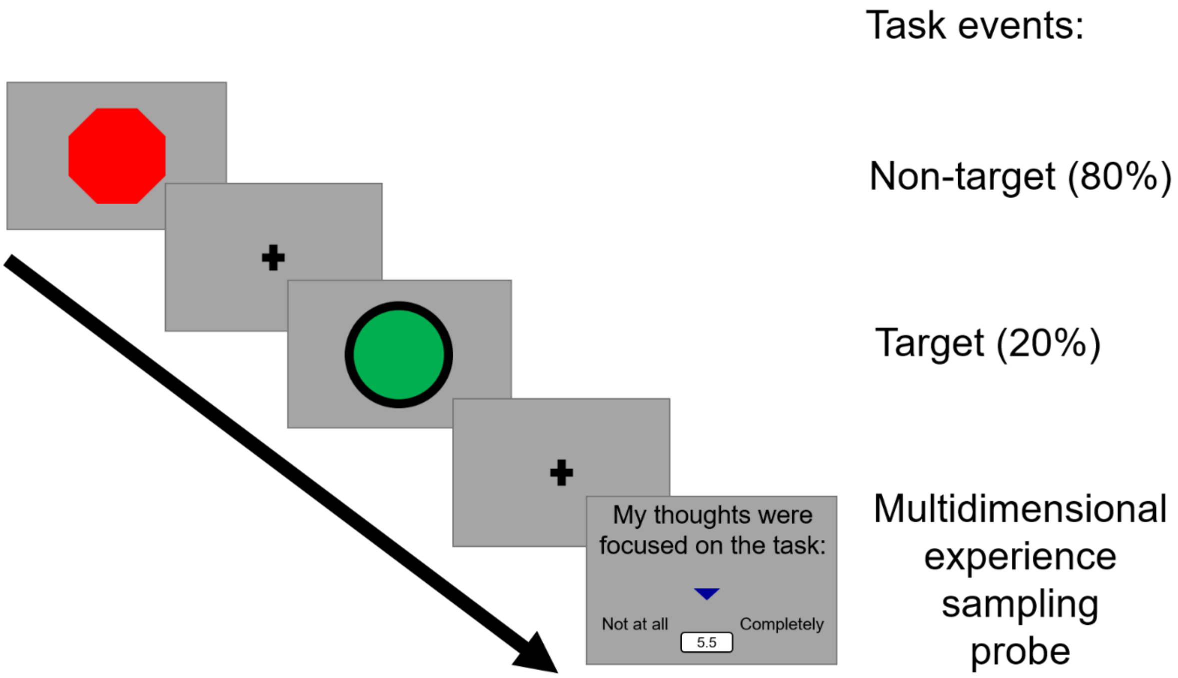

Figure 2.1 Task paradigm used in this study. Participants were asked to respond to infrequent green circles. At intermittent intervals we asked the individuals to describe the contents of their experience using Multidimensional Experience Sampling (MDES).

2.2 Methods

2.2.1 Participants

One hundred and seven participants took part in this study. Ninety-one participants participated in a behavioural session (67 females; mean age: 23.38 years, standard deviation: 4.53 years, age range: 19-40 years). Sixty-two participants participated in a scanning session (41 females; mean age: 23.29 years; standard deviation: 4.51 years, age range: 18-39 years). After excluding participants 57 remained for fMRI data analysis (due to technical difficulties or excess movement). Forty-six participants participated in both the behavioural and scanning session. All participants had normal/corrected vision, and had no history of psychiatric or neurological illness. All scanning participants were right handed. This cohort was acquired from the undergraduate and postgraduate student population at the University of York. The study was approved by the local ethics committee at the York Neuroimaging Centre and University of York Psychology Department. All volunteers provided informed written consent and received monetary compensation or course credit for their participation.

2.2.2 Task Paradigm

Participants were instructed to attend to the centre of the screen, they viewed target and non-target stimuli to which they responded only to target stimuli (mean stimulus presentation duration 1000ms). A run of the task was 13 minutes and contained eight instances of experience sampling probes when participants answered one of each question (see the next section for details of the experience sampling technique). A question was presented for 4 seconds maximum on the screen based on the average response time from previous studies, followed by a 500ms fixation cross. The rest of the time in a run was allocated to two kinds of experimental trials: target and non-target. In target trials ("go trials") a green circle was randomly presented (20% of the experiment trials) and participants were required to make a response -a single key or button press was required. In non-target ("no-go") trials a red octagon was presented (80% of the experiment trials) and no behavioural response was required. An experimental trial was fixed at 3000ms. The inter-stimulus-intervals (ISI) consisted of a fixation cross and was jittered (1500-2500ms). The stimulus was presented on screen for 500–1500ms until a response was made. Once a response was captured, a fixation cross appeared on the screen for the remaining time. This task was designed to require minimal cognitive demand since these conditions facilitate the occurrence of self-generated thought at a level that is comparable to rest (Smallwood et al., 2009). The task is presented schematically in Figure 2.1. In the scanner participants completed three runs of the task whereas in the behavioural session they completed one run of the task. Written instructions were presented at the start of each run.

2.2.3 Multidimensional Experiential Sampling (MDES)

Participant ongoing thought was measured using multidimensional experience sampling (MDES). When a probe occurred participants were asked how much their thoughts were focused on the task, followed by 12 randomly shuffled questions about their thoughts (Table 2.1). All questions were rated on a scale of 1 to 10. Within one run of the Go/No-go task, participants completed 8 sets of MDES probes yielding a total of 8 probes per individual in the behavioural session and 24 probes per individual in the scanning session. Two participants had one run dropped due to technical issues, leaving them with 16 probes overall.

Table 2.1 Multidimensional experience sampling questions used to sample thoughts in the current study.

Dimension	Statement	Scale_low	Scale_high
Task	My thoughts were focused on the task I was performing:	Not at all	Completely
Future	My thoughts involved future events:	Not at all	Completely
Past	My thoughts involved past events:	Not at all	Completely
Self	My thoughts involved myself:	Not at all	Completely
Person	My thoughts involved other people:	Not at all	Completely
Emotion	The emotion of my thoughts was:	Negative	Positive
Modality	My thoughts were in the form of:	Images	Words
Detail	My thoughts were detailed and specific:	Not at all	Completely
Deliberate	My thoughts were:	Spontaneous	Deliberate
Problem	I was thinking about solutions to problems (or goals):	Not at all	Completely
Diverse	My thoughts were:	One topic	Many topics
Intrusive	My thoughts were intrusive:	Not at all	Completely
Source	My thoughts were linked to information from:	Environment	Memory

2.2.4. Procedure

In the behavioural session participants completed a single 13-minute run of the Go/No-go task with MDES. In the scanning session participants completed three, 13-minute functional runs of the Go/No-go task with MDES while undergoing fMRI. The scanner session took around one hour and 15 minutes of which the scanning took ~45 minutes, this was separated into three blocks.

2.2.5. fMRI acquisition

All MRI scanning was carried out at the York Neuroimaging Centre. Structural and functional scans were acquired using a Siemens Prisma 3T MRI Scanner with a 64-channel phased-array head coil. Structural data were acquired using a T1-weighted (MPRAGE) whole-brain scan (TR = 2300ms, TE = 2.26ms, flip angle = 8°, matrix size = 256 x 256, 176 slices, voxel size = 1 x 1 x 1mm). Functional data were collected using a gradient-echo EPI sequence with 54 bottom-up interleaved axial slices (TR = 3000ms, TE = 30ms, flip-angle = 80°, matrix size = 80 x 80, voxel size = 3 x 3 x 3mm, 267 volumes) covering the whole brain.

2.2.6 Data pre-processing

Five participants were excluded for incorrect number of volumes being collected or excess movement (mean framewise displacement (Power et al., 2014) > 0.3mm and/or more than 15% of their data affected by motion). Functional and structural data were pre-processed and analysed using FMRIB's Software Library (FSL, version 5.0.1, http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/FEAT/). Individual T1-weighted structural images were extracted using BET (Brain Extraction Tool). Functional data were pre-processed and analysed using the FMRI Expert analysis Tool (FEAT). Individual participant analysis involved motion correction using MCFLIRT and slice-timing correction using Fourier space time-series phase-shifting. After co-registration to the structural images, individual functional images were linearly registered to the MNI-152 template using FMRIB's Linear Image Registration Tool (FLIRT). Registration from high resolution structural to standard space was then further refined using FNIRT nonlinear registration. Functional images were spatial smoothed using a Gaussian kernel of FWHM 6 mm, underwent grand-mean intensity normalisation of the entire four-dimensional dataset by a single multiplicative factor, and had high pass temporal filtering (Gaussian-weighted least-squares straight line fitting, with sigma = 50s).

2.2.7 Principal component Analysis

Analysis of the MDES data was carried out in SPSS (Version 25, 2019). Principal component analysis (PCA) was applied to the scores from the 13 experience sampling questions comprising the probes for each participant in each testing environment (lab and scanner) separately. This was applied at the trial level in the same manner as in our prior studies (Konishi et al., 2017; Ruby, Smallwood, Engen, et al., 2013; Ruby, Smallwood, Sackur, et al., 2013; Smallwood et al., 2016; Turnbull, Wang, Schooler, et al., 2019). Specifically, we concatenated the responses of each participant for each trial into a single matrix and employed a PCA with varimax rotation. We performed this analysis separately for each session (behavioural and scanning) in order to examine the similarity in the solutions produced across each situation.

2.2.8 fMRI analysis

Task-based analyses were carried out using FSL. A model was set up including 6 explanatory variables (EVs) as follows: EVs 1 and 2 modelled time periods in which participants responded to target and non-target trials. EV 3 modelled activity 6s prior to each MDES probe. EVs 4, 5 and 6 modelled the 3 thought components, with a time period of 6s prior to the MDES probes and the scores for the related task-component as a parametric regressor. EVs were mean-centred within each run and no thresholding was applied to the EVs. Standard and extended motion parameters were included as confounds. This was convolved with a hemodynamic response function using FSL's gamma function. We chose to use the same 6s interval as used in Turnbull, Wang, Schooler et al. (2019). Contrasts were included to assess brain activity that related to each component of thought during the six seconds prior to the probe. For thoughts, main effects (positively or negatively related to thoughts in both trials) were included. The three runs were included in a fixed level analysis to average across the activity threshold within an individual. Group level analyses followed best practice (Eklund et al., 2016). Specifically we used FLAME, as implemented by FSL, applied cluster-forming threshold of Z = 3.1, and corrected these at $p<.05$ (corrected for family-wise error rate using random field theory). Brain figures were made using MRICroGL (V2.1.49-0, 2019) and SurfIce (V2, 2019). Meta-analytic decoding used Neurosynth (Yarkoni et al., 2011) to find terms most commonly associated with our neural maps in the literature. This platform collects and synthesises results from many different research studies, and identifies the terms associated most often with each region of the brain.

2.2.9 Data and code availability statement

Multidimensional Experience Sampling data is available upon request from the authors via email. All unthresholded maps produced in these analyses are freely available on NeuroVault. These can be found in the "A role for ventromedial prefrontal cortex in self-generated episodic social cognition" collection:

https://identifiers.org/neurovault.collection:6069

The code for the Go/No-go task paradigm is freely available at:

https://vcs.ynic.york.ac.uk/hw1012/go_nogo_experience_sampling/tree/master/

Ethical approval conditions do not permit public sharing of raw data as participants have not provided sufficient consent. Data and analysis scripts can be accessed by contacting the Research Ethics and Governance Committee for the York Neuroimaging Centre or the corresponding author, Delali Konu. Data will be accessible upon request within accordance with General Data Protection Regulation (GDPR).

2.3 Results

2.3.1 Behavioural results

In the scanning session 24 (8 MDES per run) probes were collected with 1456 observations in total. In the behavioural session 8 probes were collected with 728 observations in total. Table 2.2 presents the average response to these questions in terms of means and standard deviations. A principal component analysis was conducted on the 13 questions comprising the MDES probes for each session, one for the behavioural session, and one for the scanning session, both using varimax rotation. This was done to describe the underlying structure of the participant responses about their thoughts in a compact low dimensional manner. For the scanning session results revealed 3 components with eigenvalues greater than 1, which was also suggested by the scree plot (Figure 2.1, Appendices). The components extracted accounted for a total of 47.41% of the variance (component 1 = 20.47%, component 2 = 15.33% and component 3 = 11.61%). The first component represents a dissociation between diverse episodic and social content and thoughts about the tasks. The second component describes a focus on task relevant problem solving, that is detailed and deliberate, and of positive emotional valence. The third component represents thoughts that are intrusive, in the form of words, related to the self, and negative in tone. These components are presented as word clouds in Figure 2.2. For the behavioural session a 3 factor solution was also apparent in the scree plot (Figure 2.1, Appendices). The PCA was run with a 3 factor selection variable; 44.82% of variance being accounted for (component 1 = 21.65%, component 2 = 14.06% and component 3 = 9.10%). It is apparent in Figure 2.2 that these components identified show very similar patterns as were present in the scanning session.

Table 2.2 Mean and standard deviations of each question type for each session.

	Behavioural session		Scanning session	
Question	Mean	SD	Mean	SD
Deliberate	5.04	2.66	4.90	2.65
Detail	5.52	2.52	5.45	2.66
Diverse	4.32	2.58	4.19	2.48
Emotion	6.12	1.91	6.39	2.09
Future	4.88	2.65	4.71	2.76
Intrusive	4.56	2.44	4.44	2.49
Modality	4.87	2.82	4.53	2.80
Past	4.29	2.43	4.06	2.45
Person	4.19	2.63	4.32	2.75
Problem	5.27	2.67	4.75	2.79
Self	5.37	2.69	5.77	2.77
Source	5.32	2.76	4.69	2.83
Task	6.22	2.52	6.34	2.57

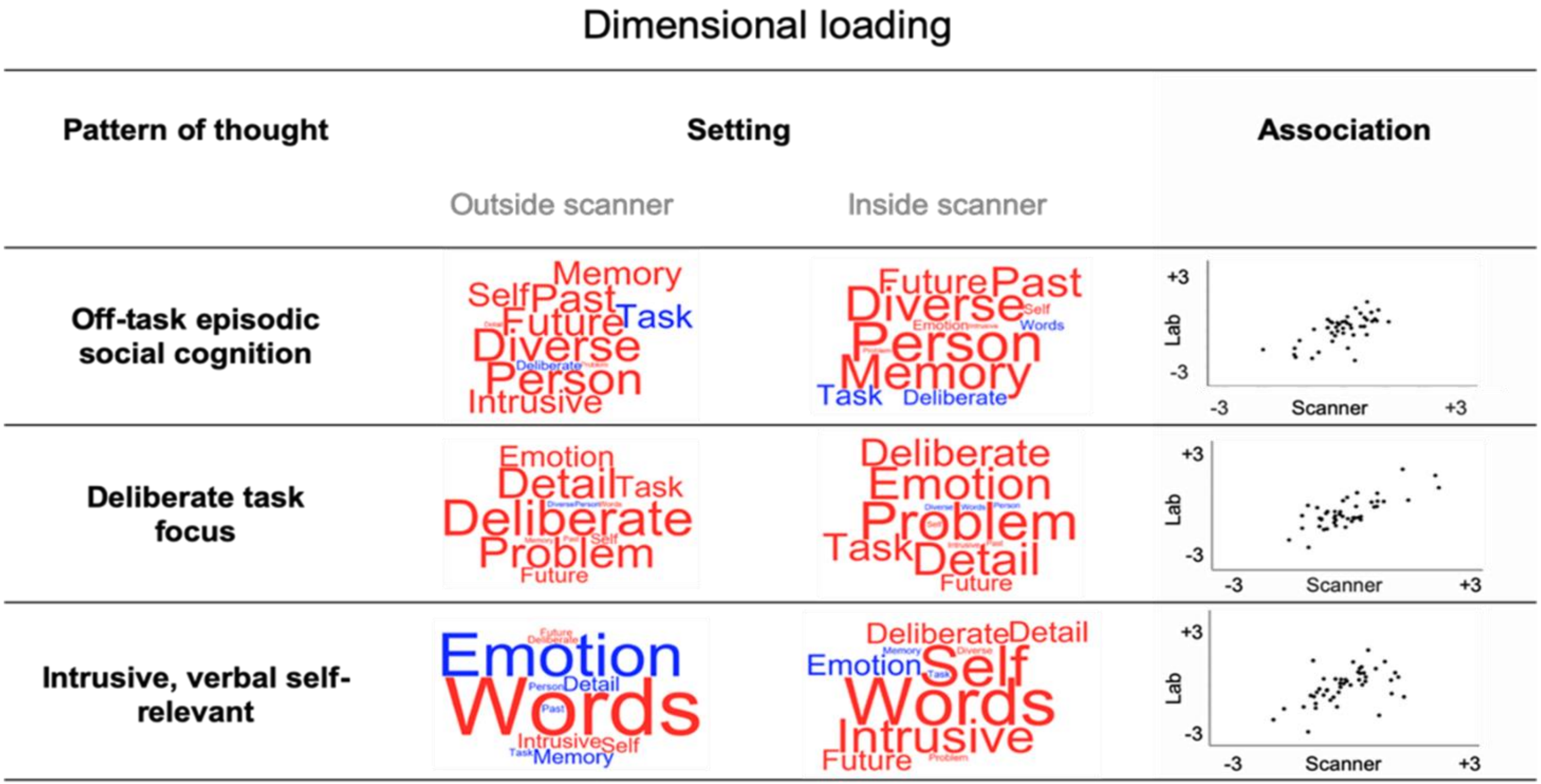
Dimensional loading
Pattern of thought
Setting
Association
Outside scanner
Inside scanner
Off-task episodic social cognition
Deliberate task focus
Intrusive, verbal self-relevant
Memory Self Past Future Task Diverse Deliberate Person Intrusive
Future Past Diverse Self Emotion Words Person Memory Task Deliberate
Emotion Detail Task Deliberate Self Problem Future
Deliberate Emotion Problem Task Detail Future
Emotion Words Detail Person Past Intrusive Self Task Memory
Deliberate Detail Memory Diverse Emotion Self Task Words Intrusive Future Problem
Lab
Scanner
+3
-3

Figure 2.2 (previous page) Patterns of thought identified in this study. The word cloud shows the loadings identified through the independent application of principal component analysis (PCA) to two different data sets (inside and outside the scanner). The colour of the word describes the direction of the relationship (red = positive, blue = negative) and the size of the item reflects the magnitude of the loading. The scatter plots in the grey subpanel show the correlations across the 46 individuals who participated in both sessions. In both cases we selected three components based on the scree plot and applied varimax rotation to the dimensions.

A proportion of our participants from the scanning session (n= 46) took part in both sessions of the study and we assessed the relationship between the individual participant loadings on each component in the behavioural lab and in the scanner. Only participants who completed both scanning and behavioural sessions were included in this analysis. Results showed strong clear positive associations between all three components (Off-task episodic thought, $r(46)=.652$, $p<.001$, two-tailed, Intra Class Coefficient (ICC) = .79, $p<.001$; Deliberate task focus, $r(46)=.753$, $p<.001$, ICC = .860, $p<.001$; Intrusive verbal self-relevant thought, $r(46)=.526$, $p<.001$, ICC = .68, $p<.001$). Together these analyses show that the application of PCA to the MDES data yields consistent dimensions of experience that are consistent across individuals. These correlations are presented in the form of scatterplots in Figure 2.2.

2.3.2 Association between experience and neural activity

Our next analysis examined whether any of the patterns of thought identified in our analyses are linked to reliable changes in neural activity. We performed a multiple regression in which spatial maps describing the associations between neural activity for each PCA for each of the 24 experience sampling probes for each individual were the dependent measures. Following the recommendations we controlled for family wise error using a cluster forming threshold of Z = 3.1, $p<.05$ FEW (Eklund et al., 2016). Results established that the ventromedial prefrontal cortex (vMPFC) was significantly more activated as participants endorsed increasingly off-task episodic social cognition experiences (PCA 1, Figure 2.3). We contextualized this result in the context of a whole brain by overlaying this region with the set of large-scale networks from Yeo and colleagues (Yeo et al., 2011). This determined that the vMPFC region fell at the intersection of the default mode (green) and limbic networks (blue). Finally, to embed this result in a functional context we decoded this spatial map using Neurosynth and the resulting meta-analysis is presented in the form of a word cloud. No significant whole-brain results were found for either component 2 or 3 even at a lower threshold (Z = 2.3).

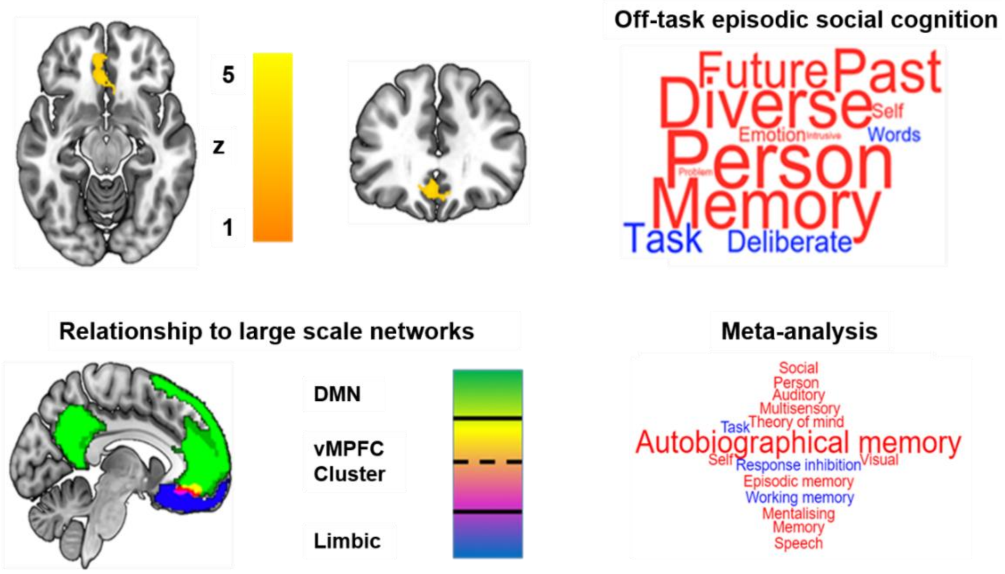

Figure 2.3 Association between ventromedial prefrontal cortex (vMPFC) activity and patterns of episodic social cognition. A region of vMPFC (BA 11) showed a positive correlation with increasing reports of off-task episodic thought. This region fell at the intersection of the limbic and default mode networks as defined by Yeo and colleagues (Yeo et al., 2011). A meta-analysis of the most likely functional associations using Neurosynth is presented in the form of a word cloud. In the word clouds the colour represents the likelihood of the association with the term (red = positive, blue = negative) and the font size describes the magnitude.

2.4 Discussion

Our study set out to determine neural regions that support patterns of self-generated thought. Using a well powered experimental design we recorded neural function using fMRI while participants performed a task with low cognitive demands. We also recorded self-reported descriptions of the individuals experience along multiple dimensions. We used these data to identify regions whose activity was associated with reports of low dimensional representations of the experience sampling data generated by principal component analysis (broadly corresponding to “patterns of thought”). Decomposing our experience sampling data gathered during scanning, revealed three patterns: episodic social cognition, a state of deliberate, detailed task-focus and a pattern of unpleasant verbal self-relevant thoughts. We found a similar factor structure in a control experiment conducted in the lab, as well as common loadings across individuals, establishing the stability of our experience sampling measures. Our neuroimaging analysis identified that a pattern of episodic social cognition was associated with enhanced neural activity within the ventromedial prefrontal cortex (vMPFC). This study, therefore, establishes neural activity in the vMPFC is recruited during periods of self-generated thought with episodic and social features.

Although our study establishes the vMPFC is recruited during complex patterns of self-generated thoughts, our data does not specify which precise aspect of ongoing thought this neurocognitive association reflects. The vMPFC plays an important role in a number of different aspects of cognition as can be seen in the meta-analysis of this region we performed using Neurosynth (Yeo et al., 2011). This analysis highlighted the terms “autobiographical memory” and “memory” as the functional terms most commonly used to interpret activity in this area, but also included aspects of social cognition (“self”, “person”, “theory of mind”) and sensory features (“visual”, “auditory” and “multisensory”). Our data shows that patterns of thoughts can also have heterogeneous features, with the component linked to the vMPFC highlighting multiple features including episodic qualities (“memory”, “future” and “past”) and socio-cognitive features (“self and “person”). This dimension was also linked to “diverse”, underlining that this pattern of thought has complex features. The broad pattern captured by our decomposition of experience sampling data, coupled with the complex functional landscape of the vMPFC, makes it difficult to delineate the specific relationship between activity in the ventromedial prefrontal cortex and patterns of ongoing thought. However, there are a number of candidate accounts within the literature that are worth considering. One line of work suggests that the vMPFC plays a role in complex episodic or social processes, given a role in autobiographical memory (Benoit et al., 2014), self / social cognition (D'Argembeau et al., 2007; Kelley et al., 2002; Macrae et al., 2004) and mental time travel (D'Argembeau, 2013). A role of vMPFC in episodic or social cognitive processes could account for the prominence of temporal and social terms in the associated pattern of thought. Other studies have highlighted the role of the vMPFC in reward-based decision making (Lin et al., 2016; Weilbacher & Gluth, 2017). It is possible, therefore, that the observed association with activity in vMPFC indicates the hypothesised motivational component to off-task thought (Seli, Cheyne, et al., 2015). Studies of affective disturbances also implicate the vMPFC (Oakes et al., 2017) and a prior study demonstrated that this region contained information regarding emotional features of both task-based and naturally occurring emotional states, albeit ones that were related to memories from the past (Tusche et al., 2014). Finally, it is possible that the vMPFC plays a more general role in self-generated experiences perhaps facilitating their elaboration through a role in associate inferences based on memory (Spalding et al., 2018). Clearly given the complex nature of ongoing thought patterns, and the heterogeneous role of the vMPFC, further work is needed to elucidate the functional significance of ventromedial prefrontal activity during self-generated thought.

Finally, it is important to bear in mind that our study is correlational, and this feature of our design limits the ability of our paradigm to address causal relationships. In this context, lesion studies could be important for profitably exploring the functional relationship between the vMPFC and patterns of ongoing thought in a more precise manner (Bertossi et al., 2016).

In conclusion, our study set out to identify the neural correlates of patterns of self-generated mental contents that transcends the here-and-now. We found that a pattern of ongoing thought that was most focused on episodic social cognition rather than the external task was linked to increased activity in a region of the ventromedial prefrontal cortex. Since states of self-generated thought are linked to both beneficial and detrimental aspects of psychological functioning

(Mooneyham & Schooler, 2013), our study highlights the ventromedial prefrontal cortex as relevant to understanding the influences that self-generated experiences play in well-being and happiness.

Chapter 3: Exploring Patterns of Ongoing Thought Under Naturalistic and Conventional Task-Based Conditions

This chapter is adapted from:

Konu, D., Mckeown, B., Turnbull, A., Ho, N.S.P., Karapanagiotidis, T., Vanderwal, T., McCall, C., Tipper, S.P., Jefferies, E. and Smallwood, J. (2021). Exploring patterns of ongoing thought under naturalistic and conventional task-based conditions. *Consciousness and cognition*, *93*, 103139.

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Authorship Contribution Statement

Delali Konu: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing - original draft, Writing - review & editing. Brontë Mckeown: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Writing - original draft, Writing - review & editing. Adam Turnbull: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Writing - original draft, Writing - review & editing. Nerissa Siu Ping Ho: Software, Writing - review & editing. Theodoros Karapanagiotidis: Project administration & Software. Tamara Vanderwal: Conceptualization, Writing - original draft, Writing - review & editing. Cade McCall: Conceptualization, Methodology, Project administration, Supervision, Visualization, Writing - original draft, Writing - review & editing. Steven P. Tipper: Conceptualization, Writing - original draft. Elizabeth Jefferies: Conceptualization, Writing - original draft. Jonathan Smallwood: Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Visualization, Writing - original draft, Writing - review & editing.

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Abstract

Previous research suggests that patterns of ongoing thought are heterogeneous, varying across situations and individuals. The current study investigated the influence of multiple tasks and affective style on ongoing patterns of thought. We used 9 different tasks and measured ongoing thought using multidimensional experience sampling. A Principal Component Analysis of the experience sampling data revealed four patterns of ongoing thought: episodic social cognition, unpleasant intrusive, concentration and self focus. Linear Mixed Modelling was used to conduct a series of exploratory analyses aimed at examining contextual distributions of these thought patterns. We found that different task contexts reliably evoke different thought patterns. Moreover, intrusive and negative thought pattern expression were influenced by individual affective style (depression level). The data establish the influence of task context and intrinsic features on ongoing thought, highlighting the importance of documenting how thought patterns emerge in cognitive tasks with different requirements.

3.1 Introduction

Patterns of ongoing experience are hypothesised to be influenced by both the environment and intrinsic features of individuals such as their cognitive expertise or affective style. For example, studies show that complex task environments reduce the self-generation of personally relevant information and increase patterns of cognition with detailed task focus (Turnbull, Wang, Murphy, et al., 2019). In addition, reading interesting texts helps individuals to maintain attention on the narrative while more complex texts show the opposite pattern (Giambra & Grodsky, 1989; Smallwood et al., 2009; Unsworth & McMillan, 2013). Most notably, recent work has demonstrated that patterns of ongoing thought in the context of the real-world have both similarities and differences with patterns observed in the laboratory (Ho et al., 2020; Linz et al., 2019). The disparity between patterns of thought in the lab and in the real-world suggests that the types of tasks that individuals often engage with in daily life may not correspond to those that are often used in experimental contexts. This may be particularly true for tasks like the Sustained Attention to Response Task (SART) which engenders situations that maximise the need to maintain attention on task-relevant material with little or no support from the external environment (Robertson et al., 1997). Paradigms such as the SART may provide a useful tool with which to study sustained attention but may not relate well to many of the everyday situations in which people generally spend their time. One specific aim of our study was to understand whether patterns of experience vary across tasks with different requirements, a possibility that has yet to be formally explored by research.

Studies examining the role of intrinsic influences on patterns of ongoing thought highlight the relevance of individual differences in affective style and cognitive expertise. For example, individuals who are anxious or unhappy engage in greater off-task thought, often with repetitive or unpleasant features (Makovac et al., 2018; Ottaviani & Couyoumdjian, 2013). In the cognitive domain, individuals with a high capacity for executive control maintain attention more effectively during complex task environments (McVay & Kane, 2009; Unsworth & McMillan, 2013) and refrain from generating off-task thoughts until task environments are less demanding (Rummel & Boywitt, 2014; Turnbull, Wang, Murphy, et al., 2019). In contrast, individuals who excel at tasks that depend on memory tend to generate patterns of thought involving mental time travel with vivid detail (Wang et al., 2019). It has also been shown that individuals who do well on creativity tasks report high levels of daydreaming (Baird et al., 2012; Smeekens & Kane, 2016; Wang et al., 2018) and that those who report engaging in highly vivid and absorbent imagination perform better in mental visualisation tasks (Bregman-Hai et al., 2018). Finally, individuals with expertise in disciplines such as poetry or physics often identify solutions to problems when their mind wanders from the task they are performing (Gable et al., 2019).

Together contemporary research highlights the influence of internal features of the individual and external features of the task environment on ongoing experience. However, no study to date has examined experience across a wide range of lab tasks and so little is known about the interplay between these factors. In the current study, we aimed to bridge this gap in the literature by examining how reported patterns of thought vary across a wide range of task environments. We chose a range of conditions, including conventional tasks that isolate discrete cognitive processes, as well as higher order tasks that rely on multiple task components (such as gambling or set-switching). We also included more naturalistic conditions such as television-viewing paradigms which are more engaging, dynamic and closely mimic the complexity of daily life (Sonkusare et al., 2019; Vanderwal et al., 2019; Vanderwal et al., 2017). To see whether thought reports during these tasks were related to measurements of individual affective style; we measured levels of anxiety (state and trait) and depression in our participants, since these have been linked to differences in both self-reported and psychophysiological correlates of thought patterns gained via experience sampling (Deng et al., 2012; Hoffmann et al., 2016; Makovac et al., 2018; Ottaviani et al., 2014; Poerio et al., 2013; Smallwood et al., 2007; Xu et al., 2017).

In our study, we used multidimensional experience sampling (MDES), a technique applied routinely in the work from our lab for the last five years to identify different features of thought patterns (Konu et al., 2020; Ruby, Smallwood, Engen, et al., 2013; Ruby, Smallwood, Sackur, et al., 2013; Smallwood et al., 2016; Sormaz et al., 2018; Turnbull, Wang, Murphy, et al., 2019; Turnbull, Wang, Schooler, et al., 2019). The experience sampling questions used in the current study had previously been applied in a brain imaging study (Konu et al., 2020). In that study we examined how the different patterns of thought were associated with ongoing neural activity during a low-demand sustained attention task using Functional Magnetic Resonance Imaging (fMRI). We found that reports of ongoing thoughts with episodic and social features were associated with increasing activity in a region of the ventromedial prefrontal cortex. In our MDES studies we employ dimension reduction techniques to create a common low-dimensional representation of the experience sampling data, thereby identifying “patterns of thought” (Konishi et al., 2017; Turnbull, Wang, Murphy, et al., 2019a; Vatansever et al., 2019). Building on our prior work, in the current study we use Principal Component Analysis (PCA) with varimax rotation to determine the dimensions that make up the matrix of our experience sampling reports. We use these as a guide to explore (i) how our tasks evoke different patterns of thought and (ii) whether any of these patterns are also related to measures of the individual affective style assessed via questionnaire. To understand how the task environment influences the types of thoughts people have, we compare patterns of thought across the different task environments. To understand the impact of individual variation on thought patterns, we examine whether the distribution of the thought patterns were associated with participant affective style (anxiety and depression). Although we expected the different tasks to be associated with different thought patterns, our analysis was exploratory and we had no specific hypotheses about the specific patterns in each task. In summary, our study is the first to characterise how the thoughts people think vary across multiple task conditions, providing new insight about the variation of ongoing thought patterns across contexts that include both conventional and naturalistic situations.

3.2 Methods

3.2.1 Participants

Seventy participants took part in a two-part behavioural study (60 females; mean age: 20.60 years; standard deviation: 2.10 years, age range: 18-34 years). As no study to date has examined experience across a wide range of lab tasks, a sample of 100 participants was intended for collection which was guided by the sample sizes of prior studies in the literature that have investigated differences in ongoing thought across easy and hard task contexts (Ruby, Smallwood, Engen, et al., 2013; Ruby, Smallwood, Sackur, et al., 2013; Turnbull et al., 2020). The intended sample size of 100 was however curtailed by the COVID-19 pandemic. All participants were native English speakers with normal/corrected vision between the ages of 18 and 35. This cohort was acquired from the undergraduate and postgraduate student population at the University of York. The study was approved by the local ethics committee at the University of York's Psychology Department. All volunteers provided informed written consent and received monetary compensation or course credit for their participation.

3.2.2 Multidimensional Experiential Sampling (MDES)

Participant ongoing thought was measured using multidimensional experience sampling (MDES). Participants were asked 16 questions as part of a larger experimental questionnaire and one instance of MDES probing required participants answering all of the questions. 13 of these questions have been retained for analysis in the current study. In the current study participants were asked how much their thoughts were focused on the task, followed by 12 questions about their thoughts (Table 3.1) presented in a random order. All questions were rated on a scale of 1 to 10. Within each block of all tasks participants completed one set of MDES probes (i.e. 13 questions in the current study). A total of 9 probes per individual for the documentary TV-based task, 8 probes per individual for the affective TV-based task, 12 probes per individual for the Go/No-go, Self/Other and Semantic tasks, and 4 probes per individual for the CANTAB tasks were completed. Overall, participants completed a total of 33 probes. Every block of each task was followed by MDES probes. A question was presented for 4 seconds on the screen, based on the average response time from previous studies. The questions were separated by a 500ms fixation cross.

