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Exploring patterns of ongoing thought under naturalistic and conventional task-based conditions

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Highlights

- Patterns of thought vary across different tasks
- Thought patterns are influenced by individual affective style
- There is a need to broaden the tasks used to study ongoing thought

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.

Keywords

Ongoing thought; mind-wandering; naturalistic paradigms; contextual variation; affective style

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., 2019a). 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, Nind, & O'Connor, 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, Pauly, Smallwood, & Engert, 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, Ridgeway, Greenfield, & Parr, 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., 2019a). 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, Hopper, & Schooler, 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, Breakspear, & Guo, 2019; Vanderwal, Eilbott, & Castellanos, 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, Banzhaf, Kanske, Bermpohl, & Singer, 2016; Makovac et al., 2018; Ottaviani et al., 2014; Poerio, Totterdell, & Miles, 2013; Smallwood, O'Connor, Sudbery, & Obonsawin, 2007; Xu, Purdon, Seli, & Smilek, 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, & Singer, 2013a; Ruby, Smallwood, Sackur, & Singer, 2013b; Smallwood et al., 2016; Sormaz et al., 2018; Turnbull, Wang, Murphy, et al., 2019a; Turnbull, Wang, Schooler, et al., 2019b). 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, Brown, Battaglini, & Smallwood, 2017; Turnbull, Wang, Murphy, et al., 2019a; Vatansever, Bozhilova, Asherson, & Smallwood, 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.

2. Methods

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 (e.g. Ruby, Smallwood, Engen, et al., 2013a; Ruby, Smallwood, Sackur, et al., 2013b; 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.

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 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.

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, Smith, Hopkins, Krietemeyer, & Toney, 2006), Intolerance of Uncertainty Scale (Carleton, Norton, & Asmundson, 2007) and Autism Spectrum Quotient (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 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 (please see Supplementary Items 1, 2 and 3 for the questionnaires used 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.

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, Kelly, Eilbott, Mayes, & Castellanos, 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.

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.

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.

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 et al., 2004).

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, Jefferies, & Smallwood, 2017), and is similar to self-reference paradigms used in the literature (Craik et al., 1999; Kelley et al., 2002; Vanderwal, Hunyadi, Grupe, Connors, & Schultz, 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.

2.6.3. Semantic Task Paradigm

This task was adapted from the task paradigm used by Rice and Colleagues (Rice, Hoffman, Binney, & Lambon Ralph, 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.

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.

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.

2.7.2. Emotional Recognition Task

In the emotional 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 emotional recognition task was designed to measure participant ability to identify each of the 6 basic emotions.

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.

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).

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 2.

Table 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

2.9. Data Analysis

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 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., 2013a; Ruby, Smallwood, Sackur, et al., 2013b; Smallwood et al., 2016; Turnbull, Wang, Schooler, et al., 2019b). 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 Supplementary Materials, Table 1 and 2). We also performed oblique oblimin rotation on the data (see Supplementary Materials Figure 1, 2 and Table 3, 4) to assess the similarity between the decompositions when they were subject to the different rotational schemes. It can be seen in the supplementary materials (see Supplementary Figure 3 and Supplementary Table 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, & Singer, 2013a; Ruby, Smallwood, Sackur, & Singer, 2013b; Smallwood et al., 2016; Sormaz et al., 2018; Turnbull, Wang, Murphy, et al., 2019a; Turnbull, Wang, Schooler, et al., 2019b).

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 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. Supplementary Figure 4, Table 6, 7 and 8 present these 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.

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.

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). 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 Supplementary Materials, Table 9 for details and descriptive statistics).

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).

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/Bronte-Mckeown/Ongoing-thought-under-naturalistic-and-task-based-conditions).

Table 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, & Lambon Ralph, 2018

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 1 and Supplementary Table 2) which in total accounted for 53.22% of the total variance. The loadings on these components are presented as word clouds in Figure 1 (also see Table 1 in the Supplementary Materials 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).