3.2.3 Affective Measures

To gain an understanding of individual affective style, we administered the Centre for Epidemiological Studies Depression Scale; CES-D (Radloff, 1977) as well as the State and Trait Anxiety Inventory; STAI (Spielberger, 1983). The measures were completed during the task session where participants completed the PsychoPy and CANTAB tasks. These questionnaires were administered to participants using November 2019, December 2019 and January 2020 Qualtrics software (Copyright © 2019 & 2020 Qualtrics). Qualtrics and all other Qualtrics product or service names are registered trademarks or trademarks of Qualtrics, Provo, UT, USA. https://www.qualtrics.com. Participants also completed the Five Facet Mindfulness Questionnaire (Baer et al., 2006), Intolerance of Uncertainty Scale (Carleton et al., 2007) and Autism Spectrum Quotient (Baron-Cohen et al., 2001) on Qualtrics during the PsychoPy and CANTAB task session, and the STAI before and after the affective video paradigm in the video session. These questionnaires were collected as part of a larger battery of questionnaires designed to test differences in intrinsic influences on thoughts and have not been used in the current study. Only the STAI and CES-D questionnaire scores completed during the PsychoPy and CANTAB task session has been included in the current study. Due to a technical error 3 participant responses to one question on the Trait Anxiety Inventory of the STAI were not recorded.

3.2.4 Documentary TV-Based Paradigm

In the passive documentary TV-based paradigm, participants were instructed to attend to the screen as they watched and listened to 3-4 minute TV-clips from a British documentary series (BBC TV program), called *Connections: Season 1* (BBC One, 1978) which reviews the history of science and innovation. Clips were presented under three audio-visual conditions: (i) congruent visual and auditory presentation (documentary condition) in which participants watched and listened to the documentary TV-clips, (ii) audio condition in which participants had audio input of the documentary clip accompanied by a white fixation cross, and (iii) *Inscapes* in which participants had audio input of the documentary clip with visuals from *Inscapes;* a nonverbal, non-social TV paradigm that features slowly moving abstract shapes from Vanderwal and colleagues (Vanderwal et al., 2017; Vanderwal et al., 2015). The *Inscapes* clip was shown to provide irrelevant yet complex dynamic visual input that was unrelated to the audio from the documentary. *Inscapes* was slowed to half speed and segmented into 3 unique clips so that the participants did not see the same clip twice. The order of audio-visual conditions was pseudo-randomised, so that 3 consecutive TV-clips always included one from each condition. Each session consisted of a total of 9 TV-clips. Participants were informed that they would watch documentary TV-clips with varying visual input but were unaware of which condition they were in before starting the block. Written instructions were presented at the start of each run. Participants were asked questions about the content of the TV-clips in a comprehension questionnaire at the end of the documentary TV-based paradigm (this data was part of the larger cohort collection and has not been used in current study). Seven participants were informed that they would be required to perform this questionnaire before the protocol was changed so that remaining participants were unaware that this was required.

3.2.5 Affective TV-Based Paradigm

In the affective TV-based paradigm, participants were instructed to attend to the screen as they watched and listened to 3-4 minute TV clips from the BBC TV programmes *Happy Valley (BBC One, 2014), Line of Duty (BBC One/Two, 2012), Luther (BBC One, 2010) and Bodyguard (BBC One, 2018)*, a range of commercial television shows including crime dramas and thrillers. The clips were selected to include a threatening event. There were two conditions which varied in the onset of the threatening event; i) an action condition in which the direct threat occurs in the first minute of the clip and the rest of the clip follows the protagonist(s)' response to the threat and ii) a suspense condition in which a potential threat, high in uncertainty, is detected early on in the clip but the direct threat only occurs in the last minute of the clip, as discussed in McCall and Laycock (in submission). Three independent raters were used to identify when the direct threat occurred in each clip. An example of an action condition clip is a scene from *Bodyguard Series 1 Episode 2* in which gunshots from a roof are fired (threatening event) at the protagonists within the first minute of the clip and the remainder of the clip follows the protagonists' reaction to continuing shots. An example of a suspense condition clip is a scene from *Luther Series 3 Episode 2* in which two characters hear a noise when they believe they are home alone and go upstairs to investigate, in the last minute of the clip the characters are attacked (threatening event after a period of suspense). After each clip, participants were invited to (a) take a break for as long as they needed and (b) withdraw from the task if they were feeling distressed. Participants were asked to fill out a questionnaire on Qualtrics (Qualtrics, Provo, UT) including the State Anxiety questionnaire from the State-Trait Inventory (STAI) just before and just after the affective TV-based paradigm and a debrief questionnaire in which participants responded to questions asking them whether they had seen the videos before.

These questionnaires were part of the larger cohort collection and are not considered in the current study.

The order of the affective TV conditions was pseudo-randomised so that the first TV clip seen by participants was either from the action or suspense condition and this was counterbalanced across participants. The remaining TV clips were pseudo-randomised so that each condition would not be shown more than twice consecutively. Each session consisted of a total of 8 TV clips. Written instructions were presented at the start of each run. Participants were informed that the clips involved dangerous behaviour, strong language, and violence on several occasions prior to starting and they were reminded repeatedly that they had the right to withdraw at any time, without giving reason and without prejudice.

3.2.6 PsychoPy Tasks

PsychoPy3 (Peirce et al., 2019) was used to present the Go/No-go, Self/Other and Semantic task paradigms to participants. Each task included 4 task blocks (2 blocks consisting of each experimental condition) and lasted ~ 3 minutes. Key press across all task paradigms was counterbalanced with participants making forced choice responses using d and k to indicate 'yes' or 'no' respectively. A tone was sounded when participants did not respond to a trial. In the Semantic and Self/Other tasks, a probe preceded stimulus presentation where each trial consisted of a probe signalling whether the trial was experimental or control. In each task paradigm trials consisted of the presentation of a target stimulus until a response was made (1500ms). Once a response was captured, a fixation cross appeared on the screen for the remaining time. The inter-stimulus-intervals (ISI) consisted of a fixation cross and was jittered (500-1500ms). Block order was counterbalanced across participants. Written instructions were presented at the start of each block. Participants also completed the CES-D, STAI, Five Facet Mindfulness Questionnaire (FFMQ), Intolerance of Uncertainty scale (IU) and Autism Spectrum Quotient (ASQ) on Qualtrics (Qualtrics, Provo, UT) during the task session. The FFMQ, IU and ASQ were part of the larger cohort collection and are not considered in the current study.

3.2.6.1 Go/No-go Task Paradigm.

Participants were instructed to attend to the centre of the screen as a single shape stimulus was presented ('X', 'Q' or 'O'). In the Go condition participants were instructed to make a single key press when the target stimulus 'X' was presented. In the No-Go condition the 'O' was the target stimulus to which participants had to make a single key press. Each block of the experiment was designed so that 60% of trials presented an 'X', 20% the 'Q' and 20% the 'O'. Each block consisted of 70 trials of either the Go condition or No-Go condition. This task was designed to provide an undemanding task context with little external demand which is commonly used in studies of ongoing experience (Smallwood, Davies, et al., 2004).

3.2.6.2 Self/Other Adjective Rating Paradigm.

This task was based on that used by de Caso and colleagues (de Caso, Karapanagiotidis, et al., 2017; de Caso, Poerio, et al., 2017), and is similar to self-reference paradigms used in the literature (Craik et al., 1999; Kelley et al., 2002; Vanderwal et al., 2008). Participants were instructed to attend to the centre of the screen, as they viewed adjectives, presented one word at a time. Each trial consisted of a probe signalling the participant to either judge the following stimulus in accordance with the referent (self or other) or indicate whether it was written capitalised. In experimental trials participants had to indicate whether they would associate the word presented with the specified referent or not. In one condition participants made judgements in relation to themselves (self condition) and in another condition they made judgements in relation to a significant other (social cognition condition). Participants were verbally instructed to think of a single friend. In control trials participants indicated whether the words shown were written in uppercase or not. Each block consisted of 48 trials where participants made judgements about themselves (self condition) or a friend (social cognition condition). The words used in this task paradigm were selected from a list of normalised personality trait adjectives with the highest meaningfulness ratings from Anderson and colleagues (Anderson, 1968), as used in de Caso and colleagues (de Caso, Karapanagiotidis, et al., 2017; de Caso, Poerio, et al., 2017). Each adjective list consisted of negative adjectives (50%) and positive adjectives (50%). The adjectives were presented in either lowercase (50%) or uppercase (50%). Participants saw a different list of words in each block. This task was designed to engage participants in social cognition, making judgements in relation to themselves as well as a significant other.

3.2.6.3 Semantic Task Paradigm.

This task was adapted from the task paradigm used by Rice and Colleagues (Rice et al., 2018) as in Alam et al. (2020) . Participants were instructed to attend to the centre of the screen, as they viewed four categories of stimuli: i) pictures of people, ii) pictures of places, iii) written people iv) written places. The stimuli used in this task consisted of trials with an 85% or greater accuracy from Rice and colleagues (Rice, Hoffman, Binney & Lambon Ralph, 2018) as in Alam et al. (2020). Each block consisted of 48 trials of each stimulus category: i) pictures of people, ii) pictures of places, iii) written people iv) written places. Each trial consisted of a probe signalling the participant to judge the following stimulus on being European or located high on the screen. In experimental trials participants had to indicate whether the stimuli shown were European. In control trials participants had to indicate whether the stimuli shown were located high on the screen (above the fixation cross). This task was designed to engage participants in making semantic judgements with stimuli of varying modality.

3.2.7 Cambridge Neuropsychological Test Automated Battery

The Cambridge neuropsychological test automated battery (CANTAB), a computerised cognitive assessment and data collection tool, was used to collect measures of executive function, memory, emotion and social cognition in participants (CANTAB® [Cognitive assessment software]. Cambridge Cognition (2019). All rights reserved. www.cantab.com). Participants completed the Cambridge gambling, emotional recognition, intra-extra dimensional set-shift and spatial working memory tasks once during the task session using i-Pads. Full details of the tasks below can be found at www.cantab.com.

3.2.7.1 Cambridge Gambling Task.

In the Cambridge gambling task (CGT) participants were instructed to attend to the screen as they viewed a row of 10 boxes, some which were red and others blue. The ratio of red to blue boxes varied on a trial-by-trial basis. On every trial a token was hidden under one of the boxes. Participants had to guess whether the token would be hidden under a red or blue box using a forced choice key response (red or blue), they could not proceed until a response was made. Following the participant response, a bet counter (circle in the middle of the screen) showing the participants current bet value (displayed at *5, 25, 50, 75 and 95 percent of their current points)* was presented on the screen for a maximum of 2000ms. During this time participants had to bet a proportion of their points on their response. Participants started the task with 100 points. If the participant did not respond, the last shown bet value was taken as the points risked. In the first block the bet counter increased, in the second block it decreased. If the answer was correct participants earned the points shown on the counter, if they were incorrect they lost the points. Participants saw a feedback screen showing the amount of points won or lost for 1000ms at the end of each trial. This task consisted of 36 trials and took ~ 12 minutes. The Cambridge gambling task was designed to measure decision-making as well as risk-taking behaviour. Due to a technical error half of the recruited participants (35 participants) completed a 6 minute longer version of this task with 36 more trials.

3.2.7.2 Emotion Recognition Task.

In the emotion recognition task (ERT), participants were presented with Caucasian female and male faces (computer-morphed images producing an average face composed from pictures of a range of individuals), which expressed one of the 6 basic emotions (anger, disgust, fear, happiness, sadness and surprise) at 15 intensities. Each face was displayed on screen for 200ms followed by an ISI of ~1000ms. Participants had to indicate which one of the 6 basic emotions the stimulus expressed using a 6-button forced choice response (participants could not proceed until a response was made). This task consisted of 90 trials and took ~ 9 minutes. The emotion recognition task was designed to measure participant ability to identify each of the 6 basic emotions.

3.2.7.3 Intra-Extra Dimensional Set Shift Task.

In the intra-extra dimensional set shift (IED) task, participants were presented with two categories of stimuli (pink shapes and white lines). The start of the task consisted of simple stimuli which only varied in one category, for example, two white lines of different shapes. As the task progressed participants were presented with more complex stimuli, for example, stimuli consisted of a mixture of the two categories such as white lines superimposed on pink shapes.

Participants had to use feedback; a high pitched tone and presentation of text (i.e. 'correct'), indicating a correct answer or a low pitched tone and presentation of text (i.e. 'incorrect'), indicating an incorrect answer, to figure out the rule used to identify the correct stimulus on each trial. The rule changed after 6 correct responses. At the start of the task, one dimension was the focus of the rule (e.g. pink shapes), and as the task progressed participants had to adapt to the change in focus of the rule (e.g. white lines become the focus). Participants could not proceed to the next trial until a response was made. An ISI of 1000ms was presented after the feedback of each trial. This task consisted of 9 stages. Each stage continued until 6 trials were successfully completed in a row. After 50 trials, if this was not the case, the task ended. This task took ~ 7 minutes. The intra-extra dimensional set shift task was designed to measure participant ability to attend to a particular category of stimuli and later shift this attention to categories of stimuli that were ignored. Due to a technical error 5 participants' reaction times were not recorded.

3.2.7.4 Spatial Working Memory Task.

In the spatial working memory task (SWM) participants were presented with boxes. They were instructed to search in the boxes to identify a hidden token using the process of elimination. During a trial, if a token was hidden under a box, it would not be hidden under that box for the remainder of the trial. Participants were presented with an increasing number of boxes as the task progressed (a trial of 4, 6 and 8 boxes). This task consisted of 3 trials, was self-paced and took ~ 4 minutes. The spatial working memory task was designed to measure search strategy and memory error (searching in a box that contained a token on a previous trial and searching in a box twice in the same trial).

3.2.8 Procedure

The task paradigms reported in the current study were part of an ERC funded project with a larger cohort collection that tested the influence of situational and intrinsic influences on ongoing thought. The current study involved 4 hours of testing split over 2 separate sessions on consecutive days for ~ 2 hours each. Order of session and task was counterbalanced across participants. The order in which participants completed these tasks was pseudorandom using a fixed order.

Participants were tested in the same environment using the same computers and i-Pads over the two sessions.

In one session participants completed the TV-based paradigms (documentary and affective TV-based paradigms), multidimensional experience sampling (MDES) and affective measure questionnaires. In both TV-based watching paradigms participants were shown unique TV-clips and no clips were shown twice.

In a separate 'task' session, participants completed 7 tasks: the Go/No-go, Self, Semantic paradigms, as well as the Cambridge neuropsychological test automated battery (CANTAB® [Cognitive assessment software]. Cambridge Cognition (2019). All rights reserved. www.cantab.com) which consisted of the Cambridge Gambling, Emotional Recognition, Intra-Extra Dimensional Set-Shift and Spatial Working Memory task paradigms. Participants also completed the multidimensional experience sampling and affective measure questionnaires. A summary of the task paradigms used in the current study can be found in Table 3.2.

Table 3.1 Multidimensional Experience Sampling questions used to sample thoughts in the current study. Participants rated statements from 1-10.

Dimension	Statements	Scale_low	Scale_high
Task	My thoughts were focused on the task:	Not at all	Completely
Future	My thoughts involved future events:	Not at all	Completely
Past	My thoughts involved past events:	Not at all	Completely
Self	My thoughts involved myself:	Not at all	Completely
Person	My thoughts involved other people:	Not at all	Completely
Emotion	The emotion of my thoughts was:	Negative	Positive
Modality	My thoughts were in the form of:	Images	Words
Detail	My thoughts were detailed and specific:	Not at all	Completely
Deliberate	My thoughts were:	Spontaneous	Deliberate
Problem	I was thinking about solutions to problems (or goals):	Not at all	Completely
Diverse	My thoughts were:	One topic	Many topics
Intrusive	My thoughts were intrusive:	Not at all	Completely
Source	My thoughts were linked to information from:	Environment	Memory

3.2.9 Data Analysis

3.2.9.1 Principal Component Analysis.

Analysis of the MDES data was carried out in SPSS (Version 25, 2019). Principal Component Analysis (PCA) was applied to the scores from the 13 experience sampling questions (see Table 3.1) comprising the probes for each participant in each task. This was applied at the trial level in the same manner as in our prior studies (Konishi et al., 2017; Ruby, Smallwood, Engen, et al., 2013; Ruby, Smallwood, Sackur, et al., 2013; Smallwood et al., 2016; Turnbull, Wang, Schooler, et al., 2019). Specifically, we concatenated the responses of each participant for each trial into a single matrix and employed a PCA with varimax rotation. Participant MDES data were z-scored prior to analysis. Orthogonal varimax rotation was used to decompose the z-scored experience sampling data (see Appendices, Table 3.1 and 3.2). We also performed oblique oblimin rotation on the data (see Appendices Figure 3.1, 3.2 and Table 3.3, 3.4) to assess the similarity between the decompositions when they were subject to the different rotational schemes. It can be seen in the Appendices (see Appendices Figure 3.3 and Appendices Table 3.5) that the orthogonal and oblique decompositions show high similarity (correlations ranging from .926 to .979), and so we used varimax rotated solutions to maintain consistency with our prior studies (Konu et al., 2020; Ruby, Smallwood, Engen, et al., 2013; Ruby, Smallwood, Sackur, et al., 2013; Smallwood et al., 2016; Sormaz et al., 2018; Turnbull, Wang, Murphy, et al., 2019; Turnbull, Wang, Schooler, et al., 2019).

Components were selected based on the variance explained by the eigenvalues and the inflexion point of the scree plot from the decomposition which yielded 4 components (Figure 3.1). All tasks were included to examine thought patterns across the range of task states measured. Due to technical issues, seven participants had seven MDES probes rather than eight in the affective TV-based task and one had three probes from the CANTAB task rather than four. Two participants' CANTAB probes were excluded from analysis due to incorrect completion of the MDES probes. A further two participants completed the sessions in a different order compared to the rest of the cohort. Finally, seven participants were also informed about comprehension questions prior to completing the documentary task. To understand if this difference impacted on their experience we repeated the PCA analysis excluding the MDES scores of these seven individuals from the documentary TV-based task. Appendices Figure 3.4, Table 3.6, 3.7 and 3.8 present the results of this analysis. It is clear that there are no broad differences between the solutions when these individuals were excluded and so we discuss the analysis that includes all participants.

3.2.9.2 Linear Mixed Model.

A linear mixed model (LMM) was implemented in SPSS version 25 to examine whether the dimensions of thought identified in the PCA varied significantly across the task conditions. We used a very simple model without explicit selection. We performed four separate models in which each of the components identified in the PCA was an outcome measure, and the task conditions were included as conditions of interest. In these models we included probe number, order and day of testing as nuisance co-variates of no interest. The participants' intercept was treated as a random factor.

3.2.9.3 Reliability Analysis.

To assess the reliability of the dimensions of ongoing thought obtained from the PCA within the various task contexts, intraclass correlation coefficients (ICC) were calculated. The reliability of multiple instances of the MDES regression scores within each task condition for each participant was compared in a two-way mixed model using average measures and consistency (Table 3.3). The four CANTAB task conditions; gambling, emotion recognition, working memory and switching were not included in the ICC as participants only completed MDES questions once for these conditions.

A reliability analysis was also run to assess the consistency in participant responses to the CES-D scale (Radloff, 1977) and STAI (Spielberger, 1983). The questionnaires were shown to have high reliability with a Cronbach's α of .88 and over (please see Appendices, Table 3.9 for details and descriptive statistics).

3.2.9.4 Repeated Measures Analysis of Variance.

A repeated measures analysis of variance (ANOVA) was run to examine how the contextual influences on each dimension of thought related to the measures of affective style recorded in the current study (symptom scores of depression, state and trait anxiety). The outcome variables were the mean scores for each participant for each PCA component (a total of 4 variables). Mean values were calculated by averaging the z-scored median values of the participants' PCA regression scores for each PCA within each task condition. Explanatory variables were the z-scored mean participant scores on the measures of affective style (symptom scores of depression, state and trait anxiety).

3.2.10 Data and Code Availability Statement

Anonymised data and analysis scripts are freely available on Mendeley Data (http://dx.doi.org/10.17632/mvb9y32hpv.1).

The scripts for the documentary TV-based paradigm, affective TV-based paradigm, PsychoPy tasks and the MDES related to CANTAB are freely available on GitHub (https://github.com/Delali-Konu/Ongoing-thought-under-naturalistic-and-task-based-conditions.git).

Table 3.2 Summary of task paradigms used in the current study with corresponding mean RT (ms), mean accuracy and standard error.

Category	Task Paradigm	Condition	Task	RT (ms) (standard error)	ACC (standard error)
Simple tasks	Go/No-go	Go	Respond to nominated target	435.27 (1.65)	0.97 (0.01)
		No-go	Respond to less frequent nominated target	484.47 (2.80)	0.96 (0.02)
	Semantic	Visual Semantics** (Picture)	Make a decision (Europe or not) based on a pictorial stimulus	808.32 (3.59)	0.80 (0.01)
		Verbal Semantics** (Word)	Make a decision (Europe or not) based on a text stimulus	818.88 (3.64)	0.81 (0.01)
	Self/Other	Self reference	Make judgement in reference to self	766.05 (3.14)	0.91 (0.01)
		Social cognition reference	Make judgement in reference to other	774.49 (3.14)	0.89 (0.01)
Complex tasks*	Working memory		Hold information in mind	N/A	N/A
	Switching		Switch between different tasks	81730.29 (3234.97)	N/A
	Gambling		Make gambling decisions	1325.955 (32.26)	N/A
	Emotion Recognition		Identify emotional expressions	1010.059 (25.51)	0.66 (0.01)
TV-based tasks	Documentary TV-based clips	Documentary	Watch a documentary	N/A	N/A
		Audiobook	Listen to a documentary	N/A	N/A
		Audio Inscapes	Listen to documentary with irrelevant visual input	N/A	N/A
	Affective TV-based clips	Suspense	Watch a TV clip in which a threat occurred at the end of the clip creating threat uncertainty	N/A	N/A
		Action	Watch a TV clip in which the threat occurred at the start of the clip creating threat certainty	N/A	N/A

* From the CANTAB battery ** From Rice, Hoffman, Binney, and Lambon Ralph (2018).

3.3 Results

To provide a compact low-dimensional representation of the experience sampling data we applied Principal Component Analysis (PCA; see Methods). Based on the inflexion point of the scree plot and variance explained by the eigenvalues we selected four components (see Figure 3.1 and Appendices Table 3.1) which in total accounted for 53.22% of the total variance. The loadings on these components are presented as word clouds in Figure 3.1 (also see Table 3.1 in the Appendices for specific loadings). Component One accounted for 15.28% of the variance and reflects patterns of positively valenced episodic social cognition (episodic social cognition). Component Two accounted for 13.91% of the experience sampling data and reflected a pattern of negatively valenced intrusive thought (unpleasant intrusive). Component Three accounted for 12.31% of the variance and reflects high loadings on deliberate detailed task focus (concentration). Finally, Component Four accounted for 11.73% of the overall variance and reflected a pattern of off-task self-relevant cognition that has negative loadings on the “Person” feature (thoughts focused on other people) but positive loadings on “Self” feature (thoughts focused on the self), separating thinking about the self from thinking about other people (self focus).

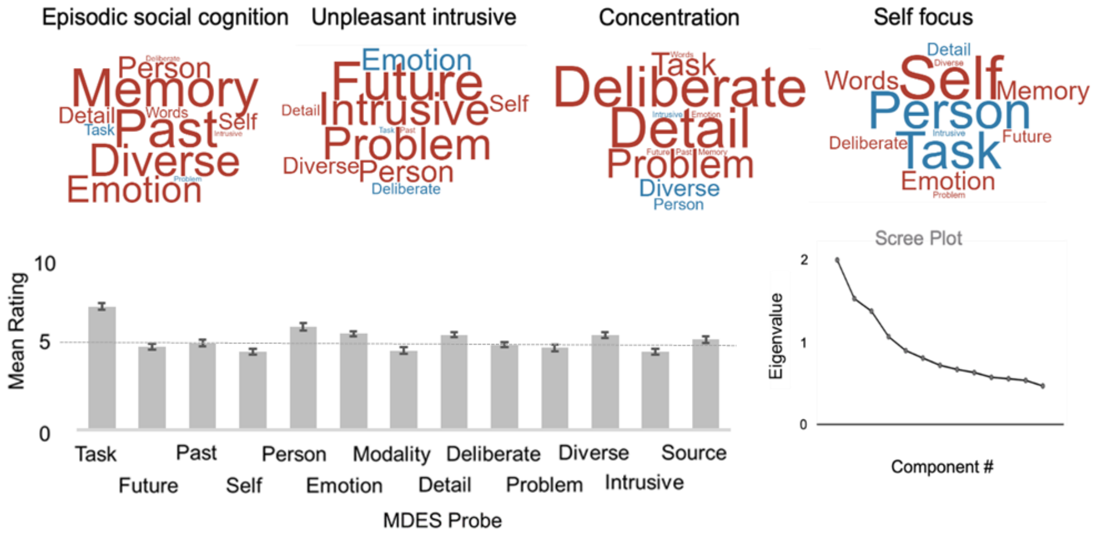


Figure 3.1 Decomposition of the experience sampling data collected in this study revealed four components across all conditions. Based on their loadings the four components were labelled as “Episodic Social Cognition”, “Unpleasant Intrusive”, “Concentration” and “Self Focus”. The word clouds in the upper panel summarise these loadings in which the colour of the word describes the direction of the relationship (red = positive, blue = negative) and the size of the item reflects the magnitude of the loading. The bar-plot in the lower panel shows the mean ratings for each item that these components are derived from. The grey dotted line represents the median rating of 5. The scree plot for this decomposition is presented in the lower right panel. Error bars represent 99.6% CI which account for the number of questions and therefore control for family-wise error in these analyses.

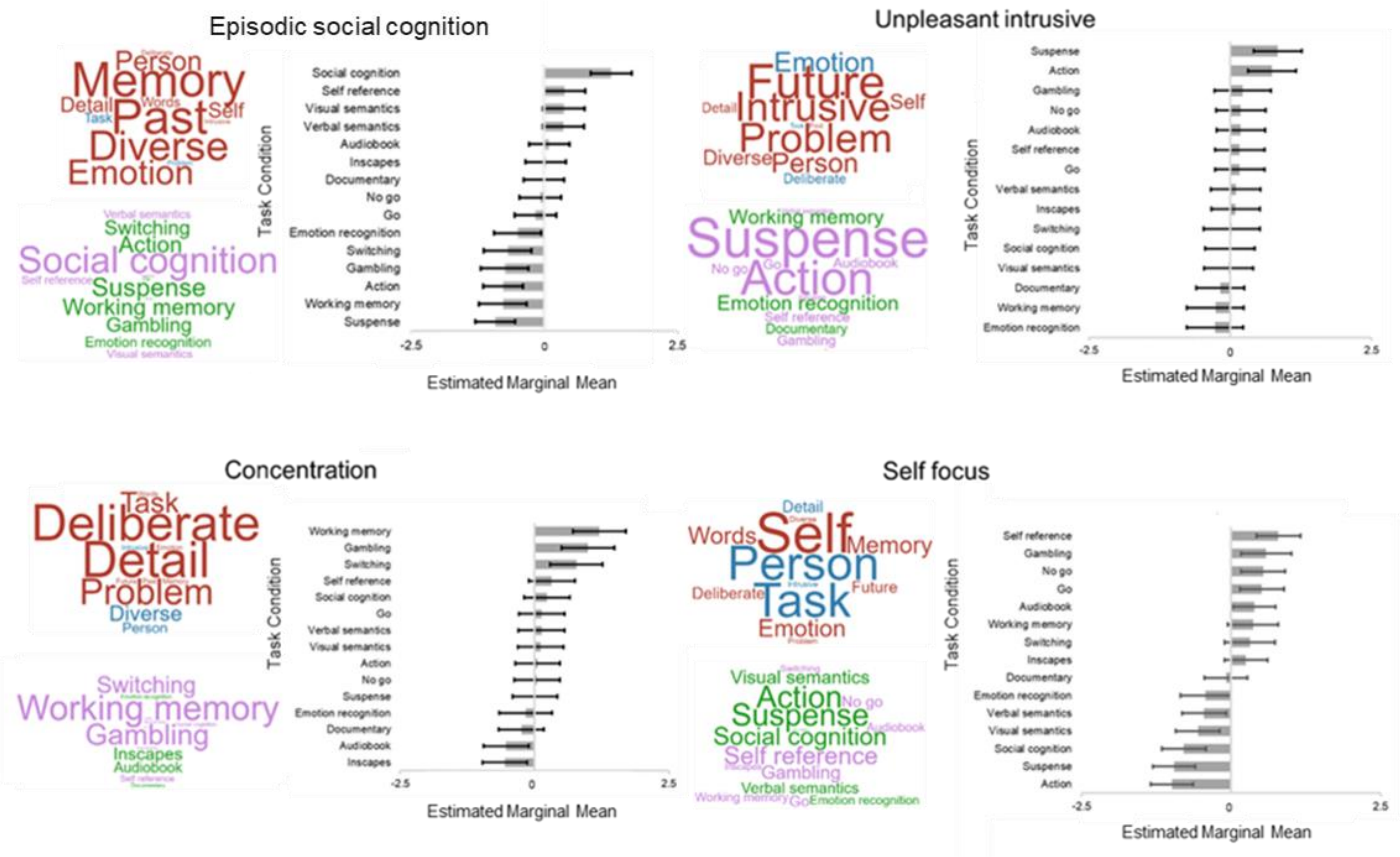
To assess the reliability of the four dimensions of ongoing thought across multiple instances of a condition within each task context an intraclass correlation coefficient (ICC) was run (see Methods). The results showed moderate to high reliability of the four dimensions of ongoing thought within each task context. Average ICC measures for each of the four dimensions for each task can be found in Table 3.3.

Table 3.3 Intraclass correlations for each component for each task condition across participants. All correlations were significant (p<.001). Note ICC for the gambling, emotion recognition, working memory and switching conditions were not suitable for an ICC as participants only completed MDES questions once per condition.

		Intraclass Correlation (ICC)		
Condition	Episodic social cognition	Unpleasant intrusive	Concentration	Self-focus
Action	.766	.828	.779	.774
Audiobook	.603	.757	.649	.692
Documentary	.714	.688	.593	.595
Go	.795	.786	.772	.602
Inscapes	.506	.715	.465	.747
No go	.676	.624	.769	.651
Self reference	.738	.763	.655	.528
Social cognition	.723	.709	.726	.771
Suspense	.764	.840	.741	.806
Verbal semantics	.756	.871	.661	.571
Visual semantics	.795	.776	.796	.667

Having determined four dimensions of ongoing thought in the experience sampling data, and established their reliability, we next examined whether these varied significantly across the task environments. We addressed this question using a linear mixed model (LMM; see Methods). We performed four separate models in which each of the four components were an outcome measure.

This analysis revealed a significant influence of task condition on the distribution of each component (Component One, $F(14, 2205.64) = 86.89$, $p = <.001$; Component Two, $F(14, 2205.54) = 27.39$, $p <.001$; Component Three, $F(14, 2205.72) = 37.70$, $p < .001$ & Component Four, $F(14, 2205.81) = 123.17$, $p <.001$). The results of this analysis are presented in Figure 3.2, both in the form of a bar plot summarising the beta weights from the model (including confidence intervals), and in the form of word clouds (please see Table 3.10 in the Appendices for the estimated marginal means). In each bar graph the conditions are ordered by their relative influence on the relevant dimension of thought. It can be seen from Figure 3.2, that Component One (episodic social cognition) was most common in the task which required participants to rate the applicability of items to a significant other (friend) and lowest weighting in more complex tasks (e.g. working memory) as well as in the affectively toned TV clips (action and suspense). Component Two (intrusive thought) was most prevalent in the affectively-toned TV clips. Component Three (concentration) was most prevalent in demanding tasks (working memory and switching) and least prevalent in the tasks with a narrative without strong affective ties (audio and video documentary conditions). Finally, Component Four (self-focus) was prevalent during the self-reference, gambling and sustained attention tasks but was least prevalent in the affectively toned TV clips (action and suspense).


Episodic social cognition
Person
Memory
Detail
Words
Task
Past
Self
Diverse
Emotion
Verbal semantics
Switching
Action
Social cognition
Self reference
Suspense
Working memory
Gambling
Emotion recognition
Visual semantics
Task Condition
Social cognition
Self reference
Visual semantics
Verbal semantics
Audiobook
Inscapes
Documentary
No go
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Emotion recognition
Switching
Gambling
Action
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Estimated Marginal Mean
Unpleasant intrusive
Emotion
Future
Detail
Intrusive
Self
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Self focus
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Inscapes
Documentary
Emotion recognition
Verbal semantics
Visual semantics
Social cognition
Suspense
Action
-2.5
0
2.5
Estimated Marginal Mean

Figure 3.2 (previous page) Results of a linear mixed model (LMM) examining the variance across task environments in the four patterns of thought identified using PCA. In each panel the top word cloud reiterates the loadings on each thought pattern (the colour of the word describes the direction of the relationship; red = positive, blue = negative, and the size reflects the magnitude of the loading). The lower word cloud highlights the loadings of this pattern in each task as described by the parameter estimates from the LMM (the colour of the word describes the direction of the relationship; purple = positive, green = negative, and the size reflects the magnitude of the loading). The bar plot shows the same data and reports the confidence intervals for these estimates ($p < .05$, corrected for family-wise error). Error bars, therefore, represent 99.7% CI and so control for family-wise error in these analyses. Action = action (affective TV-based), Audiobook = audio (documentary TV-based), Documentary = documentary (documentary TV-based), Emotion Recognition = ERT (CANTAB), Gambling = CGT (CANTAB), Go = go (Go/No-go), Inscapes = Inscapes (documentary TV-based), No-go (Go/No-go), Self reference = self (self/other paradigm), social cognition = social cognition (self/other paradigm), suspense = suspense (affective TV-based), Switching = IED (CANTAB), Verbal semantics = word (Semantic paradigm), Visual semantics = picture (Semantic paradigm), Working memory = SWM (CANTAB).

Having determined the contextual influences on each pattern of thought we next examined how they related to the measures of affective style recorded in our experiment (symptom scores of depression, state and trait anxiety). Mauchly's test showed that the data did not violate the assumption of sphericity ($\chi 2$ (5) = 10.24, p =.069). A significant Component by Depression interaction (F (3,198) = 2.93, p =.035) was revealed. Further analysis indicated that higher levels of depression were associated with higher scores on the intrusive thought component (r =.418, p<.001), see Figure 3.3.

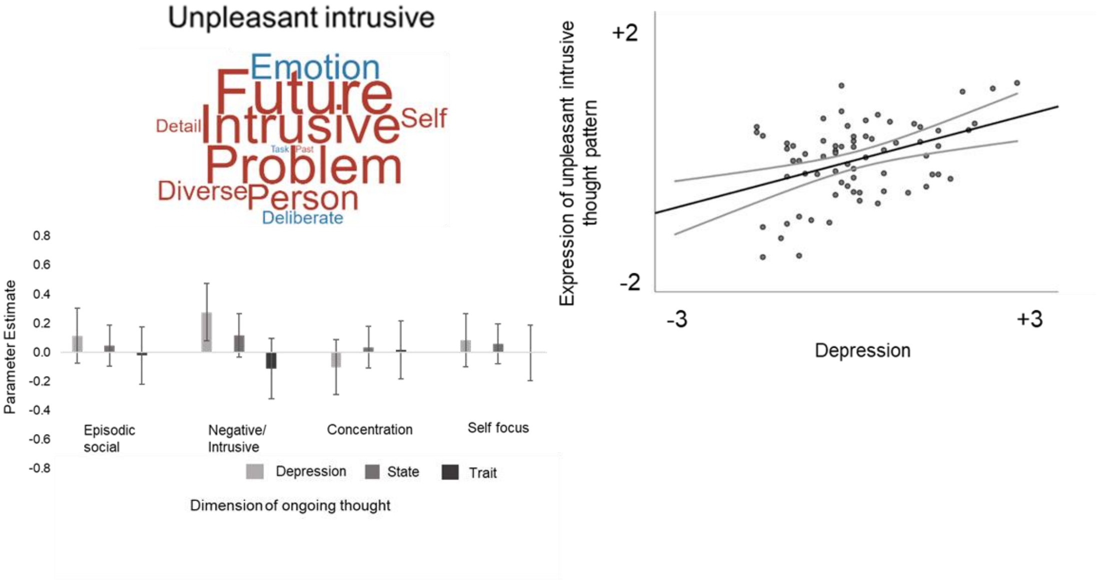

Figure 3.3 The association between patterns of thought and measures of affective disturbance (symptom scores of depression, state and trait anxiety). The bar graph summarises the beta weights from the model describing the average contribution of depression, state and trait anxiety as described by its parameter estimate and associated confidence intervals. We found that patterns of unpleasant intrusive thoughts were positively associated with levels of higher depression ($p<.05$). The scatterplot shows the distribution of this relationship in which each point is a participant. Here the x-axis shows participant mean regression scores relating to the unpleasant intrusive thought pattern across all tasks and the y-axis shows participant mean scores in the CES-D questionnaire. Error bars represent 95% CI.

3.4 Discussion

Our study set out to understand how thought patterns vary across a wide range of task environments including those which encompass both simple and complex laboratory tasks, as well as more realistic everyday task situations such as watching TV programmes with varying affective components. We used MDES to characterise patterns of thought during blocks of task performance along multiple dimensions (see Table 3.1) and applied Principal Component Analyses (PCA) to these data to identify the latent dimensions that best described these variables. Our analysis revealed four dimensions that we summarised as “episodic social cognition”, “intrusive negative thought”, “detailed deliberate thought” and “self focus”. Three of these dimensions; “episodic social cognition”, “detail and deliberate” and “intrusive negative”, are similar to dimensions observed in our prior study using the same set of questions where experience was assessed in a simple signal detection paradigm both inside and outside of the scanner (Konu et al., 2020). We also show high reliability using these dimensions within the current study. This consistency across studies and across tasks within the current study indicate that these components are a reliable way to summarise an individual’s self-reported experience, at least when they are measured by the set of questions used in our study. We also found that patterns of intrusive thought were more prevalent in self-reports of individuals with higher levels of depression. These data therefore show that thought patterns can reflect the influence of both testing conditions and affective style (specifically individual scores on measures of depression) which can both be captured using a low-dimensional space described by PCA.

In the current study each of the four dimensions captured by PCA varied across the task environments that we studied. The pattern of episodic social cognition was most evident when participants thought about features of a significant other (their friend) and least prevalent while watching affective TV clips and completing memory tasks. Demanding tasks (i.e. working memory, switching or gambling) were linked to patterns of detailed deliberate thoughts, replicating a pattern seen in our prior studies in which we found that thoughts had this property with increasing working memory demands (Sormaz et al., 2018; Turnbull, Wang, Murphy, et al., 2019). Unpleasant intrusive thoughts were most common while participants watched TV clips with affective features. Finally, when participants assessed the applicability of adjectives to themselves, performed a gambling task or sustained attention tasks, their reports were characterised by self-referential thought patterns. This thought pattern was least important while watching affectively toned TV clips or thinking about other people. We also found that patterns of intrusive thoughts were more prevalent in self-reports of individuals with higher levels of depression. These data therefore show that thought patterns can reflect the influence of both testing conditions and affective style (specifically individual scores on measures of depression) which can both be captured using a low-dimensional space described by PCA. Importantly, in our study these components showed a high degree of reliability (Table 3.3) suggesting that they are relatively consistent within a specific task environment. Below we consider these data in the context of prior work examining the features of different thought patterns.

First, our data extends an emerging literature that patterns of ongoing thought are heterogeneous by demonstrating that they vary in important ways across task environments (for a review see Smallwood, Turnbull, et al., 2021). Prior studies have generally focused on whether patterns of thought are task related or not within a given environment. Instead, our application of PCA to MDES data highlights that experience sampling data can contain multiple thought patterns. Our study demonstrates that some task environments produce patterns of thought that encompass features that mind-wandering could be argued to have: stimulus independent features (loadings of memory in Component 1), intrusive features (high loadings on Component 2), the absence of a deliberate assessment of task-relevant information (i.e. Component 3) and a trade-off between task focus in favour of self-relevant sources of information (Component 4). Importantly, we found evidence that each of these different experiential features varied in their prominence across the task conditions. These results suggest that there may be multiple patterns of experience which may be distributed in a complex way across different task contexts.

These novel observations have important implications for studies of ongoing thought. For example, work examining the phenomena of mind-wandering has reached a conceptual impasse since there is no consensus on defining features of the experience, or whether these are even necessary (Christoff et al., 2018; Seli, Kane, et al., 2018). Methodologically, our application of PCA to experience sampling data across a wide range of task environments may provide a helpful way to empirically unpack the complexity and richness of the state space that experience sampling allows experimenters to examine. Moving forward, our study adds to a growing call for both conceptual and definitional clarity when using experience sampling to define experiential states and characterise specific features or associated underlying thought processes.

Second, it is possible that the heterogeneous space identified in our analysis partly explains why findings from the laboratory and daily life often do not fully overlap (Ho et al., 2020; Kane et al., 2017; Linz et al., 2019). We found that different patterns of experience tended to be expressed in a complex manner across task environments. For example, patterns of off-task self-relevant thought were common in tasks that emphasise the self as a target (self-reference) or indirectly (gambling or undemanding sustained attention tasks) relative to when people watched extracts of affectively engaging TV clips. In contrast, detailed task focus was highest in complex tasks (working memory) and lowest while engaging with TV clips and audiobooks with fewer affective features. In laboratory studies of “mind-wandering”, researchers employ sustained attention or working memory tasks, while in daily life it is likely that listening to audiobooks or watching TV clips is a more common activity. Based on our data, systematic variation in the tasks used in cognitive experiments from those that participants tend to engage in their day-to-day lives may be one important factor to consider when trying to map between the laboratory and real world. Importantly we have recently used PCA to map similarities and differences between patterns of ongoing thoughts recorded via experience sampling in the lab and in the real world (Ho et al., 2020). In the future it could be possible to use techniques like PCA to identify task environments which best capture the patterns of thoughts that people encounter in daily life and use these in the laboratory to gain a more ecological perspective on cognition in the real world (Matusz et al., 2019; Smilek et al., 2007).

One specific implication of our results relates to task selection for laboratory studies of mind-wandering. When trying to study mind-wandering, many studies use tasks that lack compelling demands (i.e. the Go and No-Go conditions we used or relatively dry narratives such as the documentaries) due to the tactic assumption that these tasks promote off-task states. Consistent with this, we found that these tasks did not promote a state of task focus as effectively as did the working memory tasks (see Figure 3.2). Instead, these contexts emphasised patterns of self-focus to a much greater degree than tasks like watching affectively toned TV-clips. These observations support the consensus within the literature that paradigms such as the SART provide a fertile context in which to study experiences such as self-focused mind-wandering. Importantly, however, our study qualifies the assumption that these non-demanding tasks provide paradigms that are well suited to understanding how individuals maintain states of concentrated task performance. It is possible that this is why motivation plays such an important role in states of mind-wandering in tasks like the SART (Seli, Cheyne, et al., 2015).

Third, our study adds to a growing body of evidence suggesting that there are multiple mechanisms through which task conditions can influence ongoing thought. Prior studies show that patterns of social-episodic thought are reduced when individuals engage in complex external tasks, in which context experience is dominated by a pattern of detailed task focus (Turnbull, Wang, Murphy, et al., 2019; Turnbull, Wang, Schooler, et al., 2019). Our study is broadly consistent with these prior findings since we find a similar episodic social component which is most prevalent when participants engage in socially motivated tasks and is suppressed in complex tasks (e.g. working memory) where ongoing cognition emphasises patterns of detailed task focus. This pattern of suppression of episodic social thought in conditions of higher task demands is usually interpreted in terms of the need to maintain task focus to perform more complex tasks (Teasdale et al., 1995; Teasdale et al., 1993). Notably, however, affectively toned TV programmes also involved a relative absence of episodic social thought (See Figure 3.2). In the context of affectively toned TV programmes, ongoing thought was characterised by unpleasant intrusive thoughts rather than patterns of detailed task focus. It has been suggested that individuals often focus on their current concerns when they escape the here and now (Cox & Klinger, 2004; Klinger, 1987). We speculate that it may be the saliency of the information in the affective TV clips which helps individuals to anchor attention in the here and now and briefly escape from their own worries, a perspective that is supported by the fact that this same pattern of thought was generally elevated in less happy individuals for whom current concerns may be relatively high (Ruehlman, 1985). Based on these data we speculate there may be multiple different ways that task contexts can capture experience, and MDES is a tool well suited for investigating different types of contextual influences on ongoing thought (Smallwood et al., 2021).

Interestingly the results show a relation between thought that is positively valenced and past-focused (see Component 1 Figure 3.1), a result which is not in keeping with the literature relating to rumination which shows evidence of past-focused thought as pervasively negative in nature. Studies sampling past, present and future thought have shown both past and future-focused thought to be predominantly high in negative valence in comparison to present-focused thought, which is predominantly high in positive valence (Vannikov-Lugassi & Soffer-Dudek, 2018). The unusual finding of positively valenced past-focused thought, is likely a consequence of the tasks chosen, such as, in the instance of the other-reference task where participants were asked to consider a person with positive associations (i.e. their best friend). In other words, the thought pattern identified in our study may reflect a form of cognition engaged by our task, whereas in other studies spontaneous thoughts about the past have been shown to be more readily negative in valence.

While self-generated thought that enables the individual to escape the here and now (often with a focus on personal goals) may be adaptive, it has also been shown to have maladaptive consequences, for example, in perservative and negative intrusive thought. For example, there is a well-established association between these negative aspects of self-generated thought and depression (Hoffmann et al., 2016). The current study shows that patterns of intrusive thought were more prevalent in participant self-reports with higher levels of depression. There is evidence to suggest that emotional valence plays a key role in the detrimental functioning of self-generated thought. The regulation of personal goals, for example, can become maladaptive and could be a catalyst for detrimental aspects of cognition such as rumination, perseverative thought and certain types of depression (Marchetti et al., 2016). Studies have also shown that individuals high in detachment report less control and more negative affect during periods of on-going thought (Cardeña & Marcusson-Clavertz, 2016). Negative and intrusive thoughts that characterise individual concerns can persist into other states of thought such as dreaming (Gross et al., 2020). Maladaptive thought can also exacerbate psychopathological symptoms. For example, studies have shown that individual dissociation scores that correlated with negatively valenced past and future-focused thoughts were also moderated by depression and anxiety (Vannikov-Lugassi & Soffer-Dudek, 2018). Since the characteristics of maladaptive self-generated thought are particularly important when considering its impact on mental health and well-being, an important implication of our study is that the choice of task environment in which to sample ongoing thought may influence the results.

3.5 Conclusion and Limitations

Although our study establishes the role that both individual differences and situations play in patterns of ongoing thought, it leaves several important questions unanswered. First, our study was composed of university educated students and this limits the degree to which these results would generalise to older or clinical populations for whom patterns of thoughts are known to be different (Fox et al., 2018; Giambra & Grodsky, 1989). Second, although our design demonstrated the influence of both task environments and individual affective style (scores on measures of depression) on patterns of ongoing thought, it remains unclear how these two processes interact. It would be useful in the future, for example, to understand whether the association between depression and patterns of unpleasant thought is stronger or weaker in the presence or absence of threat in the environment. Third, for pragmatic reasons the number of measures of experience in each task was uneven. Although our analysis suggests that we had sufficient power to discriminate the patterns of thoughts across different situations, it remains possible that the amount of variance captured by each PCA could be influenced by the number of samples in each context, and it is also possible that this may influence the qualities of the patterns themselves.

Fourth, although the task procedures were generally adhered to, it must also be noted that there were several technical problems during data collection. Seven participants were informed about the comprehension questionnaire while others were not, which may have changed the level of focus and mind-wandering differentially. Half of the participants completed a longer version of the CGT, five participant RTs were not recorded during the IED task, seven participants had seven MDES probes rather than eight in the affective TV-based task and one had three probes from the CANTAB task rather than four. In addition two participants' CANTAB probes were excluded from analysis due to incorrect completion of the MDES and two participants completed the sessions in a different order compared to the rest of the cohort.

Fifth, although the use of TV-clips as a task environment enables us to test for patterns of thought in a more naturalistic setting, there is still room to develop more naturalistic task environments. In this regard, it is important to note that our selection of the questions to assess ongoing thoughts, the tasks used, and the measures of affective style are in no way a comprehensive description of either the thoughts people have, the types of tasks they perform, or, their affective style. It is likely that there are many task environments that our study has not captured, many aspects of experience that our questions did not query and multiple features of an individuals' disposition that influence their experiences that were not measured. However, our study uses a greater range of task environments and experience sampling questions than is standard in this type of work and thus highlights that the study of limited aspects of experience in only a subset of possible task environments in past research is likely to prohibit our ability to fully appreciate the different patterns of ongoing thoughts that individuals can have. While the field is still in its infancy, recent endeavours to better define self-generated thought have already begun. For example, comparisons between maladaptive daydreaming and other constructs of self-generated thought such as, daydreaming, mind wandering, fantasy proneness and dissociative absorption have been investigated (Schimmenti et al., 2019). Research has also investigated differences between self-generated thought in a waking state and dreaming state as well as stimulus dependent thought (Gross et al., 2020). Dissociative absorption has been shown to be a differentiable construct from Attention-Deficit/Hyperactivity Disorder and mind wandering, and associate more with obsessive compulsive symptoms (Soffer-Dudek, 2019). There is recent discussion of the methodological challenges and potential solutions for researching task-unrelated thought, such as, the suggestion to include more ecologically valid tasks (Murray, Krasich, et al., 2020). Thus, in accordance with the current literature, our study highlights the need to broaden the tasks we use to study ongoing thought and raises the need to develop a conceptual framework that accounts for the role of context within which the scientific study of self-generated thought can be embedded (Smallwood, Turnbull, et al., 2021).

Chapter 4: The Persistence of Thought: The Effect of Context and Individual Difference on Thought Over Time

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Authorship Contribution Statement:

Delali Konu: Conceptualisation, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Software, Visualisation, Writing-Original Draft. Jonathan Flavell: Software. Brontë Mckeown: Methodology, Software. Elizabeth Jefferies: Methodology. Jonathan Smallwood: Methodology. Steven Tipper: Methodology, Funding acquisition, Supervision. Cade McCall: Conceptualisation, Formal Analysis, Methodology, Project Administration, Supervision, Visualisation, Writing-review & editing.

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Abstract

Self-generated thoughts take our minds beyond the “here and now”. While the content of such thought is heterogeneous and varies across contexts, we often engage in repetitive thoughts, including autobiographical planning and rumination. The current study examined the interplay between the persistence of thoughts over time and the ongoing influence of context. We examined how ongoing thought, measured using multidimensional experience sampling, varied from an initial task context (personality judgements) to subsequent contexts (shape judgements varying in working memory requirements). Principal Component Analysis of the experience sampling data revealed four patterns of thought which bear strong similarity to those reported in prior research: episodic social cognition, concentration, future problem-solving and negative self-focus. Using liner mixed modelling, we replicated prior findings that context influences the content of self-generated thought and that increases in cognitive demand limit self-generated thought. Although no effect of context on the content of thought persisted beyond the immediate task, we found that individual differences in the expression of certain patterns of thought (future problem-solving and concentration) persisted across contexts. These data suggest that while patterns of thought are generally sensitive to context, some patterns show more stable individual differences across contexts. This study provides a method to further investigate contextual and dispositional differences in thought persistence.

4.1 Introduction

We engage in streams of ongoing cognition throughout the day, with our self-generated thoughts drifting beyond the “here and now”. Self-generated thought is described throughout the literature as a heterogenous form of cognition, varying in content over time (Andrews-Hanna et al., 2013; Fox et al., 2013; Smallwood, 2013; Smallwood & Andrews-Hanna, 2013). Our thoughts fluctuate dynamically throughout the day (Smith et al., 2018), but as part of this dynamic fluctuation, we can also fixate on particular patterns of content. For example, studies have shown that the mind has a natural tendency to focus on current concerns (Cole & Berntsen, 2016; Klinger, 1971) and engage in autobiographical planning (Baird et al., 2011; D'Argembeau & Mathy, 2011; Smallwood et al., 2009; Stawarczyk, Majerus, et al., 2013; Stawarczyk et al., 2011). Repetitive features of thought include emotional valence, purpose, personal significance, outlook and level of construal (Andrews-Hanna et al., 2013; Segerstrom et al., 2010; Segerstrom et al., 2003). Together these findings raise questions regarding the determinants of the content of our thoughts as we move from context to context.

Individual differences are important in understanding variation in the content of self-generated thoughts (Welhaf et al., 2020). For example, individual differences in mental health correlate with particular patterns of thought (Andrews-Hanna et al., 2013; Guesdon, Lejeune, Rotge, et al., 2020; Linz et al., 2019; Ruby, Smallwood, Engen, et al., 2013; Segerstrom et al., 2010). Chronic patterns of negative self-generated thoughts such as rumination (persistent negative past thoughts) and worry (persistent negative future thoughts) have been associated with the exacerbation of mental health disorders such as anxiety, depression, and obsessive-compulsive disorder (Cole & Tubbs, 2022; Hoffmann et al., 2016; Kanske et al., 2016; Kanske et al., 2017; Marchetti et al., 2016; Nolen-Hoeksema, 2000; Ottaviani et al., 2013; Smallwood et al., 2005; Smallwood et al., 2007; Vannikov-Lugassi & Soffer-Dudek, 2018). With regards to rumination, research suggests that deficits in cognitive flexibility could underlie maladaptive repetitive thinking, making it harder for individuals to break the cycle of negative and intrusive thoughts (Crowe et al., 2007; Davis & Nolen-Hoeksema, 2000).

Whilst there are clear associations between negative thought content and poor mental health there are, conversely, associations between positive thought content and good mental health (Watkins, 2008). For example, thoughts that are related to positive affect such as planning future events can boost happiness, resilience and reduce stress (Baars, 2010; Cohn et al., 2009). These adaptive and maladaptive consequences associated with self-generated thought are in line with the *content regulation hypothesis* which suggests that the content of our thoughts are associated with different functional outcomes which has great implications for our behaviour (Mooneyham & Schooler, 2013; Smallwood & Andrews-Hanna, 2013; Smallwood & Schooler, 2015; Smallwood, Turnbull, et al., 2021). Moreover, understanding the mechanisms that govern repetitive thinking might help us to understand how to address its more detrimental forms.

Age is another individual difference which has implications for the frequency and content of self-generated thought. For example, younger adults tend to report more instances of self-generated thought in comparison to older adults (Maillet et al., 2018). In addition, younger adults are more likely to report self-generated thought that is negatively focused and self-critical compared to older adults who tend to report thought that is focused on the present and positive (Irish et al., 2019; Jordao et al., 2019; Mckeown et al., 2021; Moran et al., 2021; Turnbull et al., 2021).

These examples suggest that there are individual differences in self-generated thought that are consistent across time. In a prior study (Konu et al., 2020) we examined the stability of thought content within the same task context and across different testing environments. Participants completed an undemanding task whilst being intermittently sampled using multidimensional experience sampling (MDES), a technique commonly used for identifying patterns of ongoing thought (Konu et al., 2021; Konu et al., 2020; Sormaz et al., 2018; Turnbull et al., 2021; Turnbull, Wang, Murphy, et al., 2019). A subset of participants completed the task in both the MRI scanner and the laboratory. It was found that participants' thoughts were consistent within the same task context, across the two testing environments (the lab and scanner). This study provides a clue that individuals think similar patterns of thought across time, at least when they return to similar task contexts.

Nevertheless, our thoughts are clearly shaped by the world around us. In a daily life sampling study participants reported external events as approximately equal triggers of their self-generated thought compared with internal triggers (Song &

Wang, 2012). Plimpton and colleagues' (2015) also found that the temporal orientation and frequency of participants' thoughts were sensitive to external cues (irrelevant verbal cues) presented during a simple vigilance task. Negative cue words were more likely to trigger past self-generated thoughts compared to positive cue words which triggered future self-generated thoughts. Such research suggests that the environment around us can trigger spontaneous autobiographical associations (Smallwood et al., 2009). Additionally, Vannucci and colleagues (2019) showed that the temporal orientation of participants' self-generated thoughts was sensitive to the spatial orientation demands of a task. Participants were more likely to report past focused self-generated thoughts when observing arrows pointing to the left, compared to when presented with right facing arrows, where they were more likely to report having future self-generated thoughts. This simple manipulation clearly demonstrates that our self-generated thoughts are influenced by context.

In a prior study we investigated the effects of varying task contexts on the expression of self-generated thoughts using multidimensional experience sampling (Konu et al., 2021). Participants engaged in different task-driven contexts, ranging from discrete cognitive tasks to more naturalistic tasks. The MDES data were reduced using Principal Component Analysis to obtain descriptions of the thoughts experienced across the varying task contexts. Participants reported having thoughts that were off-task episodic and social, off-task unpleasant and intrusive, on-task, detailed and deliberate, as well as off-task, self-focused and verbal. Critically, the expression of these thought patterns varied depending on the task context. Off-task episodic social thought was expressed most under contexts requiring participants to make judgements about a significant other. Unpleasant intrusive thoughts were expressed most when participants watched emotionally evocative video clips. The detailed deliberate thought pattern, on the other hand, was expressed most when participants engaged with discrete cognitive tasks. Self-focused thoughts were expressed most during tasks with self-referential components such as making judgements about the self.

While these and other data support the claim that self-generated thought is partly determined by context, it is less clear what influence context has on our self-generated thoughts over time as we move from one context to the next. Indeed, it is not unusual to engage in a particular thought within many contexts throughout the day. It is unclear the exact mechanisms that might drive some thoughts to persist across contexts while others come and go. It is possible that executive function plays a role. Current accounts of self-generated thought suggest that domain general mechanisms such as control processes support the continuity of self-generated thoughts (Smallwood, 2013; Smallwood & Schooler, 2015). This view contradicts prior accounts of mind wandering as a product of executive failure. This was supported by findings that mind wandering during high executive control tasks reduces task performance (McVay & Kane, 2010; Mrazek et al., 2012; Smallwood & Schooler, 2006; Smallwood & Schooler, 2015). According to the context regulation account, mind wandering need not be an indication of executive failure (McVay & Kane, 2010), but can be adaptive when the individual has the resources to do so (Smallwood, 2010). In this sense, self-generated thoughts are rather context dependent and therefore part of a cognitive system that is adaptive (Smallwood & Andrews-Hanna, 2013; Smallwood & Schooler, 2015). Konishi and colleagues (2015) provided evidence for this model by showing that participants reported higher instances of off-task thoughts during an undemanding task where little external attention was required (participants made judgements about shapes which were presented on screen). In comparison, participants reported fewer instances of off-task thought during a demanding task where high external attention was required (participants made judgements about shapes from prior trials). The results suggest that participants engaged in off-task, self-generated thought most frequently when they had the cognitive resources to do so.

The context regulation account suggests that executive control underlies the context dependent nature of self-generated thought by flexibly supporting perceptually guided thoughts during contexts which are high in external demand as well as self-generated thought during contexts which are low in external demand (Smallwood, 2013; Smallwood & Andrews-Hanna, 2013). Additionally, studies have shown that brain areas associated with executive function are recruited during periods of self-generated thought (Christoff et al., 2009). The dorsolateral prefrontal cortex, a brain region associated with executive function, has also been implicated in the contextual control of cognitive abstract thinking (Turnbull, Wang, Murphy, et al., 2019). As such, it appears that executive control mechanisms are essential to supporting the continuity of self-generated, as well as perceptually guided thoughts (Smallwood, Brown, Baird, & Schooler, 2012). Working memory, one mechanism of executive function, has been associated with the maintenance of self-generated thought. Working memory capacity has been shown to regulate how flexibly individuals engage in self-generated thought (Smallwood & Schooler, 2015). In accordance with the context regulation account, research has shown that generally tasks of high working memory load, i.e., high external demand, reduce reports of self-generated thoughts (Feng et al., 2013; McVay & Kane, 2009; Unsworth & McMillan, 2013). With this in mind, thoughts may be more likely to persist from one context to another when working memory load is sufficient to do so.

While the aforementioned literature suggests that both individual differences and context influence the content of thought, it is likely that our thoughts arise from some interaction between the two. Turnbull and colleagues (Turnbull et al., 2021), used MDES to understand differences in self-generated thought across ageing by focusing on interactions between content and contextual requirements. They found that older adults experienced reductions in the instances of self-generated thought although their thoughts were more positive, and task focused. These age differences related to context. There was a general increase in task detailed thought under more demanding contexts for both age groups, however for older adults this increased more in response to more demanding contexts compared to younger adults. Thoughts about the present which were goal-focused and pleasant were engaged less in younger adults and these thoughts were engaged less as a function of demanding task contexts compared to older adults.

Together these data raise questions regarding the stability of specific thought patterns across contexts. Individual differences in some patterns of thought might only emerge in specific contexts, whereas other thought patterns might show stable individual differences across a variety of contexts. Our recent work on the influence of context on thought (Konu et al., 2021) hints at this possibility. We found that intrusive and unpleasant thoughts, but not other patterns of thought, were significantly associated with higher depression scores across the different contexts. These data suggest that thoughts are not only influenced by individual differences and by different contexts, but that some thought patterns might be particularly persistent across contexts. However, many questions remain regarding which thought patterns show more consistency and for whom.

The current study explored several questions regarding the role of context and individual differences in the persistence of thought content across contexts. We sought to: 1) replicate our previous findings that patterns of thought are influenced by context, 2) use the effect of particular task contexts on thought to test the degree to which thought patterns persist from one context to the next, 3) test the potential moderating effect of working memory on that persistence, and 4) examine the degree to which specific thought patterns show stable individual differences across contexts.

To replicate the finding that context influences thought, we examined whether specific task contexts from Konu et al. (2021) would produce similar patterns of thought. To understand how thought persists into a new context, we tested the effects of a prior task thought context on thoughts during a distractor task. To test the moderating effects of executive control, we manipulated the nature of that distractor task to be either high or low in working memory. Finally, we examined the degree to which individual differences persisted across contexts for different thought patterns. More generally, we aimed to explore a methodology by which we can test for the effect of context and individual differences on the persistence of thought.

4.2. Methods

4.2.1 Participants

Two hundred and eight participants took part in this online behavioural experiment (146 females; M age = 23.17 years; s = 4.7 years, age range = 18-35). All participants were UK residents with normal/corrected vision between the ages of 18 and 35, and a prolific approval rate of 95% or above. Participants were recruited using Prolific (www.prolific.co) August 2021. The study was approved by the local ethics committee at the University of York's Psychology Department. Informed consent was obtained from all participants, and they received monetary compensation (via Prolific) for their participation. Twelve participants were excluded from analysis (please see data analysis section below).

Twelve participants' data across all task contexts were excluded due to poor performance (less than 25% mean accuracy on the shape location tasks and fewer than 75% of responses on the adjective rating tasks) to exclude extreme outliers and reported technical difficulties during the experiment. As the study aimed to investigate evidence of persistence of thought, all MDES probes per excluded participant were removed and these participants were excluded from all analyses.

4.2.2 Multidimensional Experiential Sampling (MDES)

Participant ongoing thought was measured using multidimensional experience sampling (MDES). A set of 13 questions were used as one probe as in Konu et al. (2021). Participants were first asked whether their thoughts were focused during the previous task, before being asked the remaining 12 questions in a random order (see Table 4.1). Each question was presented as a statement with a rating scale that ranged from 1 to 10. Participants dragged the cursor to indicate their rating on the scale. Each question appeared on the screen for 10 seconds. Participants could proceed to the next question by selecting a 'next' button before the 10 seconds had ended. The questions were separated by a 500ms fixation cross.

Table 4.1 Multidimensional experience sampling questions used to sample thoughts. Participants rated statements from 1-10.

Dimension	Statements	Scale low	Scale high
Task	My thoughts were focused on the task:	Not at all	Completely
Future	My thoughts involved future events:	Not at all	Completely
Past	My thoughts involved past events:	Not at all	Completely
Self	My thoughts involved myself:	Not at all	Completely
Person	My thoughts involved other people:	Not at all	Completely
Emotion	The emotion of my thoughts was:	Negative	Positive
Modality	My thoughts were in the form of:	Images	Words
Detail	My thoughts were detailed and specific:	Not at all	Completely
Deliberate	My thoughts were:	Spontaneous	Deliberate
Problem	I was thinking about solutions to problems (or goals):	Not at all	Completely
Diverse	My thoughts were:	One topic	Many topics
Intrusive	My thoughts were intrusive:	Not at all	Completely
Source	My thoughts were linked to information from:	Environment	Memory

4.2.3 Context-guided task

The context-guided task was used to engage participants in different thought contexts by encouraging them to make judgements about either themselves or a significant other. The context-guided task was implemented in a similar way to a previous study investigating the influence of varying task context on patterns of thought (Konu et al., 2021). It was based on tasks used in earlier work on mind wandering (de Caso, Karapanagiotidis, et al., 2017; de Caso, Poerio, et al., 2017) and self-referential processing (Craik et al., 1999; Kelley et al., 2002; Vanderwal et al., 2008). On each trial, an adjective (e.g., 'mean' or 'creative') appeared in the centre of the screen. Participants were asked to indicate whether they would associate the adjective with a specified referent (self or significant other) using keys corresponding to 'yes' and 'no' on the keyboard. In the self condition participants made judgements in relation to themselves whereas in the social condition participants made judgements in relation to their best friend. In the social condition participants were instructed to think of only one friend. Each condition block consisted of 48 trials. As in our prior work (de Caso, Karapanagiotidis, et al., 2017; de Caso, Poerio, et al., 2017) the list consisted of normalised personality traits with the highest meaningfulness ratings from Anderson and colleagues (Anderson, 1968). The lists consisted of negative adjectives (50%) and positive adjectives (50%). Adjectives were presented on the screen for 1500ms and preceded by a 500ms fixation cross. The adjective rating task conditions were between-subject variables: participants completed 2 runs of a single condition (i.e., 2 runs of the self condition or the social condition). Order of run was counterbalanced across participants. This task lasted approximately 3 minutes in total (including practice and instructions).

4.2.4 Distractor Task

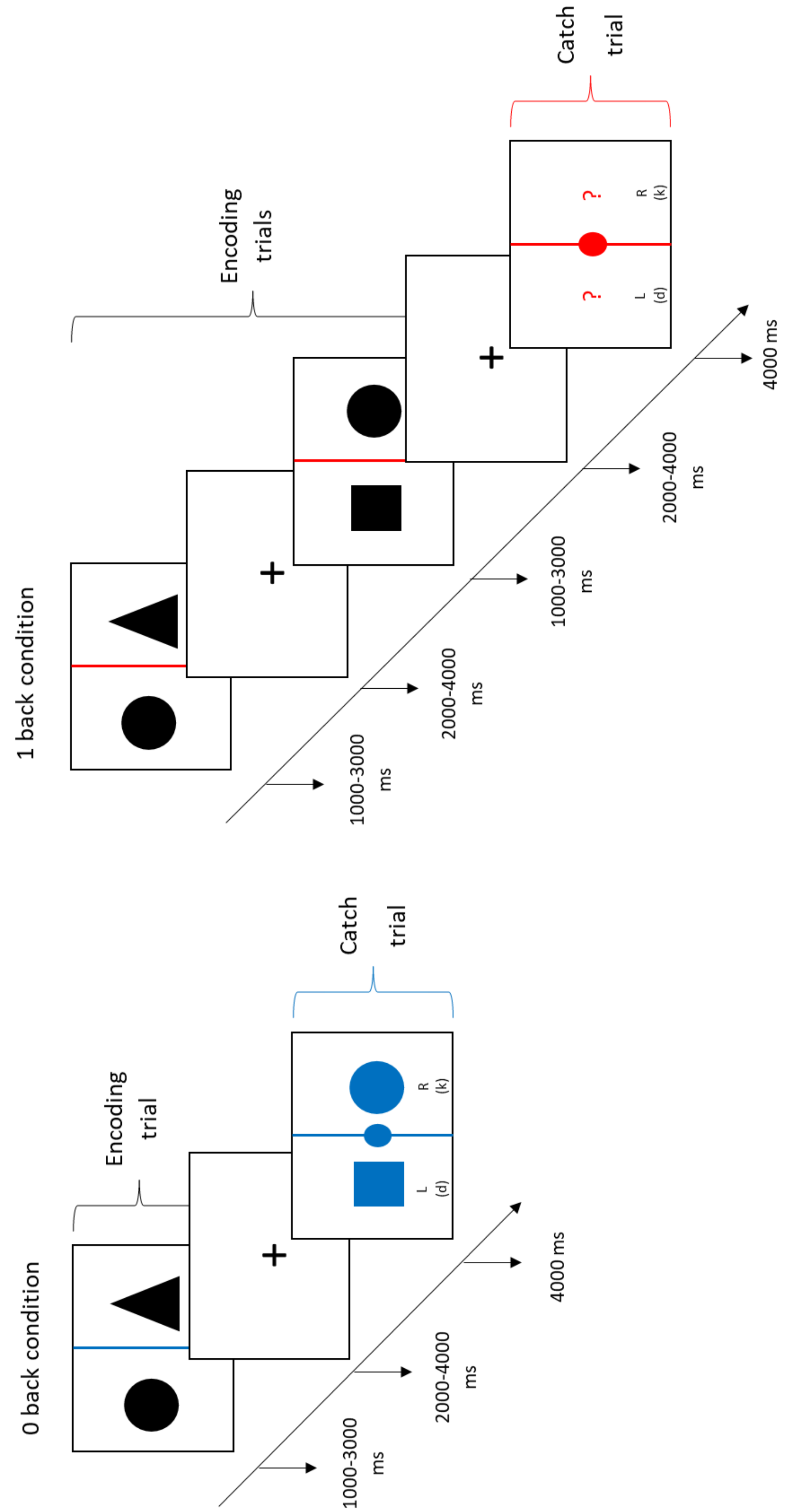
The distractor task was used to engage participants in varying easy and difficult task contexts and to test for the effect of the context-guided task conditions on participant thought persisting into a subsequent task context. This task was based on Konishi et al. (2015) 0- and 1-back task, a paradigm frequently used to investigate the effect of cognitive demand on self-generated thought (Medea et al., 2018; Murphy et al., 2018; Murphy et al., 2019; Turnbull, Wang, Murphy, et al., 2019; Wang et al., 2020). The stimuli used in this task was acquired from

Wang's (2016) GitHub repository (GitHub,2016; https://github.com/htwangtw/MindWanderingTask).

Participants completed one block of the 0-back and 1-back conditions each. For both conditions, participants attended to the middle of the screen as pairs of shapes appeared. These pairs included combinations of triangles, squares and circles such that 6 unique pair combinations of shape and location were presented. The shape pairs were separated by a vertical line. In the 0-back condition the vertical line was blue, whereas in the 1-back condition it was red. During non-target trials participants viewed the pairs of shapes. The 0-back and 1-back conditions differed in the target trials. In the 0-back condition target trials, a pair of shapes appears with an additional target shape in the middle of the screen. Target trials were indicated by all stimuli turning blue. The task was to indicate which side of the screen the target shape was located (Figure 4.1). As such, in this condition participants were required to respond solely to the stimuli on the screen. Such a low demand task context is commonly used in the mind wandering literature as an environment that easily promotes states of off task-thinking (Turnbull, Wang, Murphy, et al., 2019). In the 1-back condition, during target trials participants were presented with pairs of question marks separated by a target shape. Target trials were indicated by all stimuli turning red. The task was to indicate which side of the screen the target shape was located in the previous trial (Figure 4.1). Target shape location was indicated using keys corresponding to 'left' and 'right' on the keyboard. To answer correctly participants were required to retain representations of the stimuli from the previous trial in working memory. Typically, tasks recruiting working memory in this manner have been shown to reduce off-task thoughts (Turnbull, Wang, Murphy, et al., 2019).

In each condition participants saw 30 non-target trials (5 repetitions of the 6 unique shape combinations) and responded to 12 target trials. In the 0-back condition, both non-target and target trials were presented randomly. In the 1-back condition, target-trials were pseudo randomly presented so that they were preceded by corresponding non-target trials. The remaining non-target trials were randomly presented. Each stimulus was separated by a jittered inter-stimulus interval ranging between 2000ms and 4000ms in 500ms increments. In the non-target trials stimuli were presented between a range from 1000ms to 3000ms in increments of 500ms. In target trials stimuli were presented for 4000ms.

The 0-back and 1-back conditions were within-subject variables: participants completed one block of each shape location condition (0-back or 1-back) after completing a run of the adjective rating paradigm and one MDES probe. Order of condition was counterbalanced across participants. This task lasted ~ 5mins.


0 back condition
Encoding trial
Catch trial
L (d)
R (k)
1000-3000 ms
2000-4000 ms
4000 ms
1 back condition
Encoding trials
Catch trial
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2000-4000 ms
1000-3000 ms
2000-4000 ms
4000 ms

Figure 4.1 (previous page) Participants see pairs of shapes (non-target trials). In the 0-back condition, during target trials participants indicated the location of the target shape in the middle with all stimuli present on the screen. In the 1-back condition, participants indicated the location of the target from the stimuli in the previous trial. The answer for both conditions in this example is 'right' i.e., 'k'.

4.2.5 Procedure

Gorilla (www.gorilla.sc), an online experiment platform, was used to create and host the experiment. Participants were required to use a desktop or laptop computer. The experiment took approximately 40 minutes with a time limit of 106 minutes in one sitting.

Each run of this experiment consisted of a context-guided task followed immediately by MDES (the context MDES) and then a distractor task followed immediately by a MDES (the persistence MDES). This structure was designed to first evaluate the contents of thought after the context manipulation and then to evaluate the perseverance of those thoughts after a distractor task.

Each participant completed two runs of the experiment. The context-guided task condition (self- vs other-) varied between participants such that a given participant repeated the same context-guided task twice. However, the word list used in this task varied between runs and was counterbalanced between participants. The distractor task condition (0-back vs 1-back) varied within participants and was counterbalanced such that if a participant completed the 0-back condition in the first run, they completed the 1-back condition in the second (and vice-versa). A summary of the general task structure can be found in Figure 4.2. Participants were given practice versions at the start of each task to complete.

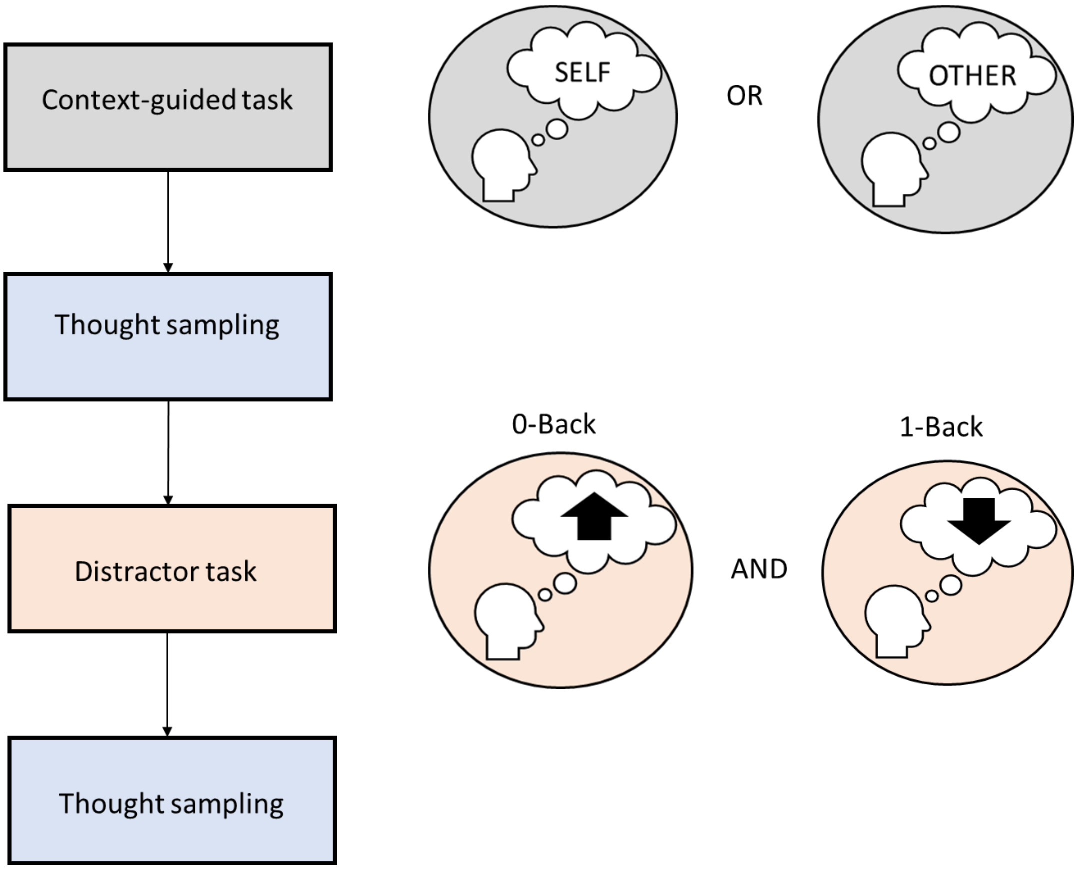


Figure 4.2 Order of experimental tasks. Participants first completed a run of either the self or social condition from the context-guided task followed by an MDES probe. They then completed either the 0-back or 1-back condition of the distractor task followed by an MDES probe. After this, participants completed a second run of the self or social condition with a unique list of adjectives. Participants completed the same condition as done previously; if they had completed one run of the self condition, they would later complete a second run of the self condition. Finally, participants completed either the 0-back or 1-back conditions from the distractor task followed by an MDES probe. If participants had previously completed the 0-back condition they would complete the 1-back condition and vice versa.

4.2.6 Data Analysis

4.2.6.1 Principal Component Analysis.

Principal Component Analysis (PCA) was conducted using SPSS (Version 27, 2021). Participant scores from the 13 experience sampling questions (see Table 4.1) comprising each MDES probe in each task condition, were applied to a PCA. The PCA was applied at trial level in keeping with prior studies (Konishi et al., 2017; Ruby, Smallwood, Engen, et al., 2013a; Ruby, Smallwood, Sackur, et al., 2013b; Smallwood et al., 2016; Turnbull, Wang, Schooler, et al., 2019b). Prior to analysis, as in Konu et al. (2021), participant responses were z-scored and orthogonal varimax rotation was applied. All conditions were included to assess thought patterns across all task environments. Variance explained by the eigenvalues and the point of inflexion on the scree plot was used to select the components.

4.2.6.2. Projected Factor Analysis.

In order to assess whether the thought patterns obtained in this study are similar to those obtained in a previous study (Konu et al., 2021), we ran a projection analysis as described by Mckeown et al. (in submission). This analysis enabled us to test whether the patterns obtained in the current study bear similarity to those obtained in a previous study which used the same tasks, but with a different sample. As in McKeown et al. (in submission), we projected the MDES scores from the current sample into the PCA space identified in Chapter 3 (Konu et al., 2021). To do so, we multiplied the rotated component loadings obtained from the PCA in Konu et al. (2021) by the standardised MDES scores for each question for each participant. These values were then summed to yield corresponding projected PCA scores. The projected PCA scores represent what the extent of expression of each thought pattern in the current study would look like in the previous study. These projected scores were then correlated using a Pearson's correlation with the original PCA score from the current study to assess the similarity of the thought patterns. We used the library ggpubr (Wickham, 2016), dplyr (Wickham et al., 2017) and corrplot (Wei et al., 2017) packages for this analysis. Figures have been produced using the ggplot2 package (Wickham, 2016).

4.2.6.3 Linear Mixed Models.

Two sets of Linear mixed models (LMM) were conducted in R (Team, 2013) using the lme4 (Bates et al., 2015), lmerTest (Kuznetsova et al., 2017) and emmeans packages (Lenth et al., 2019). Figures have been produced using the ggplot2 package (Wickham, 2016).

The first set of LMMs sought to confirm the finding from Chapter 3 (Konu et al., 2021) that specific task contexts influence the content of thought. Separate task-based models were conducted for each thought pattern identified by the PCA. These task-based models predicted the given thought patterns (the given PCA component) from the experimental task conditions (self, social, 0-back or 1-back) with the 0-back condition as the reference. All PCA scores from the entire experiment (both context and persistence MDES) were used in this analysis. The participants' intercept and run were treated as random factors in each model. F-tests and p-values for significant betas were produced using the anova function from lmerTest with Satterthwaite's method for denominator degrees-of-freedom and F-statistic. Post-hoc comparisons were performed using emmeans.

The second set of LMMs assessed evidence of the influence of the context-guided task into the distractor task context. These persistence models predicted thought patterns from the MDES after the distractor task from the context-guided task condition, the distractor task condition (0-back and 1-back), and their interaction. Again, the participants' intercept and run were treated as random factors in each model. Again, the anova function from lmerTest and emmeans were used to test significance and produce post-hoc comparisons of significant effects.

4.2.6.4 Correlations.

Participants PCA scores for each of the four reported thought patterns were correlated across all tasks to assess whether participants' thoughts were consistent within and across contexts. The library ggpubr (Wickham, 2016), dplyr (Wickham et al., 2017) and corrplot (Wei et al., 2017) packages were used for this analysis. Correlations were corrected for multiple comparisons using Holm's method (1979). Figures have been produced using the ggplot2 package (Wickham, 2016).

4.3. Results

4.3.1 Principal Component Analysis

We applied Principal Component Analysis (PCA) to the multidimensional experience sampling (MDES) data to reduce the data and describe the different types of thoughts that participants experienced across the entire experiment (see Methods). The point of inflexion in the scree plot and variance explained by the eigenvalues identified four components. The four patterns of thoughts (identified components) describe the features that characterise the different thoughts reported. The component loadings from the PCA are represented as word clouds with the scree plot from the decomposition in Figure 4.3. Also see appendices Table 4.1 for the eigenvalue table. In total the components accounted for 56.05% of the variance. Component one, “episodic social cognition”, which represented thoughts that were focused on other people, events and memories, accounted for 19.65% of the variance. Component two, “concentration”, which was characterised by detailed and deliberate task focused thoughts accounted for 14.86% of the variance. Component 3, “future problem solving”, represented thoughts that were intrusive, focused on the future and problem solving, accounted for 11.54% of the variance. Lastly, component 4, “negative self focus”, where participants engage in negative thoughts that were verbal and focused on the self, accounted for 10.00% of the variance.

Figure 4.3 Reduction of the MDES revealed four patterns of thought across the experiment. In accordance with the PCA loadings the four components were labelled “episodic social cognition”, “concentration”, “future problem solving” and “negative self focus”. The word clouds provide a summary of the loadings where the colour of each word represents the direction of the relationship to the item (red = positive, blue = negative) and the size of the word indicates the magnitude of the loading. The scree plot for this decomposition is present in the bottom panel.

4.3.2 Projection Analysis

As in McKeown et al. (in submission), we used a projection analysis to project the scores from the current study into those from Konu et al. (2021). Using a Pearson's correlation, we found that participants' PCA scores in the current study and projected PCA scores from Konu et al. (2021) were highly and significantly correlated between corresponding patterns of thoughts. Corresponding patterns of thought represent patterns of thought with a similar distribution of the component loadings (across the features of thought measured). Specifically, there was a high significant correlation between patterns of thought that characterised episodic, social and diverse thoughts, current component 1 and prior (Chapter 3) component 1 (r (780) = 0.94, p<.001). Patterns of thoughts characterised by detailed and deliberate thinking and concentration (r (780) = 0.93, p<.001) were highly correlated across the two studies (current component 2 and prior component 3). There was also a highly significant correlation between patterns of thoughts characterised by intrusive thinking that was focused on the future and problems (r (780) = 0.82, p<.001), current component 3 and prior component 2.There was a moderate significant association between the negative self focus observed in the current study which characterised negative and verbal self-focused thoughts (current component 4) and the self focus thought pattern (r (780) = 0.55, p<.001) observed in Konu et al. (2021) which characterised verbal self-focused thoughts (prior component 4). The corresponding correlation matrix can be seen in Figure 4.4.

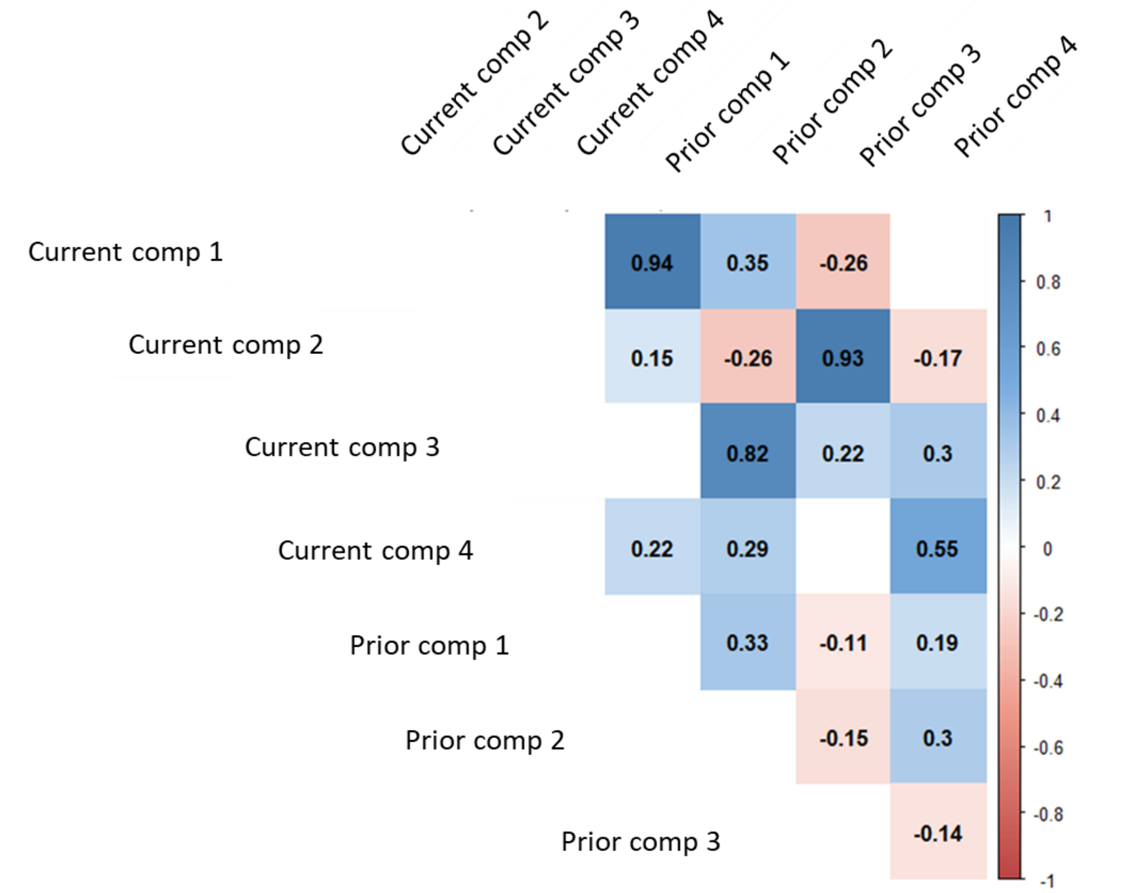


Figure 4.4 Similarity in thought patterns observed in the current study and Konu et al. (2021) from the projection analysis. Strong correlations were revealed between corresponding thought patterns observed in the current study and Chapter 3, Konu et al. (2021). One correlation revealed a moderate association. The strength of association between the thought patterns are represented in the stated r values and the colour of each grip (blue representing stronger correlations and red, weaker correlations). Significant correlations are represented by grids filled with colour. Non-significant correlations are blank. Self-correlations have been removed. 'Prior' refers to the thought patterns observed in Konu et al., 2021 whereas 'Current' refers those observed in the current study.

4.3.3 Linear Mixed Models

4.3.3.1 Task-based models.

In the task-based models, we investigated the influence of prior task on each of the four thought patterns identified by the PCA analysis. Each of these analyses revealed a significant main effect of task condition. Significant betas were probed further with an analysis of variance (ANOVA). Plots of the estimated marginal means from these analyses are illustrated in Figure 4.5. Parameter estimates from these analyses can be found in Table 4.2. Component One (episodic social cognition) was most common in the social condition of the context-guided task where participants made judgements about a significant other (F (3, 676.6) = 357, $p<.001$) which was supported by pairwise comparisons: Social - 0B (t (704) = -27.60, $p<.001$)), Social - 1B (t (704) = -25.09, $p<.001$)), Social - Self (t (749) = -9.42, $p<.001$). Component Two (concentration) was most common in the 1-back distractor task, the hard version of the distractor task (F (3,640.9) = 52.11, $p<.001$) which was supported by pairwise comparison: 1B - 0B (t (585) = -12.20, $p<.001$), 1B - Self (t (657) =7.35, $p<.001$), 1B - Social (t (663) = 4.05, $p<.001$). Component Three (future problem solving) was most common in the 0-back easier version of the distractor tasks (F (3,642.94) =32.86, $p<.001$) with pairwise comparisons also supporting this result: 0B - 1B (t (585) = 3.80, p= 0.001), 0B - Self (t (660) =5.69, $p<.001$), 0B - Social (t (666) = 9.25, $p<.001$). Component Four (negative self focus) was most common in the self condition of the context-guided task, where participants made judgements about themselves (F (3,689.5) =106.18, $p<.001$) with pairwise comparisons supporting this: Self - 0B (t (702) = -16.40, $p<.001$), Self - 1B (t (702) = -11.68, p<.001), Self - Social (t (713) =14.46, $p<.001$).

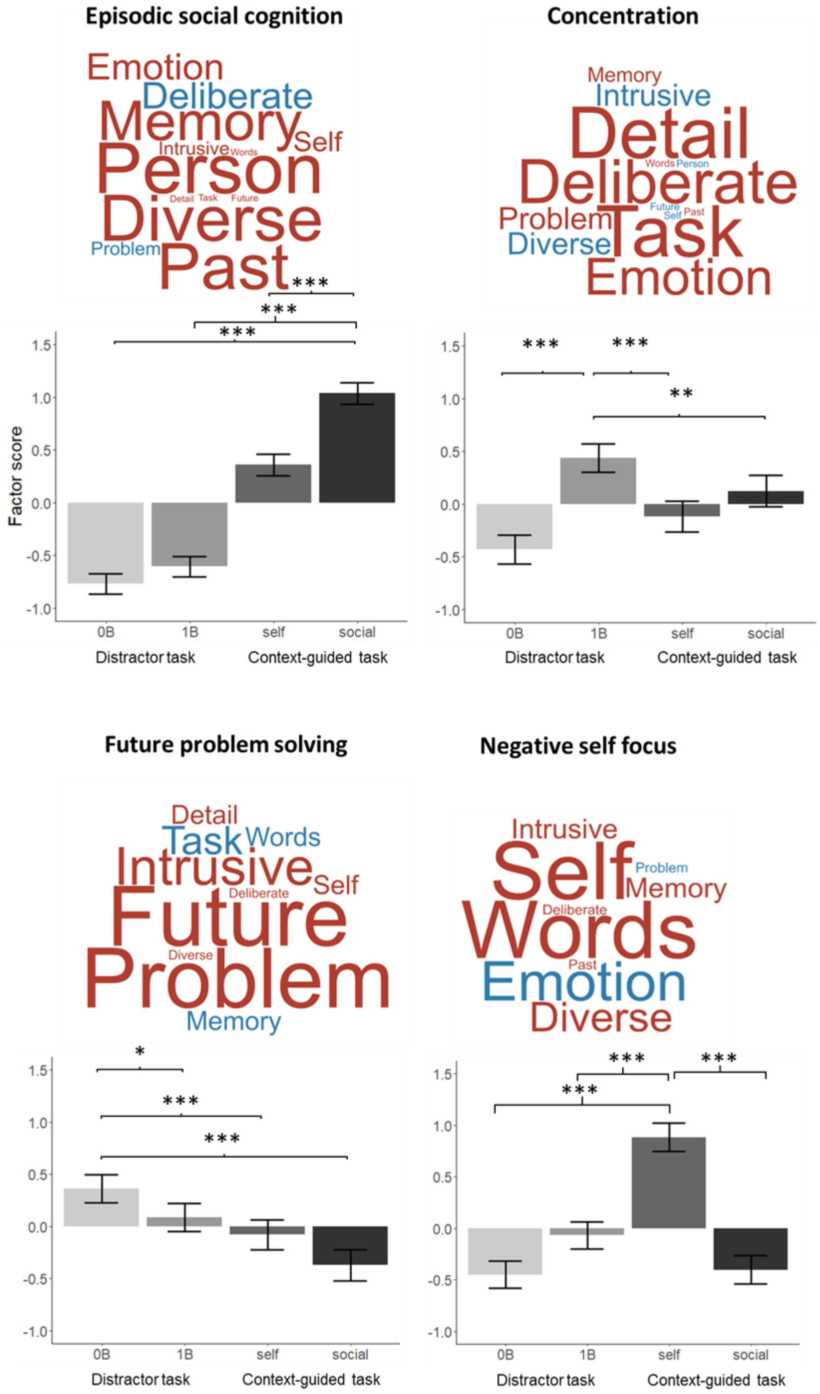


Figure 4.5 Task-based linear mixed model results examining variance across all task conditions in the four identified thought patterns. The word clouds represent the patterns of thought reported in the experiment; the colour of each word represents the direction of the relationship to the item (red = positive, blue = negative) and the size of the word indicates the magnitude of the loading. The bar plots represent the estimated marginal means for each pattern of thought in each of the experiment task conditions. Asterisks represent pairwise comparisons of the main effect of task condition. Error bars represent 95% CI.

Table 4.2 Parameters from the context-guided model.

	Context-guided model											
	FAC1 (Episodic social cognition)			FAC2 (Concentration)			FAC3 (Future problem solving)			FAC4 (Negative self focus)		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	-0.77	-0.87 – -0.67	**<0.001**	-0.43	-0.57 – -0.30	**<0.001**	0.36	0.23 – 0.50	**<0.001**	-0.45	-0.57 – -0.33	**<0.001**
1B	0.16	0.04 – 0.29	**0.008**	0.87	0.73 – 1.01	**<0.001**	-0.28	-0.42 – -0.13	**<0.001**	0.38	0.23 – 0.54	**<0.001**
Self	1.13	1.00 – 1.25	**<0.001**	0.31	0.16 – 0.46	**<0.001**	-0.44	-0.59 – -0.29	**<0.001**	1.34	1.18 – 1.50	**<0.001**
Social	1.81	1.68 – 1.94	**<0.001**	0.55	0.40 – 0.71	**<0.001**	-0.73	-0.89 – -0.58	**<0.001**	0.05	-0.11 – 0.21	0.559
Random Effects												
σ^2	0.38			0.50			0.52			0.62		
τ_{00}	0.09_{ID}			0.41_{ID}			0.41_{ID}			0.10_{ID}		
				$0.00_{Prime\ run}$						$0.00_{Prime\ run}$		
ICC	0.19			0.45			0.44			0.13		
N	196_{ID}			196_{ID}			196_{ID}			196_{ID}		
				$2_{Prime\ run}$						$2_{Prime\ run}$		
Observations	784			784			784			784		
Marginal R^2 / Conditional R^2	0.531 / 0.622			0.101 / 0.509			0.070 / 0.479			0.289 / 0.385		

4.3.3.2 Persistence model.

We next assessed whether the effect of the context-driven tasks on the thought patterns persisted into the subsequent distractor task contexts. The results from these analyses are presented in Figure 4.6, model parameters can be found in Table 4.3.

These analyses revealed no significant main effect of context-driven task condition. There were however significant main effects of distractor task for the concentration, future problem solving and negative self-focus thought patterns. Component Two (concentration) was expressed most in the harder 1-back condition than the easier 0-back condition (F (1,193.11) =141.16, p<.001). In comparison Component Three (future problem solving) was expressed most in the easier 0-back condition than the harder 1-back condition (F (1,193.06) =15.81, p<.001). Surprisingly, Component Four (negative self focus) was expressed most in the 1-back condition compared to the 0-back condition (F (1,194) =28.32, p<.001).

No significant main effects or interactions were found for Component One (episodic social cognition).

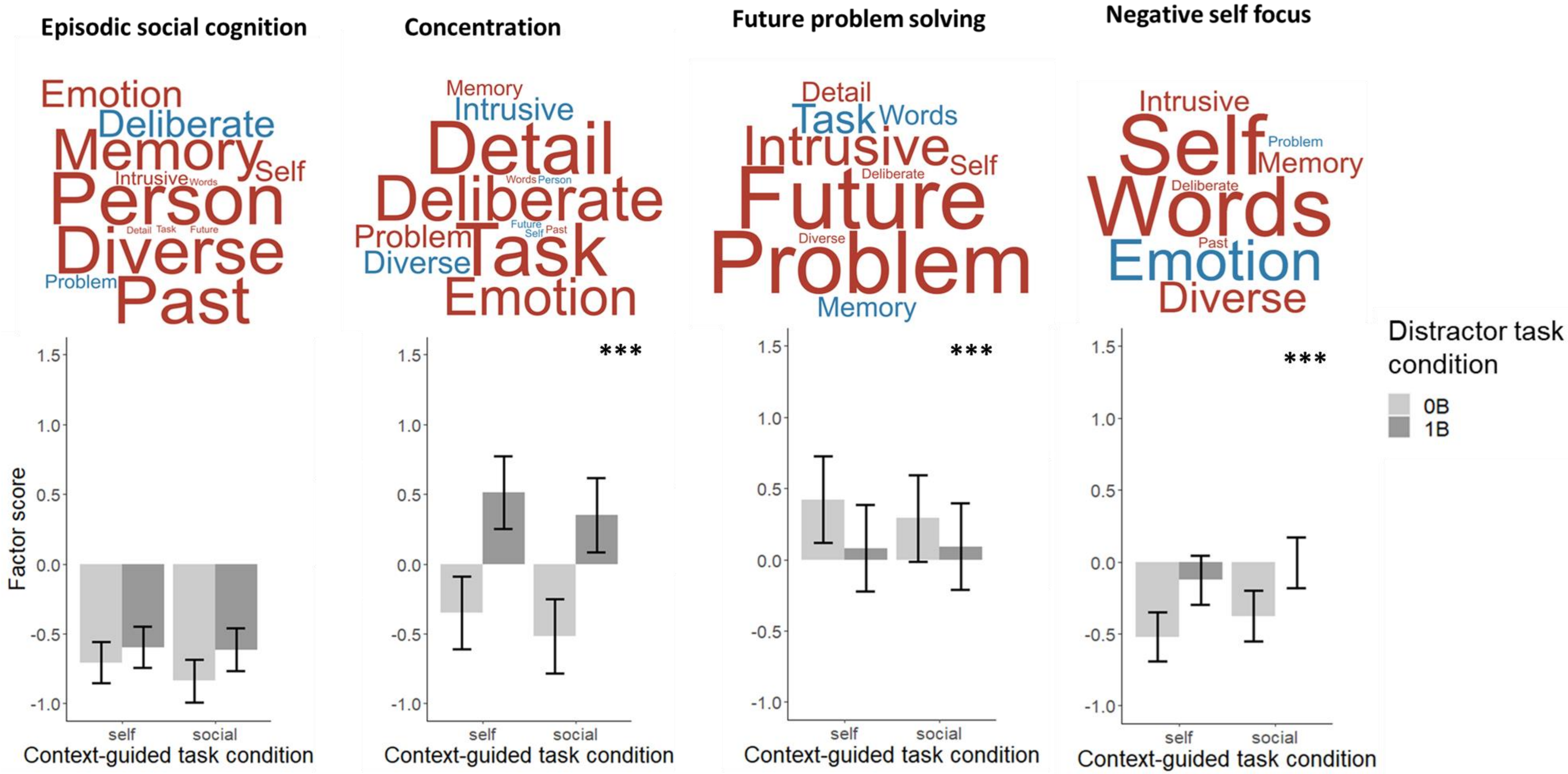

Episodic social cognition
Concentration
Future problem solving
Negative self focus
Factor score
Context-guided task condition
self
social
Distractor task condition
0B
1B
***

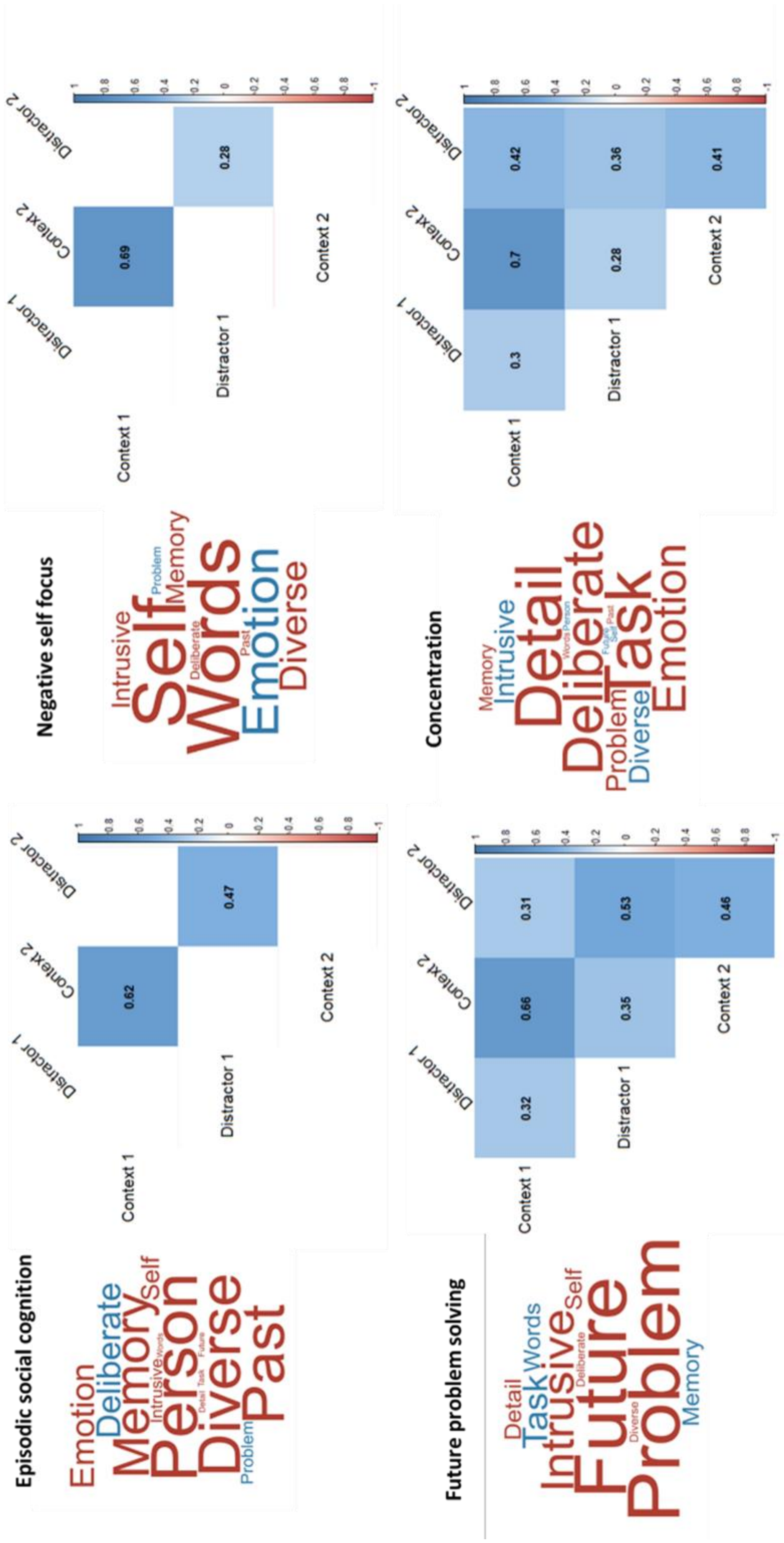
Figure 4.6 (previous page) Persistence linear mixed model results examining variance across the distractor task conditions after participants engaged in the context-driven task conditions. The word clouds represent the patterns of thought reported in the experiment; the colour of each word represents the direction of the relationship to the item (red = positive, blue = negative) and the size of the word indicates the magnitude of the loading. The bar graphs represent the estimated marginal means in the distractor task (shape task) task for each pattern of thought. The bars are further split up based on whether the distractor task was preceded by the self or the social task conditions. Asterisks represent the main effect of distractor task condition. Error bars represent 95% CI.

Table 4.3 Parameters from the persistence model.

Persistence Model												
	FAC1 (Episodic social cognition)			FAC2 (Concentration)			FAC3 (Future problem solving)			FAC4 (Episodic social cognition)		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	-0.71	-0.86 – -0.56	**<0.001**	-0.35	-0.59 – -0.11	**0.004**	0.42	0.18 – 0.67	**0.001**	-0.52	-0.69 – -0.35	**<0.001**
Context-guided task	-0.13	-0.34 – 0.08	0.235	-0.16	-0.47 – 0.14	0.292	-0.13	-0.42 – 0.15	0.368	0.15	-0.10 – 0.39	0.241
Distractor task	0.11	-0.04 – 0.26	0.148	0.86	0.66 – 1.06	**<0.001**	-0.34	-0.53 – -0.16	**<0.001**	0.40	0.20 – 0.59	**<0.001**
Context-guided task* Distractor task	0.11	-0.11 – 0.33	0.314	0.00	-0.28 – 0.29	0.978	0.14	-0.12 – 0.41	0.294	-0.03	-0.31 – 0.26	0.862
Random Effects												
σ^2	0.30			0.52			0.45			0.51		
τ_{00}	0.28_{ID}			0.67_{ID}			0.57_{ID}			0.25_{ID}		
				$0.01_{Prime\ run}$			$0.01_{Prime\ run}$					
ICC	0.48			0.57			0.56			0.33		
N	196_{ID}			196_{ID}			196_{ID}			196_{ID}		
				$2_{Prime\ run}$			$2_{Prime\ run}$					
Observations	392			392			392			392		
Marginal R^2 / Conditional R^2	0.015 / 0.493			0.140 / 0.627			0.020 / 0.572			0.052 / 0.368		

4.3.3 Correlations

Participants' PCA scores for each of the four reported thought patterns were correlated across all task conditions to assess whether participants' thoughts were consistent within and across contexts. The corresponding correlation matrix can be seen in Figure 4.7, corresponding p-values can be found in appendices table 4.2, 4.3., 4.4 and 4.5). Thought patterns were highly correlated within the context-guided task conditions of the for all thought patterns: component one (episodic social cognition), component two (concentration), component three (future problem solving) and component four (negative self focus). There were also significant and moderate correlations between the distractor task conditions for all thought patterns. Significant correlations across all different task contexts were, however, only present for the component two (concentration) and component four (future problem solving).



Episodic social cognition
Emotion Deliberate Memory Self Person Diverse Past Problem Intrusive Words Detail Task Future
Context 1
Distractor 1
Context 2
Distractor 2
0.62
0.47
Negative self focus
Intrusive Self Problem Memory Words Emotion Diverse Deliberate Past
0.69
0.28
Future problem solving
Detail Task Words Intrusive Self Future Problem Memory Diverse Deliberate
0.32
0.66
0.31
0.35
0.53
0.46
Concentration
Memory Intrusive Detail Deliberate Task Emotion Problem Diverse Words Person Future Past Self
0.3
0.7
0.42
0.28
0.36
0.41

Figure 4.7 (previous page) Similarity in thought patterns observed within and across task contexts. Strong correlations were revealed between similar task contexts across all thought patterns however for the concentration and future problem solving thought patterns significant correlations were revealed across different contexts. The strength of association between the thought patterns across the contexts is represented in the stated r values and the colour of each grid (blue representing stronger correlations and red, weaker correlations). Significant correlations are represented by grids filled with colour. Non-significant correlations are blank. Self-correlations have been removed. The word clouds represent the patterns of thought reported in the experiment; the colour of each word represents the direction of the relationship to the item (red = positive, blue = negative) and the size of the word indicates the magnitude of the loading. Context 1 and 2 represent the context-guided task conditions (either the self or social condition) and Distractor 1 and 2 represent the distractor task conditions (both the 0-back and 1-back conditions).

4.4 Discussion

This study aimed to investigate the influence of context on self-generated thought, the persistence of contextual effects, and the reliability of individual differences across contexts. To do so we recorded participants' reports of thoughts across multiple dimensions and used principal component analysis to identify patterns of thought experienced during the task conditions. These analyses revealed four patterns of thought: episodic social cognition, concentration, future problem solving and negative self focus. These thought patterns were consistent with those reported in Chapter 3 (Konu et al., 2021). Participant thoughts were differentially affected by the task conditions, generally replicating our prior research on the influence of context on thought content (Konu et al., 2021). We used knowledge of these contextual influences to investigate thought persistence from a prior task context into subsequent contexts. Whilst we found no evidence for persistence of contextual effects into subsequent contexts, individuals' thoughts in a given context were highly correlated with their thoughts when they revisited that context later in time. We also found that levels of future problem solving and detailed concentration (but not episodic social cognition or negative self focus) correlated across all tasks. This suggests that individual differences in these (but not all) thought patterns persist across from context to context.

In the current study, participants thought patterns were expressed differentially as a function of context. Thought characterised by social and episodic features were expressed most under contexts where participants were required to make judgements about a significant other, whereas thoughts characterised by negative self-focus were expressed most when participants were required to make judgements about themselves. Thought characterised by future problem solving was expressed most under low cognitive demand contexts while detailed and focused thoughts were expressed most during contexts requiring high external demand.

These findings replicate and extend research on the content of self-generated thought. In Konishi and colleagues' (2015) study, participants were asked whether their thoughts were off or on task during 0-back and 1-back tasks, with greater reporting of off task thought in the 0-back. More recent studies have used MDES to further examine the actual content of thought during 0 and 1-back task conditions. These studies demonstrate that the patterns of thought reported during the 0-back, are characteristic of more spontaneous and social focus whereas thoughts reported during the 1-back, are more characteristic of detailed and deliberate focus (Sormaz et al., 2018; Turnbull, Wang, Murphy, et al., 2019). This effect of working memory on self-generated thought is replicated in the current study and further supports the context regulation hypothesis. We find that participants engage in more personally relevant and socially focused forms of self-generated thought (episodic social cognition and future problem solving) during the 0-back where there is no working memory requirement. In the 1-back condition, which had a higher working memory requirement, more detailed and deliberate forms of self-generated thought were reported (concentration).

One interesting finding, however, is that the negative-self focus thought pattern, a thought pattern more characteristic of spontaneous off-task rather than deliberate task focus, was expressed most in the 1-back compared to 0-back condition. This finding could be a result of the task manipulation; perhaps the harder 1-back context engaged participants in self-critical thoughts, possibly related to their perception of their task performance. Studies have shown that anxious individuals are more likely to experience intrusive thoughts during high demand tasks which can relate to perceptions of task performance (Blankstein et al., 1989; Sarason & Stoops, 1978; Yee et al., 2004). Future studies could investigate whether perceived task performance has any role to play in the emergence of negative self focused thought during high demand contexts.

The thought patterns reported in this study bear strong similarity to those reported in our previous study (Konu et al., 2021). Indeed, when we projected the current data into the component space identified in that earlier study, we found strong correlations with the corresponding components identified in the current dataset. The projection method not only demonstrates the reliability of the MDES method but also demonstrates a method by which experiences of self-generated thought can be compared across studies and samples (Mckeown et al., in submission). Despite collecting subjective experiences of self-generated thoughts across different samples and contexts, similar thought patterns emerge suggesting that the categories assessed represent salient aspects of our everyday experiences of self-generated thought. It must however be noted that we found only a moderate correlation for the negative self focus thought pattern observed in the current study and the self focus thought pattern observed in our prior study. It is likely that this finding reflects a lack of similarity in the emotional valence that characterises each thought pattern, showing that similarities as well as differences can be highlighted by the projection method.

Whilst examining within-subject reliability in the current study, we evaluated the consistency of participant reports of self-generated thought. When placed in the same or similar context, participants responded reliably across all thought patterns. This is consistent with previous research in which we showed strong reliability in individual differences in all thought patterns when participants did the same task context across two testing environments (Konu et al., 2020). Such findings could be used to better understand how individuals' thoughts might be influenced by a given context, and we could have a good idea of what they might (generally) think in a similar context. This has implications for our understanding of how particular contexts will shape an individual's thoughts. Certain patterns of thought such as future problem solving and concentration, however, were also found to be consistent across different task contexts. Within this study, at least, individual differences in these thought patterns were more stable across contexts. This finding supports those of Linz and colleagues (2019) who correlated reports of self-generated thought in the laboratory and daily life. They found that certain thought content, social, future-directed and negative thoughts, were correlated across the lab and daily life. Our findings support the suggestion that certain relative differences in patterns of thought are consistent across contexts.

The stability observed in the future problem solving and concentration thought patterns in the current study, could be further tested using a broader range of task contexts (Konu et al., 2021; Murray, Krasich, et al., 2020; Smallwood, Turnbull, et al., 2021). Future research testing for the influence of individual differences will need to explore if this is a general feature of these different thought patterns, or if these consistencies are driven by the nature of the experiment. Regardless, the paradigm presented here provides a means of testing the persistence of individual differences across contexts.

Our study did not show any evidence of thought persistence as a function of prior task context. It is possible that the task conditions did not encompass salient conditions under which thoughts might persist. Studies have shown that ruminative thoughts are characterised by negative, past-focused thinking

(Andrews-Hanna et al., 2013; Ruby, Smallwood, Engen, et al., 2013; Segerstrom et al., 2011; Watkins, 2008). Perhaps engaging participants in tasks with more salient self-relevant contexts may be a more fruitful context to test persistence. There have been calls in the literature for self-generated thought paradigms to utilise more meaningful or personally relevant stimuli (Linz et al., 2019; Plimpton et al., 2015). Perhaps, to some extent, our thinking is constrained by a personal repository of thoughts to which we revert. To further probe this, the use of open reporting (Smallwood & Schooler, 2006; Smallwood & Schooler, 2015) in combination with MDES may be a useful way to gain understanding of how specific thoughts might shift across contexts (Song & Wang, 2012).

In conclusion, our study aimed to investigate the influence of context and individual reliability on the persistence of thought. We found that context and cognitive demand influence thought. We found similarities in thoughts reported in a previous study. We also found that some patterns of thought emerge more reliably across different contexts than others. Although we did not find any evidence of the persistence of contextual effects, our study highlights a method by which the persistence of thought, individual differences and context can be further investigated. Indeed, each of these factors has been highlighted as important to consider simultaneously when investigating self-generated thought (Linz et al., 2019; Turnbull et al., 2021) .

Chapter 5: General Discussion

5.1 Overview

Self-generated thought is an integral part of our everyday lives with reports that we spend a significant amount of our waking day engaged in this behaviour (Kane et al., 2007; Killingsworth & Gilbert, 2010). Within the literature, it is well established that self-generated thought is a complex form of cognition with both behavioural costs and benefits. But many questions remain regarding the causes or antecedents of the content of self-generated thought. The overall aim of this thesis was to investigate the neural correlates of the content of self-generated thought, how context and individual differences influence thought content, and the influence of context and individual differences on the persistence of thought content over time. This thesis contributes to the literature by drawing together theoretical questions regarding the cognitive processes that support self-generated thought, the extent to which a given context can influence self-generated thought and which patterns of thought are more sensitive to the influence of context over time.

Multidimensional experience sampling (MDES) was used in combination with functional magnetic resonance imaging and laboratory experiments to investigate the overall aims. In one study (Chapter 2), participants performed an undemanding task both in the laboratory and during an fMRI scan. They were intermittently asked what thoughts emerged in their minds. This paradigm was used to understand the underlying cognitive processes that support the content of self-generated thought. The findings suggest that ventromedial prefrontal cortex supports episodic and social features of self-generated thought. In a second study (Chapter 3), the influence of varying context on self-generated thought was investigated. Participants engaged in a range of tasks from discrete cognitive tasks to more naturalistic and dynamic tasks. This experiment empirically demonstrated that context does influence thought content and shows one means by which self-generated thought could be manipulated. In a third study (Chapter 4), the interplay between the persistence of thoughts over time and the ongoing influence of context was assessed by measuring how thoughts varied from an initial task context to subsequent contexts. This study highlighted the extent to which certain types of thought are influenced by context over time.

5.2 Summary Findings & Relation to Literature

5.2.1 Chapter 2

Chapter 2 sought to further understand the neural correlates that support the content of self-generated thought. Participants were given an undemanding task to complete and were intermittently asked what thoughts emerged in their mind. Undemanding contexts are well established in promoting states of self-generated thought (Robertson et al., 1997; Smallwood et al., 2009). A subsample of participants completed the experiment in the laboratory and whilst being scanned. Overall, participants reported spontaneous thoughts that were focused on others and events, thoughts that were detailed and deliberate, and thoughts that were self-focused and verbal. Critically, significant activity in the ventromedial prefrontal cortex was associated with a pattern of self-generated thought that focused on events and other people. No significant activity was found for the other patterns of thought reported.

These findings obviously raise questions regarding the role of the ventromedial prefrontal cortex (vmpfc) in the generation of thought content. One possible clue is that the vmpfc is part of the Default Mode Network (DMN). The DMN is widely associated with activating during periods of self-generated thought and a range of other internal cognitive functions. It is undeniably identified within the literature as a neural correlate of self-generated thought (Addis, 2018; Kelley et al., 2002; Macrae et al., 2004). It is therefore reassuring that in keeping with the literature (Allen et al., 2013; Christoff et al., 2009; Mason et al., 2007), the vmpfc, a subregion of the DMN, is highlighted as a neural correlate of self-generated thought content in Chapter 2. What is unclear however is exactly how subregions of the DMN individually contribute to the cognitive processes that support the content of self-generated thought (Andrews-Hanna et al., 2010; Stawarczyk et al., 2011). This lack of clarity is evident when attempting to draw any conclusions about the functional contribution of the vmpfc activity identified in Chapter 2.

In Chapter 2, vmpfc activity was associated with periods of self-generated thought characterised by memory and social features. This is a compelling finding that supports some of the existing literature regarding potential roles of the vmpfc in cognition. Episodic memory has been highlighted as a key cognitive processes that should support the content of self-generated thought as suggested by the component process account (Andrews-Hanna et al., 2014). Lesion studies show that vmpfc patients are less likely to engage in self-generated thought about future events (Bertossi & Ciaramelli, 2016). It is possible that the vmpfc supports complex episodic memory representations during periods of self-generated thought (Benoit et al., 2014). Alternatively, the vmpfc could play a more general role in memory processing such as by supporting associative memory processes (Spalding et al., 2018). These accounts suggest that the contents of our self-generated thoughts are intrinsically shaped by our memories (Conway et al., 2016; D'Argembeau & Van der Linden, 2004).

It is possible that the vmpfc activity could be supporting social processing. The vmpfc has also consistently been found to play a role in social processing including self-referential processing of personally significant content (D’Argembeau, 2013; D’Argembeau et al., 2012). Studies have shown that the vmpfc activates during judgements about the present self compared to those about the past self as well as past and present others, suggesting that the vmpfc supports the evaluation of self-relevant information (D'Argembeau et al., 2008). Furthermore, studies show that the vmpfc plays a pivotal role in relevant and personal future goal planning (D'Argembeau, 2011).

The potential cognitive processes that the vmpfc activity seen in Chapter 2 may support, are fundamentally intertwined. Episodic and social features of thought are difficult to separate. Lesion studies which implicate the vmpfc in mental time travel show that patients are impaired in the construction of episodes (both past and future) as well as episodes relating to the self and others (Bertossi et al., 2016). Additionally, studies have shown that information about personal goals is critical for the construction of future events (D'Argembeau & Mathy, 2011).

The findings in Chapter 2 are in no way conclusive regarding the functional contribution of the vmpfc during periods of self-generated thought. The complex functional profile of the vmpfc coupled with the general pattern of thought associated with its activity in Chapter 2, hinders our ability to pinpoint the relationship between the vmpfc and the episodic social cognition pattern of thought. Whilst the findings in Chapter 2 are suggestive, causality cannot be established due to correlational nature of the results. The findings show that the vmpfc activates during periods of episodic and social thought and, at best, suggest that this region potentially supports both autobiographical memory and social cognition. Lesion and transcranial direct current stimulation studies could however be used to further understand the contribution of the vmpfc to memory and social processes when our thoughts are absorbed by events and those around us (Ciaramelli & Treves, 2019). None the less, the findings in Chapter 2 suggest that thought in everyday life is highly influenced by social and memory processes.

The findings from Chapter 2 also revealed that correlating participants' thoughts reported within the same task context, across the scanner and laboratory showed consistency. These data support the notion that a given context can prime particular patterns of self-generated thought. Evaluating the reliability of thought patterns sampled in the same context is important for understanding the stability of individual differences in self-generated thought.

In terms of methodological contributions, the use of intraclass correlation demonstrates a method by which the reliability of thought reporting can be assessed. The combination of fMRI and experience sampling under an unconstrained task context in Chapter 2 enabled the triangulation of subjective measures and objective markers of the experience of self-generated thought. This triangulation allowed us to establish a neural correlate for the content of self-generated thought. Other neural correlates of other forms of self-generated thought content could be investigated by using a combination of fMRI and experience sampling under a wider range of task contexts, such as the contexts used in Chapter 3.

5.2.2 Chapter 3

Moving away from the more traditional context within which self-generated thought is primarily investigated (as used in Chapter 2), it is less clear how other contexts influence self-generated thought. As we go throughout the day, context must surely bear some influence on our inner thoughts. In Chapter 3 we sampled participants' thoughts across a range of task contexts from discrete cognitive tasks such as emotion recognition and semantic tasks to more naturalistic and dynamic tasks such as watching documentary and thriller videos, to shed some light on the influence of context on thought. After each task context participants completed MDES. We found that participants reported having off-task episodic social thoughts, off-task unpleasant and intrusive, deliberate task detailed thoughts, and off-task verbal and self-focused thoughts. The extent to which these thought patterns were expressed varied significantly as a function of task context. Although self-generated thought is widely described within the literature as generated by the individual and separate from external stimuli (Antrobus, 1968; Smallwood, 2013; Smallwood & Schooler, 2015), the findings from Chapter 3 show that our self-generated thoughts are in fact influenced by context.

These findings lend additional support to the few studies which demonstrate that external stimuli trigger self-generated thought (Berntsen & Jacobsen, 2008; Faber & D'Mello, 2018; Song & Wang, 2012). This would suggest that to some extent, self-generated thought is cue dependent (McVay & Kane, 2013; Plimpton et al., 2015; Vannucci et al., 2017). Chapter 3 extends this claim by investigating the influence of a range of task contexts (external stimuli) on self-generated thought content. The findings demonstrate that the contexts in which we think, influence the extent to which we engage in particular types of thought.

Not only does this study empirically demonstrate that context influences thought content, but it also helps us to understand exactly how different contexts influence our thoughts. By mapping out how different forms of self-generated thought are influenced by context, we gain a better understanding of how different situations might shape individuals' thoughts. This mapping of context to patterns of thought could be used to identify contexts under which particular patterns of thought are likely to emerge. This could, in turn, inform experimental design when looking to identify laboratory task contexts that are optimal to investigate particular types of thought.

The findings from this study highlight the complexity of self-generated thought: whilst the task contexts sampled influenced the thought patterns reported by participants, it is unclear what aspect of the tasks elicited the particular patterns of thoughts observed. Does the systematic variation in the cognitive process recruited by a task, change the contents of an individual's thoughts? Such a question could be addressed by employing the same method used in Chapter 3 to sample participant thought, however across a wider range of discrete task contexts.

Measures of disposition relating to mental health were collected in Chapter 3. It was found that participants who score higher on measures of depression express thoughts that are negative and intrusive in nature to a greater extent than those who score lower on such measures. This study showed that differences in mental health related to the extent to which thoughts were expressed. This is in keeping, to some extent, with the literature on the content of thoughts of individuals with mental health disorders. Generally, it is found that individuals with conditions such as depression and anxiety tend to experience self-generated thoughts that are more negative in affect and pervasive in nature (Hoffmann et al., 2016; Kanske et al., 2016; Kanske et al., 2017; Smallwood et al., 2007). One finding that is not quite in keeping with the literature however is the temporal focus of the negative thought pattern. Negative thoughts are usually associated with a past-focus (Plimpton et al., 2015; Poerio et al., 2013; Smallwood & O'Connor, 2011; Watkins & Teasdale, 2001). This could be a result of the task manipulation where this particular thought pattern was seen to emerge under contexts that may have engaged participants in future as opposed to past thinking (participants watch clips of depicting impending danger) or it could reflect a distinct pattern of worry (negative thoughts about the future) as opposed to rumination (negative thoughts about the past (McEvoy et al., 2013)). Another comparison to the findings from Chapter 3 is that other studies have suggested that individual differences in mental health are characterised by frequency rather than the content of self-generated thoughts. Guesdon and colleagues' (2020) showed that individuals with dysphoria (condition of depressive symptoms that do not meet the criteria for major depressive episode) reported more frequent experiences of mind wandering. They also found that mind wandering content did not differ between control participants and individuals with dysphoria suggesting that the condition is marked by a lack of regulation of thought occurrence rather than content. Further research could investigate the influence of both the content and frequency of self-generated thought on individual differences in mental health.

Nonetheless, the finding in Chapter 3 showed that differences in mental health related to the extent to which a particular thought content was expressed. This suggests that individual differences that influence the way that we think are likely to affect the way that we think across different contexts. A greater focus on the influence of both individual differences and context on self-generated thought will move research towards more holistic accounts of how self-generated thought is shaped in daily life.

In terms of methodological contributions, Chapter 3 highlights one approach to address the limited range of tasks that are often used to sample self-generated thought in the laboratory. There is a need to broaden the task contexts within which self-generated thought is studied which has been a topic of discussion for some time (Callard et al., 2012; Martinon et al., 2019; Smallwood, Turnbull, et al., 2021). It must however be noted that Chapter 3 does not represent a full scope of contexts within which thought can be sampled. Future studies could look to sample an even wider range of tasks that are more representative of the tasks or situations that individuals engage with in real life. It is important to adopt a wider range of naturalistic tasks (other than the affective video clips used here) that more closely map onto situations where we might engage in self-generated thought such as listening to music, running or during routine activities like ironing. Laboratory contexts that reflect such daily life situations could be implemented in future studies. For example, recent studies have shown that individuals' self-generated thoughts are shaped by conversations that they have with others (Cooney et al., 2021). Engaging participants in a similar task context in the laboratory could help us to better understand how conversations with others might influence our self-generated thoughts.

The findings from Chapter 3 show that self-generated thought is influenced by context. While MDES can capture contextual influences of self-generated thought, the items that compose MDES itself do not widely assess how context influences thought. Participants are asked whether their thoughts were linked to information from the environment or memory. However, the exact elements of an environment that may trigger a thought are not assessed. As there is growing literature on the influence of context on thought, the inclusion of MDES items that assess the triggers of thoughts would be valuable in understanding how our self-generated thoughts arise from the world around us. Alternatively, using an open question method, such as those employed in daily life sampling studies could offer the opportunity for participants to report the triggers of their thoughts. For example, in Song and Wang's (2012) study participants were asked to provide accounts of whether the thoughts they reported were triggered by external or internal cues. This approach provides researchers with the opportunity to investigate detailed accounts of triggers in the external world that ignite trains of self-generated thought (Plimpton et al., 2015).

The use of the intraclass correlation in Chapter 3 enabled the evaluation of the consistency of the patterns of thoughts reported within the many contexts for each participant. This supports MDES as a reliable tool to measure participant experiences of self-generated thought. More broadly, some of the thought patterns observed in Chapter 2 under spontaneous task contexts, are also seen in Chapter 3 under more constrained task environments, which suggests that a given thought pattern can be elicited by multiple contexts. This also suggests that patterns of thought obtained via experience sampling are generalisable across studies.

5.2.3 Chapter 4

Chapter 2 and 3 inform us that at least some individual differences in thought are stable in similar contexts. Chapter 3 further demonstrates that context influences our thought in particular ways. What is less clear from these prior chapters is how context and individual differences influence thought over time. Once our thoughts have been influenced by one context, how does that thought persist into a subsequent context and how long for? Chapter 4 examined the interplay between the persistence of thought over time and the ongoing influence of context. We investigated how ongoing thought, measured using MDES, varied from an initial task context (personality judgements) to subsequent contexts (shape judgements varying in cognitive demand). We knew from Chapter 3 that specific task contexts should influence participant thought in a particular way. It is also well established in the literature that cognitive demand is an important aspect of when participants are likely to focus attention externally or internally (Konishi et al., 2015; Turnbull, Wang, Murphy, et al., 2019). These findings left us with a promising experiment design in which we could investigate the persistence of particular patterns of thought.

We replicated prior findings that context influences self-generated thought and that increases in cognitive demand limit self-generated thought. The use of correlations allowed us to test for the stability of particular thought patterns both within and across contexts. When participants’ thoughts were tested for correlations, all thought patterns were shown to correlate within similar task contexts. This is consistent with the findings from Chapters 2 and 3, where strong reliability of reported thoughts emerged when participants repeated the same task context. Although no effect of context on the content of thought persisted beyond the immediate task, we found that individual differences in the expression of some, but not all, patterns of thought (specifically, future problem-solving and concentration thought patterns) persisted across contexts. This is a compelling finding as it suggests that some patterns of thought may be more sensitive to individual differences than others. For example, it seems that if an individual is high or low in either future problem solving or concentration, that relative difference will emerge in a consistent manner, regardless of context. Perhaps certain thought patterns relate to functions that support sustaining a continuity of the self across daily life. For example, the future problem-solving pattern may be essential for maintaining a consistent approach to goal planning and the concentration pattern could be essential for attentional style. As the study in Chapter 4 does not record any measures of individual differences, it is unclear exactly which individual differences might be underlying the stability seen across contexts. This is something that would be important to address in further studies by including measures of individual difference such as mental health and perhaps adopting a greater range of task contexts, similar to the range used in Chapter 3.

Correlating thought patterns across time points could be used in the future to assess the stability of subjective ratings reported using MDES over longer periods of time. For example, it would be interesting to understand how individual differences in self-generated thought develop across the life span (Cherry et al., 2022). It would be feasible, for example, to correlate numerous instances of MDES within and between contexts to track the consistency of individuals' thoughts across longer periods of time.

Chapter 4 replicates the findings from Chapter 3 that context influences thought and that participants tend to engage in particular patterns of thought. The study also supports the well-established findings that the availability of working memory resources effects the type of thoughts that we might have according to the demands of a task context. Tasks that require greater working memory resources recruit more detailed and deliberate thought in comparison to tasks that require little to no working memory resources. Under undemanding contexts working memory resources are available to support more 'off task' patterns of thought (Konishi et al., 2015). The negative-self focus thought pattern however was expressed most in the 1-back compared to 0-back condition which was not in keeping with the expectation that more spontaneous forms of self-generated thought emerge during less demanding contexts. As mentioned, this could be a product of the of the task manipulation. The harder 1-back context may have engaged participants in self-critical thoughts, perhaps evaluation of their performance. Future research could investigate the possibility that our self-generated thoughts during tasks are shaped by our perceptions of our task performance.

It is however less clear how the findings from this study relate to theories on the mechanisms involved in repetitive thinking, such as deficits in inhibition (Bomyea & Amir, 2011; Brewin & Smart, 2005) or switching (Davis & Nolen-Hoeksema, 2000; Whitmer & Banich, 2007), as no evidence of the persistence of contextual influences from one context to the next was found. This is however an aspect of the findings that could be further investigated by testing for the persistence of contextual effects with initial task contexts that elicit more salient thoughts. It would be possible to design a task in which participants initially report thoughts that often persist in their mind. Elements of these persistent thoughts could be presented to participants in an unrelated task context. For example, McVay and Kane (2013) cued participants' personal goals and concerns to elicit particular repetitive thoughts. Including personalised cues as part of a task context could help researchers to better understand how repetitive thoughts emerge. Perhaps incorporating this concept of meaningful cues within a study, similar to that used in Chapter 4, would create conditions under which initial task contexts could influence the persistence of thought into subsequent task contexts.

In methodological terms, the experimental design in Chapter 4 allowed us to explore two concepts: 1) particular patterns of thoughts are influenced by particular task contexts and 2) individuals are more likely to engage in self-generated thought during easier than harder task contexts. This enabled us to use a design where we could test for the effect of a particular context on thought, as well how long this contextual effect lasted when participants subsequently completed another task. It is plausible that this priming approach could be used in future studies to assess the persistence of particular patterns of thought. If so, this paradigm will however need to be revised to identify more optimal initial and subsequent task contexts. Nevertheless, Chapter 4 provides the basis of a method that could be used to further investigate contextual and individual differences in thought persistence.

The method used in Chapter 4 also allowed us to look at the reliability of thoughts across time in multiple ways. As with Chapters 2 and 3, we examined within-task correlations across time. But in Chapter 4 we also examined correlations between tasks and, using a Principal Component Analysis (PCA) projection method, between experiments. As in McKeown et al. (in press) we used a projection technique to evaluate the similarity of thought patterns in relation to thoughts reported in a similar study with a different sample of participants. This method enabled us to evaluate experiences of self-generated thought across studies and samples. Only a moderate correlation was found for the negative self focus thought pattern observed in Chapter 4 compared to the self-focus thought pattern observed in Chapter 3. This shows that the projection method is useful in highlighting differences as well as similarities between thought patterns sampled across different studies and samples. The projection method could be used more widely within the literature to establish similarities and differences between patterns of thoughts observed between studies and samples.

5.3 Limitations and Future Directions

The use of MDES and decomposition of the data using PCA in the empirical chapters of this thesis has enabled the identification of different patterns of thought that feed into the experience of self-generated thought. Whilst the thought patterns are general, this multidimensional approach to sampling enables us to identify and understand the contribution of individual features that underlie particular types of self-generated thought. This approach is important for understanding and accounting for the heterogeneity of self-generated thought (Seli, Kane, et al., 2018; Smallwood, Turnbull, et al., 2021).

It is also clear from the empirical chapters in this thesis that the application of both experience sampling and task-based methodology or neuroimaging is a valuable approach that provides meaningful results. Across the chapters similar patterns of thought have emerged. This is evident across the spontaneous contexts observed in Chapter 2 and the more constrained task contexts implemented in Chapter 3 and 4. This is formally assessed in Chapter 4 using the projection method for thought patterns reported across Chapters 3 and 4. This suggests that these thought patterns are important for everyday thinking. It is therefore important for future research to understand the function of such patterns of self-generated thought in daily life.

One clear avenue of future research, based on the findings from the empirical chapters of this thesis, could include identifying the specific functional role that brain areas play in supporting the content of self-generated thought. In Chapter 2, the findings suggest that the vmpfc is a neural correlate of social and episodic thought but does this relationship generalise across other task contexts? What other regions support other forms of self-generated thought content and how? A study similar to that conducted in Chapter 3, could use fMRI to further investigate the neural correlates that support the content of different forms of self-generated thought under varying contexts. Under the assumption that different task environments can be used to understand how thought is influenced by different conditions, the methodology used in Chapter 3 can be used to elicit particular thought patterns when participants are scanned. This would allow for more direct mapping of task context, elicited thought patterns and identified neural correlates.

There is an exciting shift in the literature towards acknowledging whole brain functional organisation and its relation to self-generated thought (Mckeown et al., 2020). Furthermore, ground-breaking work has been conducted where researchers show distinct neural correlates for different patterns of thoughts (Kam et al., 2021). This finding further supports the heterogeneity of self-generated thought and its representation in the brain. Perhaps such research could eventually be used to predict the types of thought an individual may be engaging in by deciphering the pattern of associated neural activity and a collection of reports of self-generated thought. If this were possible, online recordings of participants' thoughts as they unfold could valuable. Such an approach would lead to advancements in understanding the processes that support the unfolding and dynamic nature of thought.

Whilst each chapter acknowledges the limitations of the associated studies in relation to the aims that they address, there are additional limitations that are important to review in relation to the topic of self-generated thought. These limitations point to interesting avenues for future research. One limitation relates to the broadness of the decompositions produced from the MDES probes (as used in Chapters 2-4). There are many sampling methods that can be employed when investigating self-generated thought and the literature lacks a standardised use of these measures (Weinstein, 2018). Whilst this can be a strength, with similar findings being produced from varying sampling methods, a more standardised approach to sampling within the literature could be beneficial. The thought patterns observed in the studies described in this thesis identify general properties that comprise a given type of thought experienced. These data give us a general idea of the types of thought that participants experience during periods of self-generated thought. However, more specific aspects of the experience are not captured. What exactly were participants thinking about when they reported that their thoughts were focused on other people and from memory? Perhaps they were thinking about what it would be like to go on holiday with a friend which might in some ways differ from thinking about their sibling's birthday party that happened last week. Both thoughts however could be decomposed as belonging to the episodic social cognition thought pattern. One technique that could help to inform researchers of specific experiences is the open question sampling method (Weinstein, 2018). This method would involve participants describing their thoughts in their own words. Such an approach would not constrain participants reports and offer a detailed account of their experience (Baird et al., 2011; Klinger, 1984; McClure & Cole, 2022).

Perhaps by using a combination of MDES and open sampling, aspects of the self-generated thought experience, that the MDES questions do not query, could be accounted for. For example, participants could be asked to provide a detailed account of specifically what their thoughts were and what triggered them. This way, more general descriptions of thought types obtained from MDES could be matched to more detailed reports of the experience. The combination of MDES probing and corresponding open reports could enable a form of internal validation where the reports from the MDES probes could be compared and verified with the contents of the open reports (Kane et al., 2021).

In addition, broadening the set of questions that comprise the MDES probes could help to further query more specific aspects of self-generated thought. Turnbull and colleagues (2021) have expanded the standardised set of questions typically used within that laboratory to assess the goals and the dynamic nature of participants' thoughts. Surely the inclusion of more MDES probe questions can only help researchers to further query features of the experience.

More generally, the employment of mixed sampling approaches, increasing the variation in the contexts under which thought is sampled and tracking the consistency of thought patterns reported could help to build a more comprehensive profile of the experience of self-generated thought, the features associated with a type of thought and the contexts under which it is most and least influenced.

Moreover, the naming of principal components which correspond to patterns of thoughts is not a standardised procedure, with studies giving different general descriptions to similar patterns of thought. Standardisation of this technique could better enable the comparison of participants' thoughts reported across different samples. Having said this, applying methods such as the projection analysis to the study of self-generated thought, allows researchers to retrospectively compare the similarity in thought patterns reported in one sample, to those reported in a different sample (Mckeown et al., in press). The points raised are to highlight the importance of the self-report method, as it is essential to the study of self-generated thought. Further evaluation of this method can help to strengthen its application in laboratory studies of self-generated thought (Murray, Irving, et al., 2020).

Another limitation that is central to the study of self-generated thought is the lack of ecological validity of laboratory experiments. How best can we find a balance between constraining cognitive processes to evaluate their contribution to this behaviour whilst managing this constraint so that the conditions under which we sample the behaviour are not so far removed from daily life? It has been mentioned throughout this thesis that there is a need to broaden the contexts within which we sample self-generated thought. Doing so will enable researchers to have a more holistic understanding of the different thought patterns that rise from the mind. In addition, studies need to represent the fluidity of daily life tasks rather than engaging participants in tasks of long periods of sustained attention (Murray, Krasich, et al., 2020). The undemanding task context can be mundane for participants and is far from the different everyday activities that we engage in self-generated thought such as when cooking, driving or walking. This limits the extent to which findings from the laboratory on self-generated thought can be generalised to daily life (Seli, Carriere, et al., 2018). Recent studies report experiences of self-generated thought using daily life studies (Beaty et al., 2019;

Ho et al., 2020; Kane et al., 2017; Linz et al., 2019; Mckeown et al., 2021; Song & Wang, 2012; Turnbull et al., 2021). Daily life studies are useful for understanding how self-generated thoughts emerge in real life, researchers are informed about self-generated thought in its natural environment. It is therefore important that the task contexts used to engage participants in self-generated thought in laboratory experiments, reflect the activities and situations that people engage in self-generated thought throughout the day.

Further research also needs to focus on the overlap of individual differences and context on thought. Typically, these lines of research are separated within the literature however, for a more holistic framework of self-generated thought these should be considered simultaneously (Robison et al., 2020; Smallwood, Turnbull, et al., 2021). In reference to Chapter 4 for example, future work could explore if the general properties of the patterns of thought identified as being stable across contexts holds across a range of task contexts. This could be investigated alongside measurements of individual differences (such as anxiety and depression, trait individual differences that are found to be associated with intrusive and negative thinking) to better understand which individual differences influence thought across specific contexts. For example, narcissism is marked by a grandiose but also unstable self-concept. Kanske and colleagues (2017) showed that individuals high in narcissism are more likely to engage in positive and self focused future thought supporting the grandiose fantasies that characterise narcissism. They also showed that individuals high in narcissism engaged in negative, social and past focused thoughts supporting the vulnerable sense of self that also characterises this condition. It is possible then, that for narcissistic individuals, contexts which specifically engage thinking about the self are more likely to elicit positive future thoughts whereas contexts that specifically engage thinking about others might elicit more negative and social thought content. This possibility outlines the importance of considering how a combination of context and individual difference can influence particular thought content. Moreover, the range of individual differences that could influence an individuals' self-generated thoughts are multiple, such as personality, lifestyle and motivation. Different individual differences should be considered together rather than separately when evaluating what determines an individuals' self-generated thoughts. For example, Robinson and colleagues (2020) propose a nuanced approach (the multi-faceted framework) to evaluating the influence of individual differences on self-generated thought. Within this framework, individual differences are categorised as cognitive (e.g., working memory and attentional control), dispositional (e.g., personality traits and affective dispositions) or contextual (e.g., stress and motivation) correlates of self-generated thought.

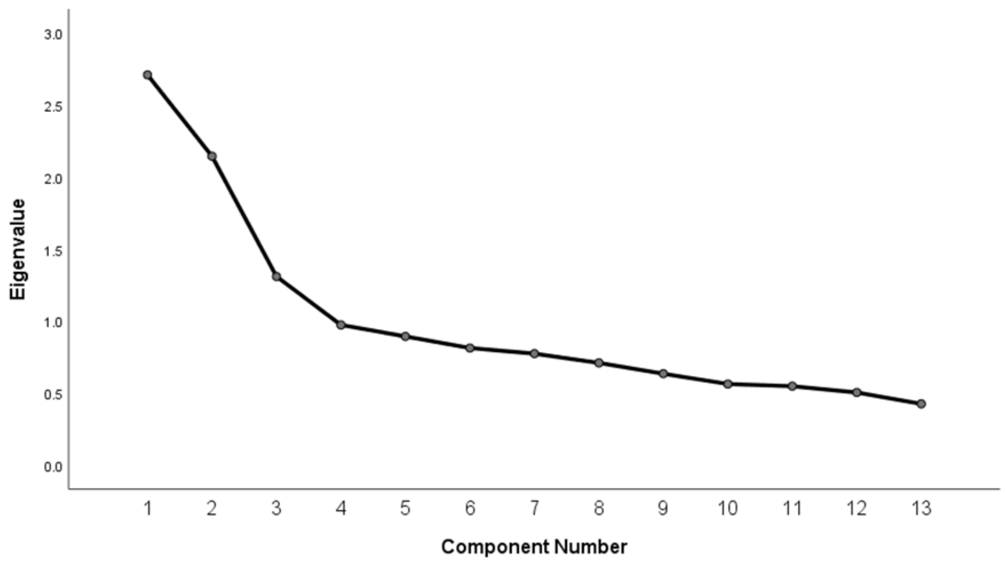
Recent research has also evaluated individual perceptions of mind wandering. Hatano et al. (2022) evaluated peoples' perceptions of engaging in self-generated thought. They showed that perceptions of the experience of engaging in self-generated thought were worse than their actual experiences. This suggests that individuals enjoyed letting their minds wander more than they anticipated. It was also found that participants avoided time designated to thinking over an alternative activity such as internet searching. It would be interesting to explore why despite thinking actually being experienced as just as enjoyable as other activities, it is initially perceived as less enjoyable than engaging in other tasks. Studies such as this which assess participants' perceptions of the experience of self-generated thought may have implications for when participants engage in self-generated thought. The types of activities that individuals engage in when they want to escape the here and now, as well their perceptions of that experience could also inform us about how context and individual differences influence self-generated thought.

5.4 Conclusions

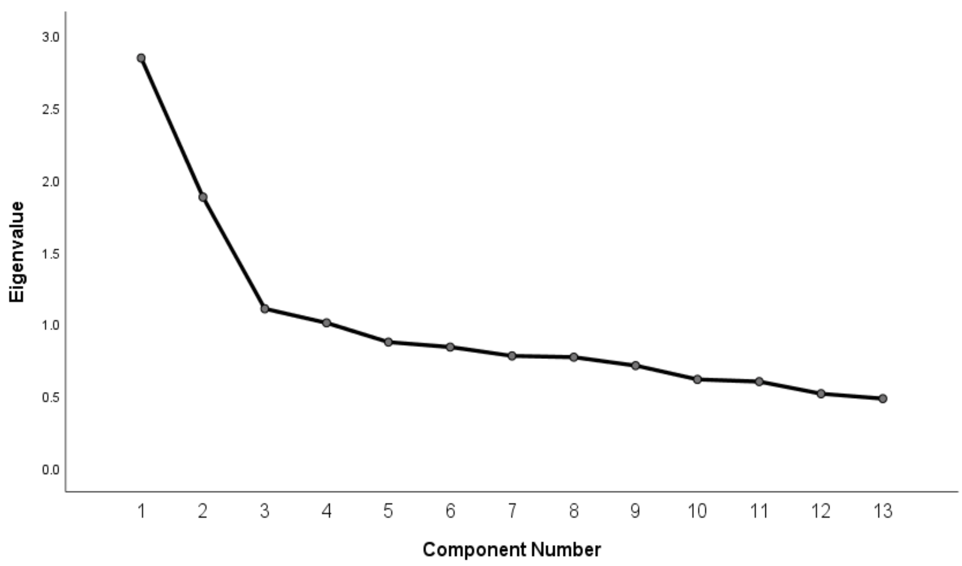
The aim was to explore the possible determinants of self-generated thought content. This included investigating the cognitive processes and neural mechanisms that support the content of self-generated thought, the potential influence of context and individual differences on the content of thought, and the persistence of thought content from one context to the next. This thesis contributes new findings which highlight a potential neural correlate of episodic and social thought content. Additionally, the results show that thought content is shaped, to some extent, by context and individual differences. Moreover, the findings suggest that individual differences in the expression of some thought content may be more stable across contexts than others. The results demonstrate the importance of considering the combined influence of the multiple determinants of self-generated thought on its content. The methodological and theoretical challenges discussed outline key issues that can be addressed in future research to further develop understanding of how the interplay between cognition, individual differences, and context gives rise to self-generated thought and its varied content. Together, the findings suggest that self-generated thought is a dynamic and complex form of cognition that is nevertheless accessible to empirical inquiry.

Appendices

Scanning Session

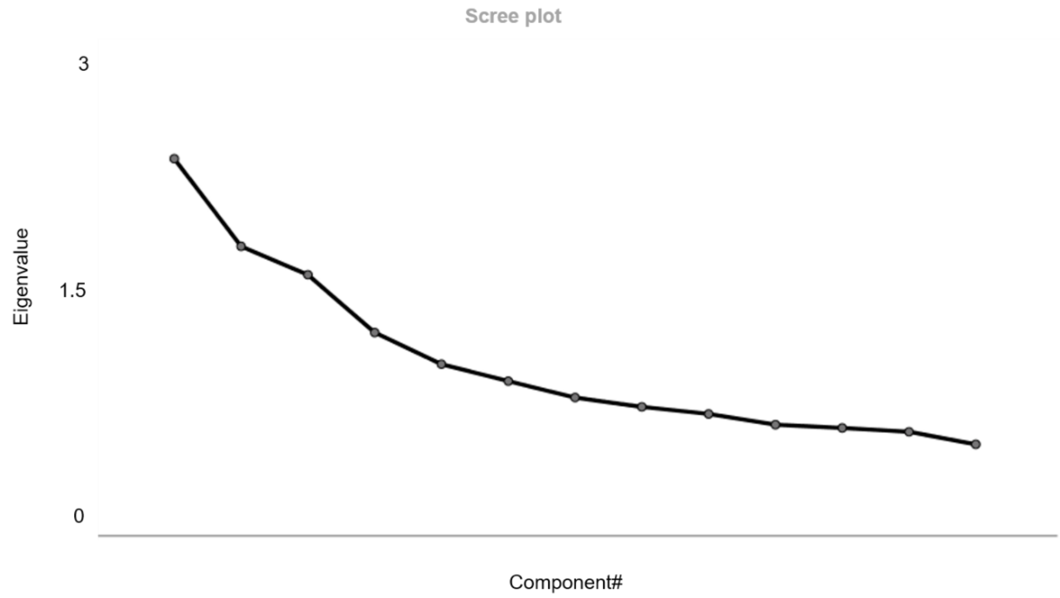


Behavioural Session

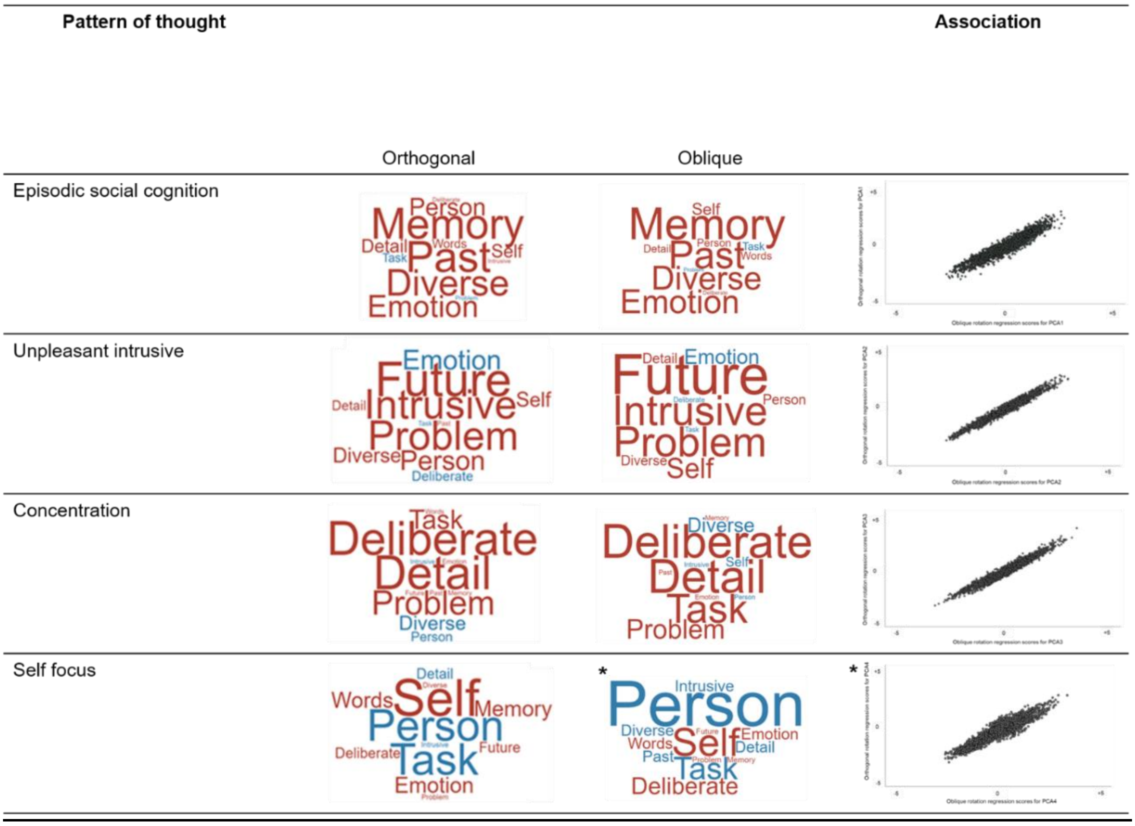


Appendices Figure 2.1. Scree plots from the application of PCA to two independent data sets. In both cases the scree plot suggests that three solutions are the optimum number.

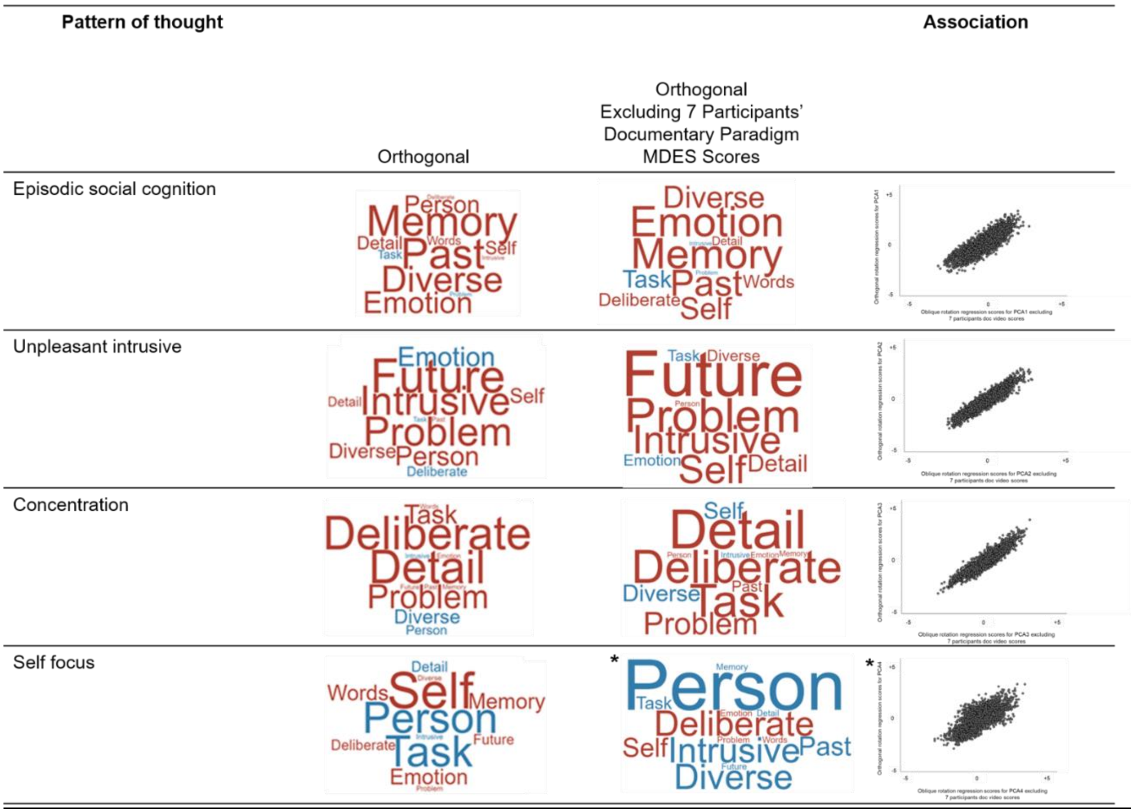
***Appendices Figure 3.1* Word clouds summarising the decomposition of the experience sampling data collected using oblique direct oblimin rotation which also revealed four components across all conditions.** For presentation purposes the component loadings for PCA4 have been inverted to demonstrate its similarity to PCA4 from the orthogonal rotation. The colour of the word describes the direction of the relationship (red = positive, blue = negative) and the size of the item reflects the magnitude of the loading.



***Appendices Figure 3.2* Scree plot showing oblique oblimin decomposition on the experience sampling data.**



Appendices Figure 3.3 **Summary of PCA rotation comparison showing similarity of the results using the two different data reduction approaches.** The word clouds show the loadings identified through the independent application of principal component analysis (PCA) to two different rotations (orthogonal and oblique). It can been seen that the components bear similarity to the orthogonal rotation components used in the current study ("Episodic Social Cognition", "Unpleasant Intrusive", "Concentration" and "Self Focus"). The colour of the word describes the direction of the relationship (red = positive, blue = negative) and the size of the word reflects the magnitude of the loading. The scatter plots show correlations between participant regression scores for each component for each PCA rotation. *For presentation purposes the component loadings and regression scores for PCA4 have been inverted to demonstrate its similarity to PCA4 from the orthogonal rotation.



Appendices Figure 3.4 **Summary of PCA rotation comparison between orthogonal rotation with and without the 7 participants' MDES scores for the documentary paradigm. The word clouds show the loadings identified through the independent application of principal component analysis (PCA) with and without the 7 participants' documentary paradigm MDES scores.** It can been seen that the components bear similarity to the orthogonal rotation components used in the current study ("Episodic Social Cognition", "Unpleasant Intrusive", "Concentration" and "Self Focus"). The colour of the word describes the direction of the relationship (red = positive, blue = negative) and the size of the item reflects the magnitude of the loading. The scatter plots show correlations between participant regression scores for each component for each PCA conducted. * For presentation purposes the component loadings and regression scores for PCA4 have been inverted to demonstrate its similarity to PCA4 from the orthogonal rotation with the 7 participants' documentary paradigm MDES scores.

Appendices* Table 3.1 *Summary of exploratory orthogonal principal component analysis of the multiple dimension experience sampling questions (N = 2294). Note factor loadings over .40 are highlighted bold.

		Components		
Dimension	Episodic social cognition	Unpleasant Intrusive	Concentration	Self focus
Task	-.16	-.07	**.45**	**-.58**
Future	.02	**.74**	.10	.17
Past	**.72**	.06	.14	.01
Self	.25	.30	-.03	**.69**
Person	**.40**	**.38**	-.20	**-.60**
Emotion	**.53**	**-.37**	.14	.30
Modality	.16	-.01	.06	.26
Detail	.25	.23	**.66**	-.18
Deliberate	.06	-.16	**.71**	.18
Problem	-.11	**.56**	**.49**	.08
Diverse	**.59**	.28	-.31	.11
Intrusive	.07	**.64**	-.12	-.06
Source	**.69**	-.05	.11	.28

Appendices Table 3.2. ***Summary of eigenvalues and corresponding cumulative variance for the exploratory orthogonal principal component analysis of the multiple dimension experience sampling.***

Total Variance Explained

	Initial Eigenvalues			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.36	18.17	18.17	1.99	15.28	15.28
2	1.78	13.66	31.83	1.81	13.91	29.19
3	1.58	12.19	44.02	1.60	12.31	41.49
4	1.20	9.21	53.22	1.53	11.73	53.22
5	0.99	7.58	60.80			
6	0.87	6.70	67.50			
7	0.76	5.85	73.35			
8	0.70	5.37	78.73			
9	0.65	5.01	83.73			
10	0.58	4.45	88.19			
11	0.56	4.28	92.47			
12	0.53	4.09	96.56			
13	0.45	3.44	100.00			

Appendices Table 3.3. ***Pattern matrix of exploratory oblique principal component analysis of the multiple dimension experience sampling questions (N = 2294).*** Note factor loadings over .40 are highlighted bold.

	Component			
Dimension	1	2	3	4
Task	-0.22	-0.14	**0.57**	0.38
Future	-0.03	**0.77**	0.04	-0.05
Past	**0.73**	0.01	0.15	0.22
Self	0.33	**0.42**	-0.19	**-0.50**
Person	0.25	0.19	-0.06	**0.79**
Emotion	**0.63**	-0.34	0.08	-0.18
Modality	0.21	0.04	0.00	-0.20
Detail	0.23	0.22	**0.68**	0.15
Deliberate	0.15	-0.06	**0.66**	-0.31
Problem	-0.13	**0.63**	0.45	-0.12
Diversity	**0.56**	0.21	-0.33	0.21
Intrusive	-0.01	**0.60**	-0.11	0.20
Source	**0.75**	-0.04	0.05	-0.05

Appendices Table 3.4. ***Summary of eigenvalues and corresponding cumulative variance for the exploratory oblique oblimin principal component analysis of the multiple dimension experience sampling.***

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotated Sums of Squared Loadings
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	2.36	18.17	18.17	2.36	18.17	18.17	2.23
2	1.78	13.66	31.83	1.78	13.66	31.83	1.85
3	1.58	12.19	44.02	1.58	12.19	44.02	1.61
4	1.20	9.21	53.22	1.20	9.21	53.22	1.41
5	0.98	7.57	60.80				
6	0.87	6.70	67.50				
7	0.76	5.85	73.35				
8	0.70	5.37	78.73				
9	0.65	5.01	83.73				
10	0.58	4.45	88.19				
11	0.56	4.28	92.47				
12	0.53	4.09	96.56				
13	0.45	3.44	100.00				

Appendices Table 3.5. ***Table of correlations between orthogonal and oblique dimension regression scores.*** Note the Oblique PCA4 regression scores were inverted to demonstrate its similarity to the orthogonal regression scores.

	Orthogonal PCA1	Orthogonal PCA2	Orthogonal PCA3	Orthogonal PCA4
Oblique PCA1	.940**	--	--	--
Oblique PCA2	--	.979**	--	--
Oblique PCA3	--	--	.973**	--
Oblique PCA4	--	--	--	.926**

**p<.01, two-tailed, N = 2294

Appendices Table 3.6. ***Rotated component scores of orthogonal principal component analysis of the multiple dimension experience sampling scores questions without the 7 participant documentary paradigm MDES scores (N = 2231).***

	Component			
Dimension	1	2	3	4
Task	-0.36	0.19	0.62	0.16
Future	0.02	0.76	0.03	0.11
Past	0.62	0.05	0.20	0.34
Self	0.52	0.48	-0.27	-0.25
Person	-0.03	0.09	0.08	0.83
Emotion	0.68	-0.23	0.06	-0.12
Modality	0.29	0.01	-0.03	-0.08
Detail	0.16	0.26	0.70	0.10
Deliberate	0.26	-0.02	0.60	-0.38
Problem	-0.07	0.62	0.42	-0.09
Diversity	0.47	0.21	-0.28	0.44
Intrusive	-0.07	0.53	-0.08	0.36
Source	0.74	0.03	0.07	0.10

Appendices Table 3.7. ***Summary of eigenvalues and corresponding cumulative variance of the orthogonal principal component analysis of the multiple dimension experience sampling scores questions without the 7 participant documentary paradigm MDES scores.***

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.38	18.27	18.27	2.38	18.27	18.27	2.21	16.99	16.99
2	1.77	13.64	31.91	1.77	13.64	31.91	1.69	13.01	30.00
3	1.60	12.30	44.21	1.60	12.30	44.21	1.61	12.41	42.41
4	1.19	9.12	53.33	1.19	9.12	53.33	1.42	10.92	53.33
5	0.98	7.53	60.86						
6	0.88	6.77	67.63						
7	0.76	5.83	73.46						
8	0.70	5.37	78.83						
9	0.64	4.96	83.79						
10	0.57	4.42	88.21						
11	0.56	4.27	92.48						
12	0.53	4.11	96.59						
13	0.44	3.41	100.00						

Appendices Table 3.8. ***Table of correlations between the orthogonal regression scores without the 7 participant documentary paradigm MDES scores and the regression scores with the 7 participant documentary paradigm MDES scores.***

	Orthogonal PCA1	Orthogonal PCA2	Orthogonal PCA3	Orthogonal PCA4
Orthogonal PCA1 without 7 participant doc paradigm MDES	.846**	--	--	--
Orthogonal PCA2 without 7 participant doc paradigm MDES	--	.926**	--	--
Orthogonal PCA3 without 7 participant doc paradigm MDES	--	--	.921**	--
Orthogonal PCA4 without 7 participant doc paradigm MDES	--	--	--	.703**

**p<.01, two-tailed, N = 2294

Appendices Table 3.9. ***Reliability scores for the 3 affective questionnaires used in the current study showing high reliability.***

Affective measure questionnaire	Mean	Standard deviation	Cronbach's Alpha(α)
Depression (CES-D)	16.51	9.99	.91
State Anxiety (STAI)	33.11	7.50	.88
Trait Anxiety (STAI)	42.50	11.11	.93

Appendices Table 3.10. ***Estimated marginal means describing the loading of each pattern of thought identified in the PCA within each task.***

	Estimated Marginal Mean			
Condition	PCA1	PCA2	PCA3	PCA4
Audiobook	0.09	0.19	-0.53	0.39
Action	-0.77	0.74	0.06	-0.99
Gambling	-0.74	0.22	1.00	0.59
Emotion recognition	-0.50	-0.27	-0.17	-0.42
Social cognition	1.26	-0.01	0.23	-0.79
Go	-0.17	0.17	0.14	0.52
Switching	-0.69	0.03	0.78	0.32
Inscapes	0.03	0.10	-0.55	0.25
No go	-0.08	0.19	0.05	0.54
Visual semantics	0.37	-0.03	0.12	-0.56
Working memory	-0.78	-0.26	1.21	0.37
Suspense	-0.92	0.84	0.01	-0.95
Documentary	0.00	-0.18	-0.25	-0.08
Verbal semantics	0.36	0.10	0.13	-0.45
Self reference	0.39	0.17	0.32	0.79

Appendices* Table 4.1 *Summary of principal component analysis of the multiple dimension experience sampling questions

	Component			
Dimension	1	2	3	4
Task	0.09	0.67	-0.27	-0.02
Deliberate	-0.37	0.62	0.08	0.12
Intrusive	0.24	-0.33	0.36	0.24
Problem	-0.25	0.26	0.68	-0.08
Detail	0.09	0.72	0.24	-0.01
Modality	0.12	0.15	-0.17	0.77
Future	0.06	-0.07	0.79	0.00
Person	0.79	-0.14	0.02	0.00
Source	0.61	0.22	-0.25	0.18
Self	0.32	-0.12	0.20	0.58
Emotion	0.42	0.45	0.00	-0.41
Diverse	0.68	-0.29	0.13	0.27
Past	0.72	0.14	-0.01	0.14

Appendices Table 4.2 Corresponding p-values (before adjustment) of correlations showing similarity in the episodic social thought pattern observed within and across task contexts

FAC1 Episodic social				
	Context 1	Distractor 1	Context 2	Distractor 2
Context 1		0.044 (.540)	0.623 (<.001)	0.075 (.293)
Distractor 1	0.044 (.540)		0.058 (.415)	0.469 (<.001)
Context 2	0.623 (<.001)	0.058 (.415)		-0.095 (.184)
Distractor 2	0.075 (.293)	0.469 (<.001)	-0.095 (.184)	

Appendices Table 4.3 Corresponding p-values (before adjustment) of correlations showing similarity in the concentration thought pattern observed within and across task contexts

FAC 2 Concentration				
	Context 1	Distractor 1	Context 2	Distractor 2
Context 1		0.301 (<.001)	0.703 (<.001)	0.425 (<.001)
Distractor 1	0.301 (<.001)		0.282 (<.001)	0.358 (<.001)
Context 2	0.703 (<.001)	0.282 (<.001)		0.412 (<.001)
Distractor 2	0.425 (<.001)	0.358 (<.001)	0.412 (<.001)	

Table 4.4 Corresponding p-values (before adjustment) of correlations showing similarity in the future problem solving thought pattern observed within and across task contexts

FAC 3 Future Problem Solving				
	Context 1	Distractor 1	Context 2	Distractor 2
Context 1		0.325 (<.001)	0.657 (<.001)	0.311 (<.001)
Distractor 1	0.325 (<.001)		0.354 (<.001)	0.532 (<.001)
Context 2	0.657 (<.001)	0.354 (<.001)		0.464 (<.001)
Distractor 2	0.311 (<.001)	0.532 (<.001)	0.464 (<.001)	

Table 4.5 Corresponding p-values (before adjustment) of correlations showing similarity in the negative self focus thought pattern observed within and across task contexts

FAC 4 Negative self focus				
	Context 1	Distractor 1	Context 2	Distractor 2
Context 1		-0.025 (.724)	0.691 (<.001)	-0.001 (.994)
Distractor 1	-0.025 (.724)		-0.146 (.041)	0.276 (<.001)
Context 2	0.691 (<.001)	-0.146 (.041)		-0.026 (.722)
Distractor 2	-0.001 (.994)	0.276 (<.001)	-0.026 (.722)	

Appendices Table A.3.1 Summary of task paradigms used in the current study with corresponding mean RT (ms), mean accuracy and standard error (screen reader compatible).

Category	Task Paradigm	Condition	Task	RT (ms) (standard error)	ACC (standard error)
Simple tasks	Go/No-go	Go	Respond to nominated target	435.27 (1.65)	0.97 (0.01)
		No-go	Respond to less frequent nominated target	484.47 (2.80)	0.96 (0.02)
	Semantic	Visual Semantics** (Picture)	Make a decision (Europe or not) based on a pictorial stimulus	808.32 (3.59)	0.80 (0.01)
		Verbal Semantics** (Word)	Make a decision (Europe or not) based on a text stimulus	818.88 (3.64)	0.81 (0.01)
	Self/Other	Self reference	Make judgement in reference to self	766.05 (3.14)	0.91 (0.01)
		Social cognition reference	Make judgement in reference to other	774.49 (3.14)	0.89 (0.01)
Complex tasks*	Working memory		Hold information in mind	N/A	N/A
	Switching		Switch between different tasks	81730.29 (3234.97)	N/A
	Gambling		Make gambling decisions	1325.955 (32.26)	N/A
	Emotion Recognition		Identify emotional expressions	1010.059 (25.51)	0.66 (0.01)
TV-based tasks	Documentary TV-based clips	Documentary	Watch a documentary	N/A	N/A
		Audiobook	Listen to a documentary	N/A	N/A
		Audio Inscapes	Listen to documentary with irrelevant visual input	N/A	N/A
	Affective TV-based clips	Suspense	Watch a TV clip in which a threat occurred at the end of the clip creating threat uncertainty	N/A	N/A
		Action	Watch a TV clip in which the threat occurred at the start of the clip creating threat certainty	N/A	N/A

* From the CANTAB battery ** From Rice, Hoffman, Binney, and Lambon Ralph (2018).

Appendices Table A.3.7. ***Summary of eigenvalues and corresponding cumulative variance of the orthogonal principal component analysis of the multiple dimension experience sampling scores questions without the 7 participant documentary paradigm MDES scores (screen reader compatible).***

				Total Variance Explained					
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.38	18.27	18.27	2.38	18.27	18.27	2.21	16.99	16.99
2	1.77	13.64	31.91	1.77	13.64	31.91	1.69	13.01	30.00
3	1.60	12.30	44.21	1.60	12.30	44.21	1.61	12.41	42.41
4	1.19	9.12	53.33	1.19	9.12	53.33	1.42	10.92	53.33
5	0.98	7.53	60.86						
6	0.88	6.77	67.63						
7	0.76	5.83	73.46						
8	0.70	5.37	78.83						
9	0.64	4.96	83.79						
10	0.57	4.42	88.21						
11	0.56	4.27	92.48						
12	0.53	4.11	96.59						
13	0.44	3.41	100.00						

Table A.4.4 Parameters from the context-guided model (screen reader compatible).

	Context-guided model											
	FAC1 (Episodic social cognition)			**FAC2 (Concentration)**			**FAC3 (Future problem solving)**			**FAC4 (Negative self focus)**		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	-0.77	-0.87 – -0.67	**<0.001**	-0.43	-0.57 – -0.30	**<0.001**	0.36	0.23 – 0.50	**<0.001**	-0.45	-0.57 – -0.33	**<0.001**
1B	0.16	0.04 – 0.29	**0.008**	0.87	0.73 – 1.01	**<0.001**	-0.28	-0.42 – -0.13	**<0.001**	0.38	0.23 – 0.54	**<0.001**
Self	1.13	1.00 – 1.25	**<0.001**	0.31	0.16 – 0.46	**<0.001**	-0.44	-0.59 – -0.29	**<0.001**	1.34	1.18 – 1.50	**<0.001**
Social	1.81	1.68 – 1.94	**<0.001**	0.55	0.40 – 0.71	**<0.001**	-0.73	-0.89 – -0.58	**<0.001**	0.05	-0.11 – 0.21	0.559
Random Effects												
σ^2	0.38			0.50			0.52			0.62		
τ_{00}	0.09 $_{ID}$			0.41 $_{ID}$			0.41 $_{ID}$			0.10 $_{ID}$		
				0.00 $_{Prime\_run}$						0.00 $_{Prime\_run}$		
ICC	0.19			0.45			0.44			0.13		
N	196 $_{ID}$			196 $_{ID}$			196 $_{ID}$			196 $_{ID}$		
				2 $_{Prime\_run}$						2 $_{Prime\_run}$		
Observations	784			784			784			784		
Marginal R^2 / Conditional R^2	0.531 / 0.622			0.101 / 0.509			0.070 / 0.479			0.289 / 0.385		

Appendices Table A.4.5 Parameters from the persistence model (screen reader compatible)

						Persistence Model						
	FAC1 (Episodic social cognition)			**FAC2 (Concentration)**			**FAC3 (Future problem solving)**			**FAC4 (Episodic social cognition)**		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	-0.71	-0.86 – -0.56	**<0.001**	-0.35	-0.59 – -0.11	**0.004**	0.42	0.18 – 0.67	**0.001**	-0.52	-0.69 – -0.35	**<0.001**
Context-guided task	-0.13	-0.34 – 0.08	0.235	-0.16	-0.47 – 0.14	0.292	-0.13	-0.42 – 0.15	0.368	0.15	-0.10 – 0.39	0.241
Distractor task	0.11	-0.04 – 0.26	0.148	0.86	0.66 – 1.06	**<0.001**	-0.34	-0.53 – -0.16	**<0.001**	0.40	0.20 – 0.59	**<0.001**
Context-guided task* Distractor task	0.11	-0.11 – 0.33	0.314	0.00	-0.28 – 0.29	0.978	0.14	-0.12 – 0.41	0.294	-0.03	-0.31 – 0.26	0.862
Random Effects												
σ^2	0.30			0.52			0.45			0.51		
τ_{00}	0.28_{ID}			0.67_{ID}			0.57_{ID}			0.25_{ID}		
				0.01_{Prime_run}			0.01_{Prime_run}					
ICC	0.48			0.57			0.56			0.33		
N	196_{ID}			196_{ID}			196_{ID}			196_{ID}		
				2_{Prime_run}			2_{Prime_run}					
Observations	392			392			392			392		
Marginal R^2 / Conditional R^2	0.015 / 0.493			0.140 / 0.627			0.020 / 0.572			0.052 / 0.368		

References

Addis, D. R. (2018). Are episodic memories special? On the sameness of remembered and imagined event simulation. *Journal of the Royal Society of New Zealand*, *48*(2-3), 64-88.

Addis, D. R., Pan, L., Vu, M. A., Laiser, N., & Schacter, D. L. (2009). Constructive episodic simulation of the future and the past: Distinct subsystems of a core brain network mediate imagining and remembering. *Neuropsychologia*, *47*(11), 2222-2238. https://doi.org/10.1016/j.neuropsychologia.2008.10.026

Alam, T. R. G., Krieger-Redwood, K., Evans, M., Rice, G. E., Smallwood, J., & Jefferies, E. (2020). Intrinsic Connectivity of Anterior Temporal Lobe Relates to Individual Differences in in Semantic Retrieval for Landmarks. *Cortex*.

Allen, M., Smallwood, J., Christensen, J., Gramm, D., Rasmussen, B., Jensen, C. G., Roepstorff, A., & Lutz, A. (2013). The balanced mind: the variability of task-unrelated thoughts predicts error monitoring. *Frontiers in human neuroscience*, *7*, 743.

Anderson, N. H. (1968). Likableness ratings of 555 personality-trait words. *Journal of personality and social psychology*, *9*(3), 272.

Andrews-Hanna, J. R. (2012). The Brain's Default Network and Its Adaptive Role in Internal Mentation. *Neuroscientist*, *18*(3), 251-270. https://doi.org/10.1177/1073858411403316

Andrews-Hanna, J. R., Kaiser, R. H., Turner, A. E. J., Reineberg, A. E., Godinez, D., Dimidjian, S., & Banich, M. T. (2013). A penny for your thoughts: dimensions of self-generated thought content and relationships with individual differences in emotional wellbeing. *Frontiers in psychology*, *4*. https://doi.org/ARTN 900

10.3389/fpsyg.2013.00900

Andrews-Hanna, J. R., Reidler, J. S., Sepulcre, J., Poulin, R., & Buckner, R. L. (2010). Functional-anatomic fractionation of the brain's default network. *Neuron*, *65*(4), 550-562.

Andrews-Hanna, J. R., Smallwood, J., & Spreng, R. N. (2014). The default network and self-generated thought: component processes, dynamic control, and clinical relevance. *Annals of the New York Academy of Sciences*, *1316*(1), 29.

Antrobus, J. S. (1968). Information theory and stimulus-independent thought. *British Journal of Psychology*, *59*(4), 423-430.

Axelrod, V., Rees, G., Lavidor, M., & Bar, M. (2015). Increasing propensity to mind-wander with transcranial direct current stimulation. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(11), 3314-3319. https://doi.org/10.1073/pnas.1421435112

Baars, B. J. (2010). Spontaneous Repetitive Thoughts Can Be Adaptive: Postscript on "Mind Wandering". *Psychological bulletin*, *136*(2), 208-210. https://doi.org/10.1037/a0018726

Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment*, *13*(1), 27-45.

Baird, B., Smallwood, J., Gorgolewski, K. J., & Margulies, D. S. (2013). Medial and Lateral Networks in Anterior Prefrontal Cortex Support Metacognitive Ability for Memory and Perception. *Journal of Neuroscience*, *33*(42), 16657-16665. https://doi.org/10.1523/Jneurosci.0786-13.2013

Baird, B., Smallwood, J., Mrazek, M. D., Kam, J. W., Franklin, M. S., & Schooler, J. W. (2012). Inspired by distraction: Mind wandering facilitates creative incubation. *Psychological science*, *23*(10), 1117-1122.

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

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

Banks, J. B., & Welhaf, M. S. (2022). Individual differences in dimensions of mind wandering: the mediating role of emotional valence and intentionality. *Psychological Research-Psychologische Forschung*, *86*(5), 1495-1517. https://doi.org/10.1007/s00426-021-01579-2

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from asperger syndrome/high-functioning autism, malesand females, scientists and mathematicians. *Journal of autism and developmental disorders*, *31*(1), 5-17.

Barron, E., Riby, L. M., Greer, J., & Smallwood, J. (2011). Absorbed in Thought: The Effect of Mind Wandering on the Processing of Relevant and Irrelevant Events. *Psychological science*, *22*(5), 596-601. https://doi.org/10.1177/0956797611404083

Bates, D., Machler, M., Bolker, B. M., & Walker, S. C. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, *67*(1), 1-48. https://doi.org/DOI 10.18637/jss.v067.i01

Baumeister, R. F., & Masicampo, E. J. (2010). Conscious Thought Is for Facilitating Social and Cultural Interactions: How Mental Simulations Serve the Animal-Culture Interface. *Psychological Review*, *117*(3), 945-971. https://doi.org/10.1037/a0019393

Beaty, R. E., Seli, P., & Schacter, D. L. (2019). Thinking about the past and future in daily life: an experience sampling study of individual differences in mental time travel. *Psychological Research*, *83*(4), 805-816.

Beaty, R. E., Seli, P., & Schacter, D. L. (2019). Thinking about the past and future in daily life: an experience sampling study of individual differences in mental time travel. *Psychological Research-Psychologische Forschung*, *83*(4), 805-816. https://doi.org/10.1007/s00426-018-1075-7

Benoit, R. G., Szpunar, K. K., & Schacter, D. L. (2014). Ventromedial prefrontal cortex supports affective future simulation by integrating distributed knowledge. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(46), 16550-16555. https://doi.org/10.1073/pnas.1419274111

Bernhardt, B. C., Smallwood, J., Tusche, A., Ruby, F. J. M., Engen, H. G., Steinbeis, N., & Singer, T. (2014). Medial prefrontal and anterior cingulate cortical thickness predicts, shared individual differences in self-generated thought and temporal discounting. *Neuroimage*, *90*, 290-297. https://doi.org/10.1016/j.neuroimage.2013.12.040

Berntsen, D., & Jacobsen, A. S. (2008). Involuntary (spontaneous) mental time travel into the past and future. *Consciousness and Cognition*, *17*(4), 1093-1104.

Bertossi, E., & Ciaramelli, E. (2016). Ventromedial prefrontal damage reduces mind-wandering and biases its temporal focus. *Social cognitive and affective neuroscience*, *11*(11), 1783-1791.

Bertossi, E., Tesini, C., Cappelli, A., & Ciaramelli, E. (2016). Ventromedial prefrontal damage causes a pervasive impairment of episodic memory and future thinking. *Neuropsychologia*, *90*, 12-24.

Biswal, B., Yetkin, F. Z., Haughton, V. M., & Hyde, J. S. (1995). Functional Connectivity in the Motor Cortex of Resting Human Brain Using Echo-Planar Mri. *Magnetic Resonance in Medicine*, *34*(4), 537-541. https://doi.org/DOI 10.1002/mrm.1910340409

Blankstein, K. R., Toner, B. B., & Flett, G. L. (1989). Test Anxiety and the Contents of Consciousness - Thought-Listing and Endorsement Measures. *Journal of Research in Personality*, *23*(3), 269-286. https://doi.org/Doi 10.1016/0092-6566(89)90001-9

Bomyea, J., & Amir, N. (2011). The Effect of an Executive Functioning Training Program on Working Memory Capacity and Intrusive Thoughts. *Cognitive Therapy and Research*, *35*(6), 529-535. https://doi.org/10.1007/s10608-011-9369-8

Bregman-Hai, N., Abitbul-Gordon, S., Deutsch, I., Garbi, D., Shelef, L., & Soffer-Dudek, N. (2018). Leave everything to the imagination: Cognitive functioning of individuals high in dissociative absorption and imaginative involvement. *Journal of Research in Personality*, *76*, 129-138.

Brewin, C. R., & Smart, L. (2005). Working memory capacity and suppression of intrusive thoughts. *Journal of Behavior Therapy and Experimental Psychiatry*, *36*(1), 61-68. https://doi.org/10.1016/j.jbtep.2004.11.006

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network - Anatomy, function, and relevance to disease. *Year in Cognitive Neuroscience 2008*, *1124*, 1-38. https://doi.org/10.1196/annals.1440.011

Burgess, N., Maguire, E. A., & O'Keefe, J. (2002). The human hippocampus and spatial and episodic memory. *Neuron*, *35*(4), 625-641.

Callard, F., & Margulies, D. S. (2011). The subject at rest: novel conceptualizations of self and brain from cognitive neuroscience's study of the 'resting state'. *Subjectivity*, *4*(3), 227-257.

Callard, F., Smallwood, J., Golchert, J., & Margulies, D. S. (2013). The era of the wandering mind? Twenty-first century research on self-generated mental activity. *Front Psychol*, *4*, 891. https://doi.org/10.3389/fpsyg.2013.00891

Callard, F., Smallwood, J., & Margulies, D. S. (2012). Default positions: how neuroscience's historical legacy has hampered investigation of the resting mind. *Frontiers in psychology*, *3*, 321.

Cardeña, E., & Marcusson-Clavertz, D. (2016). The relation of hypnotizability and dissociation to everyday mentation: An experience-sampling study. *Psychology of Consciousness: Theory, Research, and Practice*, *3*(1), 61.

Carleton, R. N., Norton, M. P. J., & Asmundson, G. J. (2007). Fearing the unknown: A short version of the Intolerance of Uncertainty Scale. *Journal of anxiety disorders*, *21*(1), 105-117.

Cherry, J., McCormack, T., & Graham, A. (2022). The intentionality of mind wandering in adolescence. *The Cognitive Psychology Bulletin*, *7*.

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

Christoff, K., Irving, Z. C., Fox, K. C., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: a dynamic framework. *Nature Reviews Neuroscience*, *17*(11), 718.

Christoff, K., Mills, C., Andrews-Hanna, J. R., Irving, Z. C., Thompson, E., Fox, K. C., & Kam, J. W. (2018). Mind-wandering as a scientific concept: cutting through the definitional haze. *Trends in cognitive sciences*, *22*(11), 957-959.

Ciaramelli, E., & Treves, A. (2019). A mind free to wander: neural and computational constraints on spontaneous thought. *Frontiers in psychology*, *10*, 39.

Cohn, M. A., Fredrickson, B. L., Brown, S. L., Mikels, J. A., & Conway, A. M. (2009). Happiness Unpacked: Positive Emotions Increase Life Satisfaction by Building Resilience. *Emotion*, *9*(3), 361-368. https://doi.org/10.1037/a0015952

Cole, S. N., & Berntsen, D. (2016). Do future thoughts reflect personal goals? Current concerns and mental time travel into the past and future. *Quarterly Journal of Experimental Psychology*, *69*(2), 273-284. https://doi.org/10.1080/17470218.2015.1044542

Cole, S. N., & Tubbs, P. M. C. (2022). Predictors of obsessive-compulsive symptomology: mind wandering about the past and future. *Psychological Research-Psychologische Forschung*, *86*(5), 1518-1534. https://doi.org/10.1007/s00426-021-01585-4

Conway, M. A., Loveday, C., & Cole, S. N. (2016). The remembering–imagining system. *Memory Studies*, *9*(3), 256-265.

Cooney, G., Boothby, E. J., & Lee, M. (2021). The thought gap after conversation: Underestimating the frequency of others' thoughts about us. *Journal of Experimental Psychology: General*.

Cox, W., & Klinger, E. (2004). Handbook of motivational counselling: Motivating people for change. In: London: Wiley.

Craik, F. I., Moroz, T. M., Moscovitch, M., Stuss, D. T., Winocur, G., Tulving, E., & Kapur, S. (1999). In search of the self: A positron emission tomography study. *Psychological science*, *10*(1), 26-34.

Crowe, S. F., Matthews, C., & Walkenhorst, E. (2007). Relationship between worry, anxiety and thought suppression and the components of working memory in a non-clinical sample. *Australian Psychologist*, *42*(3), 170-177. https://doi.org/10.1080/00050060601089462

D'Argembeau, A. (2011). Motivational aspects of future thinking in the ventromedial prefrontal cortex. *978-0-470-54396-2*.

D'Argembeau, A. (2013). On the role of the ventromedial prefrontal cortex in self-processing: the valuation hypothesis. *Front Hum Neurosci*, *7*, 372. https://doi.org/10.3389/fnhum.2013.00372

D'Argembeau, A., Collette, F., Van der Linden, M., Laureys, S., Del Fiore, G., Degueldre, C., Luxen, A., & Salmon, E. (2005). Self-referential reflective activity and its relationship with rest: a PET study. *Neuroimage*, *25*(2), 616-624. https://doi.org/10.1016/j.neuroimage.2004.11.048

D'Argembeau, A., Feyers, D., Majerus, S., Collette, F., Van der Linden, M., Maquet, P., & Salmon, E. (2008). Self-reflection across time: cortical midline structures differentiate between present and past selves. *Social cognitive and affective neuroscience*, *3*(3), 244-252. https://doi.org/10.1093/scan/nsn020

D'Argembeau, A., Lardi, C., & Van der Linden, M. (2012). Self-defining future projections: Exploring the identity function of thinking about the future. *Memory*, *20*(2), 110-120. https://doi.org/10.1080/09658211.2011.647697

D'Argembeau, A., & Mathy, A. (2011). Tracking the Construction of Episodic Future Thoughts. *Journal of Experimental Psychology-General*, *140*(2), 258-271. https://doi.org/10.1037/a0022581

D'Argembeau, A., Renaud, O., & Van der Linden, M. (2011). Frequency, Characteristics and Functions of Future-oriented Thoughts in Daily Life. *Applied Cognitive Psychology*, *25*(1), 96-103. https://doi.org/10.1002/acp.1647

D'Argembeau, A., Ruby, P., Collette, F., Degueldre, C., Balteau, E., Luxen, A., Maquet, P., & Salmon, E. (2007). Distinct regions of the medial prefrontal cortex are associated with self-referential processing and perspective taking. *J Cogn Neurosci*, *19*(6), 935-944. https://doi.org/10.1162/jocn.2007.19.6.935

D'Argembeau, A., Ruby, P., Collette, F., Degueldre, C., Balteau, E., Luxen, A., Maquet, P., & Salmon, E. (2007). Distinct regions of the medial prefrontal cortex are associated with self-referential processing and perspective taking. *Journal of cognitive neuroscience*, *19*(6), 935-944. https://doi.org/DOI 10.1162/jocn.2007.19.6.935

D'Argembeau, A., Stawarczyk, D., Majerus, S., Collette, F., Van der Linden, M., Feyers, D., Maquet, P., & Salmon, E. (2010). The Neural Basis of Personal Goal Processing When Envisioning Future Events. *Journal of cognitive neuroscience*, *22*(8), 1701-1713. https://doi.org/DOI 10.1162/jocn.2009.21314

D'Argembeau, A., & Van der Linden, M. (2004). Phenomenal characteristics associated with projecting oneself back into the past and forward into the future: Influence of valence and temporal distance. *Consciousness and Cognition*, *13*(4), 844-858. https://doi.org/10.1016/j.concog.2004.07.007

D'Argembeau, A., & Van der Linden, M. (2006). Individual differences in the phenomenology of mental time travel: The effect of vivid visual imagery and emotion regulation strategies. *Consciousness and Cognition*, *15*(2), 342-350. https://doi.org/10.1016/j.concog.2005.09.001

D'Argembeau, A. (2013). On the role of the ventromedial prefrontal cortex in self-processing: the valuation hypothesis. *Frontiers in human neuroscience*, *7*, 372.

D'Argembeau, A., Jedidi, H., Balteau, E., Bahri, M., Phillips, C., & Salmon, E. (2012). Valuing one's self: medial prefrontal involvement in epistemic and emotive investments in self-views. *Cerebral Cortex*, *22*(3), 659-667.

Davis, R. N., & Nolen-Hoeksema, S. (2000). Cognitive inflexibility among ruminators and nonruminators. *Cognitive Therapy and Research*, *24*(6), 699-711. https://doi.org/Doi 10.1023/A:1005591412406

de Caso, I., Karapanagiotidis, T., Aggius-Vella, E., Konishi, M., Margulies, D. S., Jefferies, E., & Smallwood, J. (2017). Knowing me, knowing you: Resting-state functional connectivity of ventromedial prefrontal cortex dissociates memory related to self from a familiar other. *Brain Cogn*, *113*, 65-75. https://doi.org/10.1016/j.bandc.2017.01.004

de Caso, I., Poerio, G., Jefferies, E., & Smallwood, J. (2017). That's me in the spotlight: neural basis of individual differences in self-consciousness. *Soc Cogn Affect Neurosci*, *12*(9), 1384-1393. https://doi.org/10.1093/scan/nsx076

Deng, Y.-Q., Li, S., Tang, Y.-Y., Zhu, L.-H., Ryan, R., & Brown, K. (2012). Psychometric properties of the Chinese translation of the mindful attention awareness scale (MAAS). *Mindfulness*, *3*(1), 10-14.

Dixon, M. L., Andrews-Hanna, J. R., Spreng, R. N., Irving, Z. C., Mills, C., Girn, M., & Christoff, K. (2017). Interactions between the default network and dorsal attention network vary across default subsystems, time, and cognitive states. *Neuroimage*, *147*, 632-649. https://doi.org/10.1016/j.neuroimage.2016.12.073

Eklund, A., Nichols, T. E., & Knutsson, H. (2016). Cluster failure: Why fMRI inferences for spatial extent have inflated false-positive rates. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(28), 7900-7905. https://doi.org/10.1073/pnas.1602413113

Ellamil, M., Fox, K. C., Dixon, M. L., Pritchard, S., Todd, R. M., Thompson, E., & Christoff, K. (2016). Dynamics of neural recruitment surrounding the spontaneous arising of thoughts in experienced mindfulness practitioners. *Neuroimage*, *136*, 186-196. https://doi.org/10.1016/j.neuroimage.2016.04.034

Ellamil, M., Fox, K. C., Dixon, M. L., Pritchard, S., Todd, R. M., Thompson, E., & Christoff, K. (2016). Dynamics of neural recruitment surrounding the spontaneous arising of thoughts in experienced mindfulness practitioners. *Neuroimage*, *136*, 186-196.

Faber, M., & D'Mello, S. K. (2018). How the stimulus influences mind wandering in semantically rich task contexts. *Cognitive Research-Principles and Implications*, *3*. https://doi.org/ARTN 35

10.1186/s41235-018-0129-0

Feng, S., D'Mello, S., & Graesser, A. C. (2013). Mind wandering while reading easy and difficult texts. *Psychonomic bulletin & review*, *20*(3), 586-592.

Finnbogadottir, H., & Berntsen, D. (2013). Involuntary future projections are as frequent as involuntary memories, but more positive. *Consciousness and Cognition*, *22*(1), 272-280. https://doi.org/10.1016/j.concog.2012.06.014

Fox, K. C. R., Andrews-Hanna, J. R., Mills, C., Dixon, M. L., Markovic, J., Thompson, E., & Christoff, K. (2018). Affective neuroscience of self-generated thought. *Ann N Y Acad Sci*. https://doi.org/10.1111/nyas.13740

Fox, K. C. R., & Christoff, K. (2015). Transcranial direct current stimulation to lateral prefrontal cortex could increase meta-awareness of mind wandering. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(19), E2414-E2414. https://doi.org/10.1073/pnas.1504686112

Fox, K. C. R., Nijeboer, S., Solomonova, E., Domhoff, G. W., & Christoff, K. (2013). Dreaming as mind wandering: evidence from functional neuroimaging and first-person content reports. *Frontiers in human neuroscience*, *7*. https://doi.org/ARTN 412

10.3389/fnhum.2013.00412

Fox, M. D., Snyder, A. Z., Vincent, J. L., Corbetta, M., Van Essen, D. C., & Raichle, M. E. (2005). The human brain is intrinsically organized into dynamic, anticorrelated functional networks. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(27), 9673-9678. https://doi.org/10.1073/pnas.0504136102

Franklin, M. S., Broadway, J. M., Mrazek, M. D., Smallwood, J., & Schooler, J. W. (2013). Window to the wandering mind: Pupillometry of spontaneous thought while reading. *Quarterly Journal of Experimental Psychology*, *66*(12), 2289-2294. https://doi.org/10.1080/17470218.2013.858170

Gable, S. L., Hopper, E. A., & Schooler, J. W. (2019). When the muses strike: Creative ideas of physicists and writers routinely occur during mind wandering. *Psychological science*, *30*(3), 396-404.

Giambra, L. M. (1989). Task-Unrelated Thought Frequency as a Function of Age - a Laboratory Study. *Psychology and Aging*, *4*(2), 136-143. https://doi.org/Doi 10.1037/0882-7974.4.2.136

Giambra, L. M. (1995). A laboratory method for investigating influences on switching attention to task-unrelated imagery and thought. *Consciousness and Cognition: An International Journal*.

Giambra, L. M., & Grodsky, A. (1989). Task-unrelated images and thoughts while reading. In *Imagery* (pp. 27-31). Springer.

Gorgolewski, K. J., Lurie, D., Urchs, S., Kipping, J. A., Craddock, R. C., Milham, M. P., Margulies, D. S., & Smallwood, J. (2014). A Correspondence between Individual Differences in the Brain's Intrinsic Functional Architecture and the Content and Form of Self-Generated Thoughts. *PloS one*, *9*(5). https://doi.org/ARTN e97176

10.1371/journal.pone.0097176

Greicius, M. D., Krasnow, B., Reiss, A. L., & Menon, V. (2003). Functional connectivity in the resting brain: A network analysis of the default mode hypothesis. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(1), 253-258. https://doi.org/10.1073/pnas.0135058100

Gross, M., Smith, A. P., Graveline, Y., Beaty, R., Schooler, J., & Seli, P. (2020). Comparing the phenomenological qualities of stimulus-independent thought, stimulusdependent thought, and dreams using experience sampling.

Guesdon, A., Lejeune, F.-X., Rotgé, J.-Y., George, N., & Fossati, P. (2020). Mind-wandering changes in dysphoria. *Frontiers in Psychiatry*, *11*, 544999.

Guesdon, A., Lejeune, F. X., Rotge, J. Y., George, N., & Fossati, P. (2020). Mind-Wandering Changes in Dysphoria. *Frontiers in Psychiatry*, *11*. https://doi.org/ARTN 544999

10.3389/fpsyt.2020.544999

Hamilton, J., & Cole, S. N. (2017). Imagining possible selves across time: Characteristics of self-images and episodic thoughts. *Consciousness and Cognition*, *52*, 9-20. https://doi.org/10.1016/j.concog.2017.04.015

Hatano, A., Ogulmus, C., Shigemasu, H., & Murayama, K. (2022). Thinking About Thinking: People Underestimate How Enjoyable and Engaging Just Waiting Is. *Journal of Experimental Psychology-General*. https://doi.org/10.1037/xge0001255

Ho, N. S. P., Poerio, G., Konu, D., Turnbull, A., Sormaz, M., Leech, R., Bernhardt, B., Jefferies, E., & Smallwood, J. (2020). Facing up to why the wandering mind: Patterns of off-task laboratory thought are associated with stronger neural recruitment of right fusiform cortex while processing facial stimuli. *Neuroimage*, 116765. https://doi.org/10.1016/j.neuroimage.2020.116765

Ho, N. S. P., Wang, X., Vatansever, D., Margulies, D. S., Bernhardt, B., Jefferies, E., & Smallwood, J. (2019). Individual variation in patterns of task focused, and detailed, thought are uniquely associated within the architecture of the medial temporal lobe. *Neuroimage*, *202*, 116045.

Hoffmann, F., Banzhaf, C., Kanske, P., Bermpohl, F., & Singer, T. (2016). Where the depressed mind wanders: Self-generated thought patterns as assessed through experience sampling as a state marker of depression. *Journal of affective disorders*, *198*, 127-134.

Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics*, 6, 65–70. https://www.jstor.org/stable/4615733.

Huijser, S., van Vugt, M. K., & Taatgen, N. A. (2018). The wandering self: Tracking distracting self-generated thought in a cognitively demanding context. *Consciousness and Cognition*, *58*, 170-185. https://doi.org/10.1016/j.concog.2017.12.004

Irish, M., Addis, D. R., Hodges, J. R., & Piguet, O. (2012). Considering the role of semantic memory in episodic future thinking: evidence from semantic dementia. *Brain*, *135*, 2178-2191. https://doi.org/10.1093/brain/aws119

Irish, M., Goldberg, Z. I., Alaeddin, S., O'Callaghan, C., & Andrews-Hanna, J. R. (2019). Age-related changes in the temporal focus and self-referential content of spontaneous cognition during periods of low cognitive demand. *Psychological Research-Psychologische Forschung*, *83*(4), 747-760. https://doi.org/10.1007/s00426-018-1102-8

Irish, M., & Piguet, O. (2013). The pivotal role of semantic memory in remembering the past and imagining the future. *Frontiers in behavioral neuroscience*, *7*. https://doi.org/ARTN 27

10.3389/fnbeh.2013.00027

Ji, J. L., Holmes, E. A., MacLeod, C., & Murphy, F. C. (2019). Spontaneous cognition in dysphoria: reduced positive bias in imagining the future. *Psychological Research-Psychologische Forschung*, *83*(4), 817-831. https://doi.org/10.1007/s00426-018-1071-y

Jordao, M., Pinho, M. S., & St Jacques, P. L. (2019). Inducing spontaneous future thoughts in younger and older adults by priming future-oriented personal goals. *Psychological Research-Psychologische Forschung*, *83*(4), 710-726. https://doi.org/10.1007/s00426-019-01146-w

Kahneman, D., Krueger, A. B., Schkade, D. A., Schwarz, N., & Stone, A. A. (2004). A survey method for characterizing daily life experience: The day reconstruction method. *Science*, *306*(5702), 1776-1780. https://doi.org/DOI 10.1126/science.1103572

Kam, J. W. Y., Irving, Z. C., Mills, C., Patel, S., Gopnik, A., & Knight, R. T. (2021). Distinct electrophysiological signatures of task-unrelated and dynamic thoughts. *Proceedings of the National Academy of Sciences of the United States of America*, *118*(4). https://doi.org/ARTN e2011796118

10.1073/pnas.2011796118

Kane, M. J., Brown, L. H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. *Psychological science*, *18*(7), 614-621.

Kane, M. J., Gross, G. M., Chun, C. A., Smeekens, B. A., Meier, M. E., Silvia, P. J., & Kwapil, T. R. (2017). For whom the mind wanders, and when, varies across laboratory and daily-life settings. *Psychological science*, *28*(9), 1271-1289.

Kane, M. J., Smeekens, B. A., Meier, M. E., Welhaf, M. S., & Phillips, N. E. (2021). Testing the construct validity of competing measurement approaches to probed mind-wandering reports. *Behavior research methods*, *53*(6), 2372-2411.

Kanske, P., Schulze, L., Dziobek, I., Scheibner, H., Roepke, S., & Singer, T. (2016). The wandering mind in borderline personality disorder: Instability in self- and other-related thoughts. *Psychiatry Research*, *242*, 302-310. https://doi.org/10.1016/j.psychres.2016.05.060

Kanske, P., Sharifi, M., Smallwood, J., Dziobek, I., & Singer, T. (2017). Where the Narcissistic Mind Wanders: Increased Self-Related Thoughts Are More Positive and Future Oriented. *Journal of Personality Disorders*, *31*(4), 553-566. <Go to ISI>://WOS:000408599100008

Karapanagiotidis, T., Bernhardt, B. C., Jefferies, E., & Smallwood, J. (2017). Tracking thoughts: Exploring the neural architecture of mental time travel during mind-wandering. *Neuroimage*, *147*, 272-281. https://doi.org/10.1016/j.neuroimage.2016.12.031

Karapanagiotidis, T., Vidaurre, D., Quinn, A. J., Vatansever, D., Poerio, G. L., Turnbull, A., Ho, N. S. P., Leech, R., Bernhardt, B. C., Jefferies, E., Margulies, D. S., Nichols, T. E., Woolrich, M. W., & Smallwood, J. (2020). The psychological correlates of distinct neural states occurring during wakeful rest. *Scientific Reports*, *10*(1). https://doi.org/ARTN 21121

10.1038/s41598-020-77336-z

Kelley, W. M., Macrae, C. N., Wyland, C. L., Caglar, S., Inati, S., & Heatherton, T. F. (2002). Finding the self? An event-related fMRI study. *Journal of cognitive neuroscience*, *14*(5), 785-794.

Kelley, W. M., Macrae, C. N., Wyland, C. L., Caglar, S., Inati, S., & Heatherton, T. F. (2002). Finding the self? An event-related fMRI study. *J Cogn Neurosci*, *14*(5), 785-794. https://doi.org/10.1162/08989290260138672

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

Klein, S. B., Loftus, J., & Kihlstrom, J. F. (2002). Memory and temporal experience: The effects of episodic memory loss on an amnesic patient's ability to remember the past and imagine the future. *Social Cognition*, *20*(5), 353-379. https://doi.org/DOI 10.1521/soco.20.5.353.21125

Klinger, E. (1971). Structure and functions of fantasy.

Klinger, E. (1984). A Consciousness-Sampling Analysis of Test Anxiety and Performance. *Journal of personality and social psychology*, *47*(6), 1376-1390. https://doi.org/Doi 10.1037/0022-3514.47.6.1376

Klinger, E. (1987). Current concerns and disengagement from incentives. In *Motivation, intention, and volition* (pp. 337-347). Springer.

Klinger, E. (2013). Goal commitments and the content of thoughts and dreams: basic principles. *Frontiers in psychology*, *4*. https://doi.org/ARTN 415

10.3389/fpsyg.2013.00415

Konishi, M., Brown, K., Battaglini, L., & Smallwood, J. (2017). When attention wanders: Pupillometric signatures of fluctuations in external attention. *Cognition*, *168*, 16-26.

Konishi, M., McLaren, D. G., Engen, H., & Smallwood, J. (2015). Shaped by the Past: The Default Mode Network Supports Cognition that Is Independent of Immediate Perceptual Input. *PloS one*, *10*(6). https://doi.org/ARTN e0132209

10.1371/journal.pone.0132209

Konu, D., Mckeown, B., Turnbull, A., Ho, N. S. P., Karapanagiotidis, T., Vanderwal, T., McCall, C., Tipper, S. P., Jefferies, E., & Smallwood, J. (2021). Exploring patterns of ongoing thought under naturalistic and conventional task-based conditions. *Consciousness and Cognition*, *93*. https://doi.org/ARTN 103139

10.1016/j.concog.2021.103139

Konu, D., Turnbull, A., Karapanagiotidis, T., Wang, H.-t., Brown, L., Jefferies, E., & Smallwood, J. (2020). A role for ventromedial prefrontal cortex in self-generated episodic social cognition. *Neuroimage*, 116977.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software*, *82*(13), 1-26. https://doi.org/DOI 10.18637/jss.v082.i13

Lenth, R., Singmann, H., Love, J., Buerkner, P., & Herve, M. (2019). Estimated marginal means, aka least-squares means. R package version 1.3. 2. *Journal of Statistical Software*(69), 1.

Levinson, D. B., Smallwood, J., & Davidson, R. J. (2012). The Persistence of Thought: Evidence for a Role of Working Memory in the Maintenance of Task-Unrelated Thinking. *Psychological science*, *23*(4), 375-380. https://doi.org/10.1177/0956797611431465

Lin, W. J., Horner, A. J., & Burgess, N. (2016). Ventromedial prefrontal cortex, adding value to autobiographical memories. *Scientific Reports*, *6*. https://doi.org/ARTN 28630

10.1038/srep28630

Linz, R., Pauly, R., Smallwood, J., & Engert, V. (2019). Mind-wandering content differentially translates from lab to daily life and relates to subjective stress experience. *Psychol Res*. https://doi.org/10.1007/s00426-019-01275-2

Mace, J. H., & Unlu, M. (2020). Semantic-to-autobiographical memory priming occurs across multiple sources: Implications for autobiographical remembering. *Memory & cognition*, *48*(6), 931-941. https://doi.org/10.3758/s13421-020-01029-1

Macrae, C. N., Moran, J. M., Heatherton, T. F., Banfield, J. F., & Kelley, W. M. (2004). Medial prefrontal activity predicts memory for self. *Cereb Cortex*, *14*(6), 647-654. https://doi.org/10.1093/cercor/bhh025

Maillet, D., Beaty, R. E., Jordan, M. L., Touron, D. R., Adrian, A., Silvia, P. J., Kwapil, T. R., Turner, G. R., Spreng, R. N., & Kane, M. J. (2018). Age-Related Differences in Mind-Wandering in Daily Life. *Psychology and Aging*, *33*(4), 643-653. https://doi.org/10.1037/pag0000260

Makovac, E., Smallwood, J., Watson, D. R., Meeten, F., Critchley, H. D., & Ottaviani, C. (2018). The verbal nature of worry in generalized anxiety: Insights from the brain. *Neuroimage Clin*, *17*, 882-892. https://doi.org/10.1016/j.nicl.2017.12.014

Marchetti, I., Koster, E. H., & De Raedt, R. (2013). Rest-related dynamics of risk and protective factors for depression: A behavioral study. *Clinical Psychological Science*, *1*(4), 443-451.

Marchetti, I., Koster, E. H. W., Klinger, E., & Alloy, L. B. (2016). Spontaneous Thought and Vulnerability to Mood Disorders: The Dark Side of the Wandering Mind. *Clin Psychol Sci*, *4*(5), 835-857. https://doi.org/10.1177/2167702615622383

Margulies, D. S., Ghosh, S. S., Goulas, A., Falkiewicz, M., Huntenburg, J. M., Langs, G., Bezgin, G., Eickhoff, S. B., Castellanos, F. X., Petrides, M., Jefferies, E., & Smallwood, J. (2016). Situating the default-mode network along a principal gradient of macroscale cortical organization. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(44), 12574-12579. https://doi.org/10.1073/pnas.1608282113

Martinon, L. M., Smallwood, J., McGann, D., Hamilton, C., & Riby, L. M. (2019). The disentanglement of the neural and experiential complexity of self-generated thoughts: A users guide to combining experience sampling with neuroimaging data. *Neuroimage*.

Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T., & Macrae, C. N. (2007). Wandering minds: The default network and stimulus-independent thought. *Science*, *315*(5810), 393-395. https://doi.org/10.1126/science.1131295

Matusz, P. J., Dikker, S., Huth, A. G., & Perrodin, C. (2019). Are we ready for real-world neuroscience? In: MIT Press.

McClure, H., & Cole, S. (2020). Manipulating Verbal Cues within the Vigilance Task: Standardised Goal Cues Facilitate Spontaneous Future Thought.

McClure, J. H. C., & Cole, S. N. (2022). Controllability is key: Goal pursuit during COVID-19 and insights for theories of self-regulation. *Journal of Applied Social Psychology*. https://doi.org/10.1111/jasp.12920

McCormick, C., Rosenthal, C. R., Miller, T. D., & Maguire, E. A. (2018). Mind-wandering in people with hippocampal damage. *Journal of Neuroscience*, *38*(11), 2745-2754.

McEvoy, P. M., Watson, H., Watkins, E. R., & Nathan, P. (2013). The relationship between worry, rumination, and comorbidity: Evidence for repetitive negative thinking as a transdiagnostic construct. *Journal of affective disorders*, *151*(1), 313-320.

Mckeown, B., Konu, D., Strawson, W., Poerio, G., Turnbull, A., Karapanagiotidis, T., Ho, N.S.P., Jefferies, E., McCall, C., & Smallwood, J. (under review). What happens next? Ongoing thoughts about the future in the laboratory and daily life. PloS one.

Mckeown, B., Poerio, G. L., Strawson, W. H., Martinon, L. M., Riby, L. M., Jefferies, E., McCall, C., & Smallwood, J. (2021). The impact of social isolation and changes in work patterns on ongoing thought during the first COVID-19 lockdown in the United Kingdom. *Proceedings of the National Academy of Sciences of the United States of America*, *118*(40). https://doi.org/ARTN e2102565118

10.1073/pnas.2102565118

Mckeown, B., Strawson, W. H., Wang, H. T., Karapanagiotidis, T., de Wael, R. V., Benkarim, O., Turnbull, A., Margulies, D., Jefferies, E., McCall, C., Bernhardt, B., & Smallwood, J. (2020). The relationship between individual variation in macroscale functional gradients and distinct aspects of ongoing thought. *Neuroimage*, *220*. https://doi.org/ARTN 117072

10.1016/j.neuroimage.2020.117072

McKiernan, K. A., D'Angelo, B. R., Kaufman, J. N., & Binder, J. R. (2006). Interrupting the "stream of consciousness": An fMRI investigation. *Neuroimage*, *29*(4), 1185-1191. https://doi.org/10.1016/j.neuroimage.2005.09.030

McVay, J. C., & Kane, M. J. (2009). Conducting the train of thought: working memory capacity, goal neglect, and mind wandering in an executive-control task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(1), 196.

McVay, J. C., & Kane, M. J. (2010). Does mind wandering reflect executive function or executive failure? Comment on Smallwood and Schooler (2006) and Watkins (2008).

McVay, J. C., & Kane, M. J. (2013). Dispatching the wandering mind? Toward a laboratory method for cuing "spontaneous" off-task thought. *Frontiers in psychology*, *4*. https://doi.org/ARTN 570

10.3389/fpsyg.2013.00570

McVay, J. C., Meier, M. E., Touron, D. R., & Kane, M. J. (2013). Aging ebbs the flow of thought: Adult age differences in mind wandering, executive control, and self-evaluation. *Acta Psychologica*, *142*(1), 136-147. https://doi.org/10.1016/j.actpsy.2012.11.006

Medea, B., Karapanagiotidis, T., Konishi, M., Ottaviani, C., Margulies, D., Bernasconi, A., Bernasconi, N., Bernhardt, B. C., Jefferies, E., & Smallwood, J. (2018). How do we decide what to do? Resting-state connectivity patterns and components of self-generated thought linked to the development of more concrete personal goals. *Experimental brain research*, *236*(9), 2469-2481.

Miles, L. K., Karpinska, K., Lumsden, J., & Macrae, C. N. (2010). The Meandering Mind: Vection and Mental Time Travel. *PloS one*, *5*(5). https://doi.org/ARTN e10825

10.1371/journal.pone.0010825

Mooneyham, B., & Schooler, J. (2013). The Costs and Benefits of Mind-Wandering: A Review. *Canadian Journal of Experimental Psychology-Revue Canadienne De Psychologie Experimentale*, *67*(1), 11-18. https://doi.org/10.1037/a0031569

Moran, C. N., McGovern, D. P., Warren, G., Gralaigh, R. O., Kenney, J. P. M., Smeaton, A., & Dockree, P. M. (2021). Young and Restless, Old and Focused: Age-Differences in Mind-Wandering Frequency and Phenomenology. *Psychology and Aging*, *36*(2), 252-267. https://doi.org/10.1037/pag0000526

Morcom, A. M., & Fletcher, P. C. (2007). Does the brain have a baseline ? Why we should be resisting a rest. *Neuroimage*, *37*(4), 1073-1082. https://doi.org/10.1016/j.neuroimage.2006.09.013

Mrazek, M. D., Smallwood, J., & Schooler, J. W. (2012). Mindfulness and Mind-Wandering: Finding Convergence Through Opposing Constructs. *Emotion*, *12*(3), 442-448. https://doi.org/10.1037/a0026678

Murphy, C., Jefferies, E., Rueschemeyer, S. A., Sormaz, M., Wang, H. T., Margulies, D. S., & Smallwood, J. (2018). Distant from input: Evidence of regions within the default mode network supporting perceptually-decoupled and conceptually-guided cognition. *Neuroimage*, *171*, 393-401. https://doi.org/10.1016/j.neuroimage.2018.01.017

Murphy, C., Poerio, G., Sormaz, M., Wang, H. T., Vatansever, D., Allen, M., Margulies, D. S., Jefferies, E., & Smallwood, J. (2019). Hello, is that me you are looking for? A re-examination of the role of the DMN in social and self relevant aspects of off-task thought. *PloS one*, *14*(11). https://doi.org/ARTN e0216182

10.1371/journal.pone.0216182

Murray, S., Irving, Z., & Krasich, K. (2020). The scientific study of passive thinking: the methodology of mind wandering research.

Murray, S., Irving, Z. C., & Krasich, K. (2022). The scientific study of passive thinking: Methods of mind wandering research. In F. De Brigard & W. Sinnott-Armstrong (Eds.), *Neuroscience and Philosophy* (pp. 389-426). MIT Press.

Murray, S., Krasich, K., Schooler, J. W., & Seli, P. (2020). What's in a task? Complications in the study of the task-unrelated-thought variety of mind wandering. *Perspectives on Psychological Science*, *15*(3), 572-588.

Murray, S., Krasich, K., Schooler, J. W., & Seli, P. (2020). What's in a Task? Complications in the Study of the Task-Unrelated-Thought Variety of Mind Wandering. *Perspectives on Psychological Science*, 1745691619897966.

Nolen-Hoeksema, S. (2000). The role of rumination in depressive disorders and mixed anxiety/depressive symptoms. *Journal of Abnormal Psychology*, *109*(3), 504-511. https://doi.org/Doi 10.1037/0021-843x.109.3.504

Nolen-Hoeksema, S., Wisco, B. E., & Lyubomirsky, S. (2008). Rethinking Rumination. *Perspectives on Psychological Science*, *3*(5), 400-424. https://doi.org/10.1111/j.1745-6924.2008.00088.x

O'Callaghan, C., Shine, J. M., Hodges, J. R., Andrews-Hanna, J. R., & Irish, M. (2019). Hippocampal atrophy and intrinsic brain network dysfunction relate to alterations in mind wandering in neurodegeneration. *Proceedings of the National Academy of Sciences*, *116*(8), 3316-3321.

Oakes, P., Loukas, M., Oskouian, R. J., & Tubbs, R. S. (2017). The neuroanatomy of depression: A review. *Clinical Anatomy*, *30*(1), 44-49. https://doi.org/10.1002/ca.22781

Okuda, J., Fujii, T., Ohtake, H., Tsukiura, T., Tanji, K., Suzuki, K., Kawashima, R., Fukuda, H., Itoh, M., & Yamadori, A. (2003). Thinking of the future and past: The roles of the frontal pole and the medial temporal lobes. *Neuroimage*, *19*(4), 1369-1380. https://doi.org/10.1016/S1053-8119(03)00179-4

Ottaviani, C., & Couyoumdjian, A. (2013). Pros and cons of a wandering mind: a prospective study. *Front Psychol*, *4*, 524. https://doi.org/10.3389/fpsyg.2013.00524

Ottaviani, C., Shahabi, L., Tarvainen, M., Cook, I., Abrams, M., & Shapiro, D. (2014). Cognitive, behavioral, and autonomic correlates of mind wandering and perseverative cognition in major depression. *Front Neurosci*, *8*, 433. https://doi.org/10.3389/fnins.2014.00433

Ottaviani, C., Shapiro, D., & Couyoumdjian, A. (2013). Flexibility as the key for somatic health: From mind wandering to perseverative cognition. *Biological Psychology*, *94*(1), 38-43. https://doi.org/10.1016/j.biopsycho.2013.05.003

Peirce, J., Gray, J. R., Simpson, S., MacAskill, M., Höchenberger, R., Sogo, H., Kastman, E., & Lindeløv, J. K. (2019). PsychoPy2: Experiments in behavior made easy. *Behavior research methods*, *51*(1), 195-203.

Pelagatti, C., Binda, P., & Vannucci, M. (2018). Tracking the Dynamics of Mind Wandering: Insights from Pupillometry. *J Cogn*, *1*(1), 38. https://doi.org/10.5334/joc.41

Plimpton, B., Patel, P., & Kvavilashvili, L. (2015). Role of triggers and dysphoria in mind-wandering about past, present and future: A laboratory study. *Consciousness and Cognition*, *33*, 261-276. https://doi.org/10.1016/j.concog.2015.01.014

Poerio, G. L., & Smallwood, J. (2016). Daydreaming to navigate the social world: What we know, what we don't know, and why it matters. *Social and Personality Psychology Compass*, *10*(11), 605-618. https://doi.org/10.1111/spc3.12288

Poerio, G. L., Sormaz, M., Wang, H.-T., Margulies, D., Jefferies, E., & Smallwood, J. (2017). The role of the default mode network in component processes underlying the wandering mind. *Social cognitive and affective neuroscience*, *12*(7), 1047-1062.

Poerio, G. L., Totterdell, P., & Miles, E. (2013). Mind-wandering and negative mood: Does one thing really lead to another? *Consciousness and Cognition*, *22*(4), 1412-1421.

Power, J. D., Mitra, A., Laumann, T. O., Snyder, A. Z., Schlaggar, B. L., & Petersen, S. E. (2014). Methods to detect, characterize, and remove motion artifact in resting state fMRI. *Neuroimage*, *84*, 320-341.

Qin, P. M., & Northoff, G. (2011). How is our self related to midline regions and the default-mode network? *Neuroimage*, *57*(3), 1221-1233. https://doi.org/10.1016/j.neuroimage.2011.05.028

Radloff, L. S. (1977). The CES-D scale: A self-report depression scale for research in the general population. *Applied psychological measurement*, *1*(3), 385-401.

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences*, *98*(2), 676-682.

Ralph, M. A. L., Jefferies, E., Patterson, K., & Rogers, T. T. (2017). The neural and computational bases of semantic cognition. *Nature Reviews Neuroscience*, *18*(1), 42-55. https://doi.org/10.1038/nrn.2016.150

Rathbone, C. J., Conway, M. A., & Moulin, C. J. A. (2011). Remembering and imagining: The role of the self. *Consciousness and Cognition*, *20*(4), 1175-1182. https://doi.org/10.1016/j.concog.2011.02.013

Rice, G. E., Hoffman, P., Binney, R. J., & Lambon Ralph, M. A. (2018). Concrete versus abstract forms of social concept: an fMRI comparison of knowledge about people versus social terms. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1752), 20170136.

Ritchey, M., & Cooper, R. A. (2020). Deconstructing the Posterior Medial Episodic Network. *Trends in cognitive sciences*, *24*(6), 451-465. https://doi.org/10.1016/j.tics.2020.03.006

Robertson, I. H., Ridgeway, V., Greenfield, E., & Parr, A. (1997). Motor recovery after stroke depends on intact sustained attention: a 2-year follow-up study. *Neuropsychology*, *11*(2), 290-295. https://doi.org/10.1037//0894-4105.11.2.290

Robison, M. K., Miller, A. L., & Unsworth, N. (2020). A multi-faceted approach to understanding individual differences in mind-wandering. *Cognition*, *198*. https://doi.org/ARTN 104078

10.1016/j.cognition.2019.104078

Ruby, F. J., Smallwood, J., Engen, H., & Singer, T. (2013). How self-generated thought shapes mood—the relation between mind-wandering and mood depends on the socio-temporal content of thoughts. *PloS one*, *8*(10).

Ruby, F. J., Smallwood, J., Sackur, J., & Singer, T. (2013). Is self-generated thought a means of social problem solving? *Frontiers in psychology*, *4*, 962.

Ruehlman, L. S. (1985). Depression and affective meaning for current concerns. *Cognitive Therapy and Research*, *9*(5), 553-560.

Rummel, J., & Boywitt, C. D. (2014). Controlling the stream of thought: working memory capacity predicts adjustment of mind-wandering to situational demands. *Psychon Bull Rev*, *21*(5), 1309-1315. https://doi.org/10.3758/s13423-013-0580-3

Sarason, I. G., & Stoops, R. (1978). Test anxiety and the passage of time. *Journal of consulting and clinical psychology*, *46*(1), 102.

Schacter, D. L., Addis, D. R., & Buckner, R. L. (2007). Remembering the past to imagine the future: the prospective brain. *Nature Reviews Neuroscience*, *8*(9), 657-661. https://doi.org/10.1038/nrn2213

Schimmenti, A., Somer, E., & Regis, M. (2019). Maladaptive daydreaming: Towards a nosological definition. Annales Médico-psychologiques, revue psychiatrique,

Schlagman, S., & Kvavnashvili, L. (2008). Involuntary autobiographical memories in and outside the laboratory: How different are they from voluntary autobiographical memories? *Memory & cognition*, *36*(5), 920-932. https://doi.org/10.3758/Mc.36.5.920

Schooler, J. W. (2002). Re-representing consciousness: dissociations between experience and meta-consciousness. *Trends in cognitive sciences*, *6*(8), 339-344. https://doi.org/Pii S1364-6613(02)01949-6

Doi 10.1016/S1364-6613(02)01949-6

Segerstrom, S. C., Evans, D. R., & Eisenlohr-Moul, T. A. (2011). Optimism and pessimism dimensions in the Life Orientation Test-Revised: Method and meaning. *Journal of Research in Personality*, *45*(1), 126-129. https://doi.org/10.1016/j.jrp.2010.11.007

Segerstrom, S. C., Roach, A. R., Evans, D. R., Schipper, L. J., & Darville, A. K. (2010). The Structure and Health Correlates of Trait Repetitive Thought in Older Adults. *Psychology and Aging*, *25*(3), 505-515. https://doi.org/10.1037/a0019456

Segerstrom, S. C., Stanton, A. L., Alden, L. E., & Shortridge, B. E. (2003). A multidimensional structure for repetitive thought: What's on your mind, and how, and how much? *Journal*

of personality and social psychology, 85(5), 909-921. https://doi.org/10.1037/0022-3514.85.5.909
Seli, P., Carriere, J. S., & Smilek, D. (2015). Not all mind wandering is created equal: Dissociating deliberate from spontaneous mind wandering. *Psychological Research*, *79*(5), 750-758.
Seli, P., Carriere, J. S., Wammes, J. D., Risko, E. F., Schacter, D. L., & Smilek, D. (2018). On the clock: Evidence for the rapid and strategic modulation of mind wandering. *Psychological science*, *29*(8), 1247-1256.
Seli, P., Cheyne, J. A., Xu, M., Purdon, C., & Smilek, D. (2015). Motivation, intentionality, and mind wandering: Implications for assessments of task-unrelated thought. *J Exp Psychol Learn Mem Cogn*, *41*(5), 1417-1425. https://doi.org/10.1037/xlm0000116
Seli, P., Kane, M. J., Smallwood, J., Schacter, D. L., Maillet, D., Schooler, J. W., & Smilek, D. (2018). Mind-wandering as a natural kind: A family-resemblances view. *Trends in cognitive sciences*, *22*(6), 479-490.
Seli, P., Maillet, D., Smilek, D., Oakman, J. M., & Schacter, D. L. (2017). Cognitive Aging and the Distinction Between Intentional and Unintentional Mind Wandering. *Psychology and Aging*, *32*(4), 315-324. https://doi.org/10.1037/pag0000172
Shao, X. M., Mckeown, B., Karapanagiotidis, T., de Wael, R. V., Margulies, D. S., Bernhardt, B., Smallwood, J., Krieger-Redwood, K., & Jefferies, E. (2022). Individual differences in gradients of intrinsic connectivity within the semantic network relate to distinct aspects of semantic cognition. *Cortex*, *150*, 48-60. https://doi.org/10.1016/j.cortex.2022.01.019
Shrimpton, D., McGann, D., & Riby, L. M. (2017). Daydream Believer: Rumination, Self-Reflection and the Temporal Focus of Mind Wandering Content. *Europes Journal of Psychology*, *13*(4), 794-809. https://doi.org/10.5964/ejop.v13i4.1425
Smallwood, J. (2010). Why the global availability of mind wandering necessitates resource competition: reply to McVay and Kane (2010).
Smallwood, J. (2013). Distinguishing How From Why the Mind Wanders: A Process-Occurrence Framework for Self-Generated Mental Activity. *Psychological bulletin*, *139*(3), 519-535. https://doi.org/10.1037/a0030010
Smallwood, J. (2013). Distinguishing how from why the mind wanders: a process–occurrence framework for self-generated mental activity. *Psychological bulletin*, *139*(3), 519.
Smallwood, J., & Andrews-Hanna, J. (2013). Not all minds that wander are lost: the importance of a balanced perspective on the mind-wandering state. *Frontiers in psychology*, *4*, 441.
Smallwood, J., Beach, E., Schooler, J. W., & Handy, T. C. (2008). Going AWOL in the brain: Mind wandering reduces cortical analysis of external events. *Journal of cognitive neuroscience*, *20*(3), 458-469.
Smallwood, J., Bernhardt, B. C., Leech, R., Bzdok, D., Jefferies, E., & Margulies, D. S. (2021). The default mode network in cognition: a topographical perspective. *Nature Reviews Neuroscience*, *22*(8), 503-513. https://doi.org/10.1038/s41583-021-00474-4
Smallwood, J., Brown, K., Baird, B., & Schooler, J. W. (2012). Cooperation between the default mode network and the frontal-parietal network in the production of an internal train of thought. *Brain Research*, *1428*, 60-70. https://doi.org/10.1016/j.brainres.2011.03.072
Smallwood, J., Brown, K. S., Baird, B., Mrazek, M. D., Franklin, M. S., & Schooler, J. W. (2012). Insulation for Daydreams: A Role for Tonic Norepinephrine in the Facilitation of Internally Guided Thought. *PloS one*, *7*(4). https://doi.org/ARTN e33706

10.1371/journal.pone.0033706
Smallwood, J., Brown, K. S., Tipper, C., Giesbrecht, B., Franklin, M. S., Mrazek, M. D., Carlson, J. M., & Schooler, J. W. (2011). Pupillometric Evidence for the Decoupling of Attention from Perceptual Input during Offline Thought. *PloS one*, *6*(3). https://doi.org/ARTN e18298

10.1371/journal.pone.0018298
Smallwood, J., Davies, J. B., Heim, D., Finnigan, F., Sudberry, M., O'Connor, R., & Obonsawin, M. (2004). Subjective experience and the attentional lapse: Task engagement and

disengagement during sustained attention. *Consciousness and Cognition*, *13*(4), 657-690.
Smallwood, J., Gorgolewski, K. J., Golchert, J., Ruby, F. J. M., Engen, H., Baird, B., Vinski, M. T., Schooler, J. W., & Margulies, D. S. (2013). The default modes of reading: modulation of posterior cingulate and medial prefrontal cortex connectivity associated with comprehension and task focus while reading. *Frontiers in human neuroscience*, *7*. https://doi.org/ARTN 734

10.3389/fnhum.2013.00734
Smallwood, J., Karapanagiotidis, T., Ruby, F., Medea, B., De Caso, I., Konishi, M., Wang, H.-T., Hallam, G., Margulies, D. S., & Jefferies, E. (2016). Representing representation: Integration between the temporal lobe and the posterior cingulate influences the content and form of spontaneous thought. *PloS one*, *11*(4).
Smallwood, J., McSpadden, M., & Schooler, J. W. (2008). When attention matters: The curious incident of the wandering mind. *Memory & cognition*, *36*(6), 1144-1150. https://doi.org/10.3758/Mc.36.6.1144
Smallwood, J., Nind, L., & O'Connor, R. C. (2009). When is your head at? An exploration of the factors associated with the temporal focus of the wandering mind. *Consciousness and Cognition*, *18*(1), 118-125.
Smallwood, J., & O'Connor, R. C. (2011). Imprisoned by the past: unhappy moods lead to a retrospective bias to mind wandering. *Cognition & emotion*, *25*(8), 1481-1490.
Smallwood, J., O'Connor, R. C., & Heim, D. (2005). Rumination, dysphoria, and subjective experience. *Imagination, cognition and personality*, *24*(4), 355-367.
Smallwood, J., O'Connor, R. C., Sudbery, M. V., & Obonsawin, M. (2007). Mind-wandering and dysphoria. *Cognition and Emotion*, *21*(4), 816-842.
Smallwood, J., O'Connor, R. C., Sudberry, M. V., Haskell, C., & Ballantyne, C. (2004). The consequences of encoding information on the maintenance of internally generated images and thoughts: The role of meaning complexes. *Consciousness and Cognition*, *13*(4), 789-820.
Smallwood, J., Obsonsawin, M., Baracaia, S. F., Reid, H., O'Connor, R., & Heim, D. (2003). The relationship between rumination, dysphoria, and self-referent thinking: Some preliminary findings. *Imagination, cognition and personality*, *22*(4), 317-342.
Smallwood, J., Ruby, F. J. M., & Singer, T. (2013). Letting go of the present: Mind-wandering is associated with reduced delay discounting. *Consciousness and Cognition*, *22*(1), 1-7. https://doi.org/10.1016/j.concog.2012.10.007
Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological bulletin*, *132*(6), 946-958. https://doi.org/10.1037/0033-2909.132.6.946
Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological bulletin*, *132*(6), 946.
Smallwood, J., & Schooler, J. W. (2015). The science of mind wandering: empirically navigating the stream of consciousness. *Annual review of psychology*, *66*, 487-518.
Smallwood, J., Schooler, J. W., Turk, D. J., Cunningham, S. J., Burns, P., & Macrae, C. N. (2011). Self-reflection and the temporal focus of the wandering mind. *Consciousness and Cognition*, *20*(4), 1120-1126. https://doi.org/10.1016/j.concog.2010.12.017
Smallwood, J., Turnbull, A., Wang, H.-t., Ho, N. S., Poerio, G. L., Karapanagiotidis, T., Konu, D., Mckeown, B., Zhang, M., & Murphy, C. (2021). The neural correlates of ongoing conscious thought. *iScience*, 102132.
Smeekens, B. A., & Kane, M. J. (2016). Working Memory Capacity, Mind Wandering, and Creative Cognition: An Individual-Differences Investigation Into the Benefits of Controlled Versus Spontaneous Thought. *Psychology of Aesthetics Creativity and the Arts*, *10*(4), 389-415. https://doi.org/10.1037/aca0000046
Smeekens, B. A., & Kane, M. J. (2016). Working Memory Capacity, Mind Wandering, and Creative Cognition: An Individual-Differences Investigation into the Benefits of Controlled Versus Spontaneous Thought. *Psychol Aesthet Creat Arts*, *10*(4), 389-415. https://doi.org/10.1037/aca0000046

Smilek, D., Eastwood, J. D., Reynolds, M. G., & Kingstone, A. (2007). Metacognitive errors in change detection: Missing the gap between lab and life. *Consciousness and Cognition*, *16*(1), 52-57.

Smith, G. K., Mills, C., Paxton, A., & Christoff, K. (2018). Mind-wandering rates fluctuate across the day: evidence from an experience-sampling study. *Cognitive Research-Principles and Implications*, *3*. https://doi.org/ARTN 54

10.1186/s41235-018-0141-4

Soffer-Dudek, N. (2019). Dissociative absorption, mind-wandering, and attention-deficit symptoms: Associations with obsessive-compulsive symptoms. *British Journal of Clinical Psychology*, *58*(1), 51-69.

Song, X. L., & Wang, X. (2012). Mind Wandering in Chinese Daily Lives - An Experience Sampling Study. *PloS one*, *7*(9). https://doi.org/ARTN e44423

10.1371/journal.pone.0044423

Sonkusare, S., Breakspear, M., & Guo, C. (2019). Naturalistic stimuli in neuroscience: critically acclaimed. *Trends in cognitive sciences*, *23*(8), 699-714.

Sormaz, M., Jefferies, E., Bernhardt, B. C., Karapanagiotidis, T., Mollo, G., Bernasconi, N., Bernasconi, A., Hartley, T., & Smallwood, J. (2017). Knowing what from where: Hippocampal connectivity with temporoparietal cortex at rest is linked to individual differences in semantic and topographic memory. *Neuroimage*, *152*, 400-410. https://doi.org/10.1016/j.neuroimage.2017.02.071

Sormaz, M., Murphy, C., Wang, H.-t., Hymers, M., Karapanagiotidis, T., Poerio, G., Margulies, D. S., Jefferies, E., & Smallwood, J. (2018). Default mode network can support the level of detail in experience during active task states. *Proceedings of the National Academy of Sciences*, *115*(37), 9318-9323.

Spalding, K. N., Schlichting, M. L., Zeithamova, D., Preston, A. R., Tranel, D., Duff, M. C., & Warren, D. E. (2018). Ventromedial prefrontal cortex is necessary for normal associative inference and memory integration. *Journal of Neuroscience*, *38*(15), 3767-3775.

Spielberger, C. D. (1983). State-trait anxiety inventory for adults.

Spreng, R. N., DuPre, E., Selarka, D., Garcia, J., Gojkovic, S., Mildner, J., Luh, W. M., & Turner, G. R. (2014). Goal-Congruent Default Network Activity Facilitates Cognitive Control. *Journal of Neuroscience*, *34*(42), 14108-14114. https://doi.org/10.1523/Jneurosci.2815-14.2014

Spreng, R. N., & Grady, C. L. (2010). Patterns of Brain Activity Supporting Autobiographical Memory, Prospection, and Theory of Mind, and Their Relationship to the Default Mode Network. *Journal of cognitive neuroscience*, *22*(6), 1112-1123. https://doi.org/DOI 10.1162/jocn.2009.21282

Spreng, R. N., Mar, R. A., & Kim, A. S. N. (2009). The Common Neural Basis of Autobiographical Memory, Prospection, Navigation, Theory of Mind, and the Default Mode: A Quantitative Meta-analysis. *Journal of cognitive neuroscience*, *21*(3), 489-510. https://doi.org/DOI 10.1162/jocn.2008.21029

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

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

10.3389/fpsyg.2013.00425

Stawarczyk, D., Majerus, S., Catale, C., & D'Argembeau, A. (2014). Relationships between mind-wandering and attentional control abilities in young adults and adolescents. *Acta Psychologica*, *148*, 25-36. https://doi.org/10.1016/j.actpsy.2014.01.007

Stawarczyk, D., Majerus, S., & D'Argembeau, A. (2013). Concern-induced negative affect is associated with the occurrence and content of mind-wandering. *Consciousness and Cognition*, *22*(2), 442-448. https://doi.org/10.1016/j.concog.2013.01.012

Stawarczyk, D., Majerus, S., Maquet, P., & D'Argembeau, A. (2011). Neural Correlates of Ongoing Conscious Experience: Both Task-Unrelatedness and Stimulus-Independence Are Related to Default Network Activity. *PloS one*, *6*(2). https://doi.org/ARTN e16997

10.1371/journal.pone.0016997

Takano, K., & Tanno, Y. (2009). Self-rumination, self-reflection, and depression: self-rumination counteracts the adaptive effect of self-reflection. *Behav Res Ther*, *47*(3), 260-264. https://doi.org/10.1016/j.brat.2008.12.008

Team, R. C. (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. *http://www. R-project. org/*.

Teasdale, J. D., Dritschel, B. H., Taylor, M. J., Proctor, L., Lloyd, C. A., Nimmo-Smith, I., & Baddeley, A. D. (1995). Stimulus-independent thought depends on central executive resources. *Memory & cognition*, *23*(5), 551-559.

Teasdale, J. D., Proctor, L., Lloyd, C. A., & Baddeley, A. D. (1993). Working memory and stimulus-independent thought: Effects of memory load and presentation rate. *European Journal of Cognitive Psychology*, *5*(4), 417-433.

Turnbull, A., Karapanagiotidis, T., Wang, H. T., Bernhardt, B. C., Leech, R., Margulies, D., Schooler, J., Jefferies, E., & Smallwood, J. (2020). Reductions in task positive neural systems occur with the passage of time and are associated with changes in ongoing thought. *Scientific Reports*, *10*(1). https://doi.org/ARTN 9912

10.1038/s41598-020-66698-z

Turnbull, A., Karapanagiotidis, T., Wang, H. T., Bernhardt, B. C., Leech, R., Margulies, D., Schooler, J., Jefferies, E., & Smallwood, J. (2020). Reductions in task positive neural systems occur with the passage of time and are associated with changes in ongoing thought (vol 10, 9912, 2020). *Scientific Reports*, *10*(1). https://doi.org/ARTN 12941

10.1038/s41598-020-69654-z

Turnbull, A., Poerio, G. L., Ho, N. S. P., Martinon, L. M., Riby, L. M., Lin, F. V., Jefferies, E., & Smallwood, J. (2021). Age-related changes in ongoing thought relate to external context and individual cognition. *Consciousness and Cognition*, *96*. https://doi.org/ARTN 103226

10.1016/j.concog.2021.103226

Turnbull, A., Wang, H. T., Murphy, C., Ho, N. S. P., Wang, X., Sormaz, M., Karapanagiotidis, T., Leech, R. M., Bernhardt, B., Margulies, D. S., Vatansever, D., Jefferies, E., & Smallwood, J. (2019). Left dorsolateral prefrontal cortex supports context-dependent prioritisation of off-task thought. *Nat Commun*, *10*(1), 3816. https://doi.org/10.1038/s41467-019-11764-y

Turnbull, A., Wang, H. T., Schooler, J. W., Jefferies, E., Margulies, D. S., & Smallwood, J. (2019). The ebb and flow of attention: Between-subject variation in intrinsic connectivity and cognition associated with the dynamics of ongoing experience. *Neuroimage*, *185*, 286-299. https://doi.org/10.1016/j.neuroimage.2018.09.069

Tusche, A., Smallwood, J., Bernhardt, B. C., & Singer, T. (2014). Classifying the wandering mind: revealing the affective content of thoughts during task-free rest periods. *Neuroimage*, *97*, 107-116. https://doi.org/10.1016/j.neuroimage.2014.03.076

Tusche, A., Smallwood, J., Bernhardt, B. C., & Singer, T. (2014). Classifying the wandering mind: Revealing the affective content of thoughts during task-free rest periods. *Neuroimage*, *97*, 107-116. https://doi.org/10.1016/j.neuroimage.2014.03.076

Unsworth, N., & McMillan, B. D. (2013). Mind wandering and reading comprehension: examining the roles of working memory capacity, interest, motivation, and topic experience. *J Exp Psychol Learn Mem Cogn*, *39*(3), 832-842. https://doi.org/10.1037/a0029669

Vanderwal, Eilbott, J., & Castellanos, F. X. (2019). Movies in the magnet: Naturalistic paradigms in developmental functional neuroimaging. *Dev Cogn Neurosci*, *36*, 100600. https://doi.org/10.1016/j.dcn.2018.10.004

Vanderwal, Eilbott, J., Finn, E. S., Craddock, R. C., Turnbull, A., & Castellanos, F. X. (2017). Individual differences in functional connectivity during naturalistic viewing conditions. *Neuroimage*, *157*, 521-530. https://doi.org/10.1016/j.neuroimage.2017.06.027

Vanderwal, Hunyadi, E., Grupe, D. W., Connors, C. M., & Schultz, R. T. (2008). Self, mother and abstract other: an fMRI study of reflective social processing. *Neuroimage*, *41*(4), 1437-1446.

Vanderwal, Kelly, C., Eilbott, J., Mayes, L. C., & Castellanos, F. X. (2015). Inscapes: A movie paradigm to improve compliance in functional magnetic resonance imaging. *Neuroimage*, *122*, 222-232. https://doi.org/10.1016/j.neuroimage.2015.07.069

Vannikov-Lugassi, M., & Soffer-Dudek, N. (2018). No time like the present: Thinking about the past and the future is related to state dissociation among individuals with high levels of psychopathological symptoms. *Frontiers in psychology*, *9*, 2465.

Vannucci, M., Pelagatti, C., Chiorri, C., & Brugger, P. (2019). Space-time interaction: visuo-spatial processing affects the temporal focus of mind wandering. *Psychological Research-Psychologische Forschung*, *83*(4), 698-709. https://doi.org/10.1007/s00426-018-1080-x

Vannucci, M., Pelagatti, C., & Marchetti, I. (2017). Manipulating cues in mind wandering: Verbal cues affect the frequency and the temporal focus of mind wandering. *Consciousness and Cognition*, *53*, 61-69. https://doi.org/10.1016/j.concog.2017.06.004

Vatansever, D., Bozhilova, N. S., Asherson, P., & Smallwood, J. (2019). The devil is in the detail: exploring the intrinsic neural mechanisms that link attention-deficit/hyperactivity disorder symptomatology to ongoing cognition. *Psychol Med*, *49*(7), 1185-1194. https://doi.org/10.1017/S0033291718003598

Vatansever, D., Bozhilova, N. S., Asherson, P., & Smallwood, J. (2019). The devil is in the detail: exploring the intrinsic neural mechanisms that link attention-deficit/hyperactivity disorder symptomatology to ongoing cognition. *Psychological Medicine*, *49*(7), 1185-1194. https://doi.org/10.1017/S0033291718003598

Verhaeghen, P., Joormann, J., & Aikman, S. N. (2014). Creativity, Mood, and the Examined Life: Self-Reflective Rumination Boosts Creativity, Brooding Breeds Dysphoria. *Psychology of Aesthetics Creativity and the Arts*, *8*(2), 211-218. https://doi.org/10.1037/a0035594

Vincent, J. L., Kahn, I., Snyder, A. Z., Raichle, M. E., & Buckner, R. L. (2008). Evidence for a Frontoparietal Control System Revealed by Intrinsic Functional Connectivity. *Journal of Neurophysiology*, *100*(6), 3328-3342. https://doi.org/10.1152/jn.90355.2008

Wang, H.-T., Ho, N. S. P., Bzdok, D., Bernhardt, B. C., Margulies, D. S., Jefferies, E., & Smallwood, J. (2019). Neurocognitive patterns dissociating semantic processing from executive control are linked to more detailed off-task mental time travel. *bioRxiv*, 765073.

Wang, H.-T., Poerio, G., Murphy, C., Bzdok, D., Jefferies, E., & Smallwood, J. (2018). Dimensions of experience: exploring the heterogeneity of the wandering mind. *Psychological science*, *29*(1), 56-71.

Wang, H. T., Ho, N. S. P., Bzdok, D., Bernhardt, B. C., Margulies, D. S., Jefferies, E., & Smallwood, J. (2020). Neurocognitive patterns dissociating semantic processing from executive control are linked to more detailed off-task mental time travel. *Sci Rep*, *10*(1), 11904. https://doi.org/10.1038/s41598-020-67605-2

Watkins, E., & Teasdale, J. D. (2001). Rumination and overgeneral memory in depression: effects of self-focus and analytic thinking. *Journal of Abnormal Psychology*, *110*(2), 353.

Watkins, E. R. (2008). Constructive and unconstructive repetitive thought. *Psychological bulletin*, *134*(2), 163-206. https://doi.org/10.1037/0033-2909.134.2.163

Watts, F. N., Macleod, A. K., & Morris, L. (1988). Associations between Phenomenal and Objective Aspects of Concentration Problems in Depressed-Patients. *British Journal of Psychology*, *79*, 241-250. https://doi.org/DOI 10.1111/j.2044-8295.1988.tb02285.x

Wei, T., Simko, V., Levy, M., Xie, Y., Jin, Y., & Zemla, J. (2017). Package 'corrplot'. *Statistician*, *56*(316), e24.

Weilbacher, R. A., & Gluth, S. (2017). The Interplay of Hippocampus and Ventromedial Prefrontal Cortex in Memory-Based Decision Making. *Brain Sciences*, *7*(1). https://doi.org/ARTN 4

10.3390/brainsci7010004

Weinstein, Y. (2018). Mind-wandering, how do I measure thee with probes? Let me count the ways. *Behavior research methods*, *50*(2), 642-661.

Welhaf, M. S., Smeekens, B. A., Gazzia, N. C., Perkins, J. B., Silvia, P. J., Meier, M. E., Kwapil, T. R., & Kane, M. J. (2020). An Exploratory Analysis of Individual Differences in Mind Wandering Content and Consistency. *Psychology of Consciousness-Theory Research and Practice*, *7*(2), 103-125. https://doi.org/10.1037/cns0000180

Whitmer, A. J., & Banich, M. T. (2007). Inhibition versus switching deficits in different forms of rumination. *Psychological science*, *18*(6), 546-553. https://doi.org/DOI 10.1111/j.1467-9280.2007.01936.x

Wickham, H. (2016). Package 'ggplot2': elegant graphics for data analysis. *Springer-Verlag New York. doi*, *10*, 978-970.

Wickham, H., Francois, R., Henry, L., & Müller, K. (2017). dplyr: A grammar of data manipulation, 2015. *URL https://github. com/hadley/dplyr. version 0.1.[p 1]*.

Xu, M., Purdon, C., Seli, P., & Smilek, D. (2017). Mindfulness and mind wandering: The protective effects of brief meditation in anxious individuals. *Consciousness and Cognition*, *51*, 157-165. https://doi.org/10.1016/j.concog.2017.03.009

Yarkoni, T., Poldrack, R. A., Nichols, T. E., Van Essen, D. C., & Wager, T. D. (2011). Large-scale automated synthesis of human functional neuroimaging data. *Nature Methods*, *8*(8), 665-U695. https://doi.org/10.1038/Nmeth.1635

Yee, P. L., Hsieh-Yee, I., Pierce, G. R., Grome, R., & Schantz, L. (2004). Self-evaluative intrusive thoughts impede successful searching on the Internet. *Computers in Human Behavior*, *20*(1), 85-101. https://doi.org/10.1016/S0747-5632(03)00042-6

Yeo, B. T. T., Krienen, F. M., Sepulcre, J., Sabuncu, M. R., Lashkari, D., Hollinshead, M., Roffman, J. L., Smoller, J. W., Zoller, L., Polimeni, J. R., Fischl, B., Liu, H. S., & Buckner, R. L. (2011). The organization of the human cerebral cortex estimated by intrinsic functional connectivity. *Journal of Neurophysiology*, *106*(3), 1125-1165. https://doi.org/10.1152/jn.00338.2011

Yin, S. H., Li, Y. L., & Chen, A. T. (2022). Functional coupling between frontoparietal control subnetworks bridges the default and dorsal attention networks. *Brain Structure & Function*, *227*(7), 2243-2260. https://doi.org/10.1007/s00429-022-02517-7

Zhang, M. C., Bernhardt, B. C., Wang, X. Y., Varga, D., Krieger-Redwood, K., Royer, J., Rodriguez-Cruces, R., de Wael, R. V., Margulies, D. S., Smallwood, J., & Jefferies, E. (2022). Perceptual coupling and decoupling of the default mode network during mind-wandering and reading. *Elife*, *11*. https://doi.org/ARTN e74011

10.7554/eLife.74011