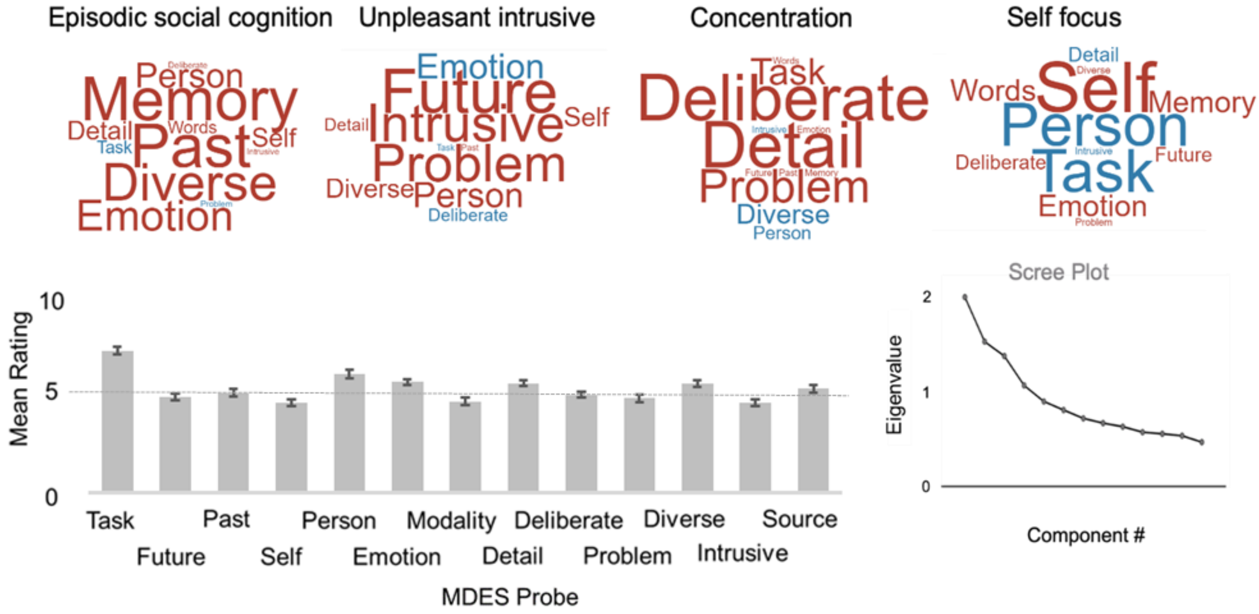


Figure 1. **Decomposition of the experience sampling data collected in this study revealed four components across all conditions.** Based on their loadings the four components were labelled as “Episodic Social Cognition”, “Unpleasant Intrusive”, “Concentration” and “Self Focus”. The word clouds in the 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.

Table 3 Intraclass correlations for each components 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 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 10 in the Supplementary Materials 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 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).

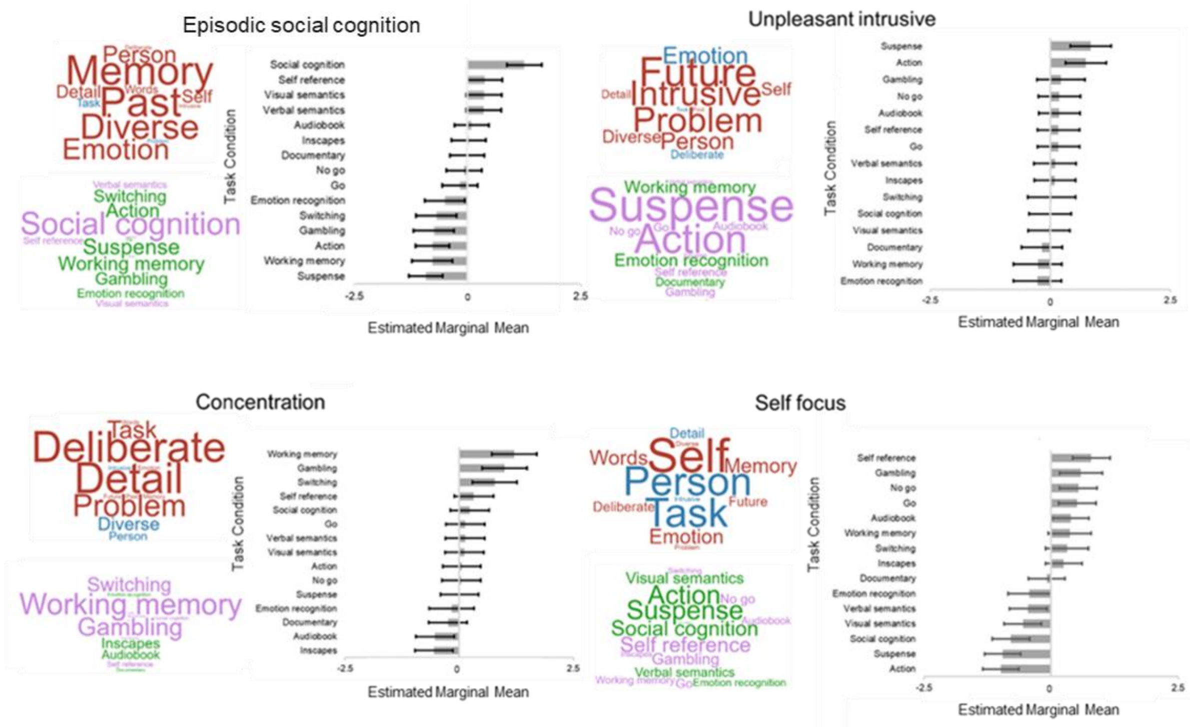


Figure 2. **Results of a linear mixed model (LMM) examining the variance across task environments in the four patterns of thought identified using PCA**. In each panel the top word cloud reiterates the loadings on each thought pattern (the colour of the word describes the direction of the relationship; 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), Emotional 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).

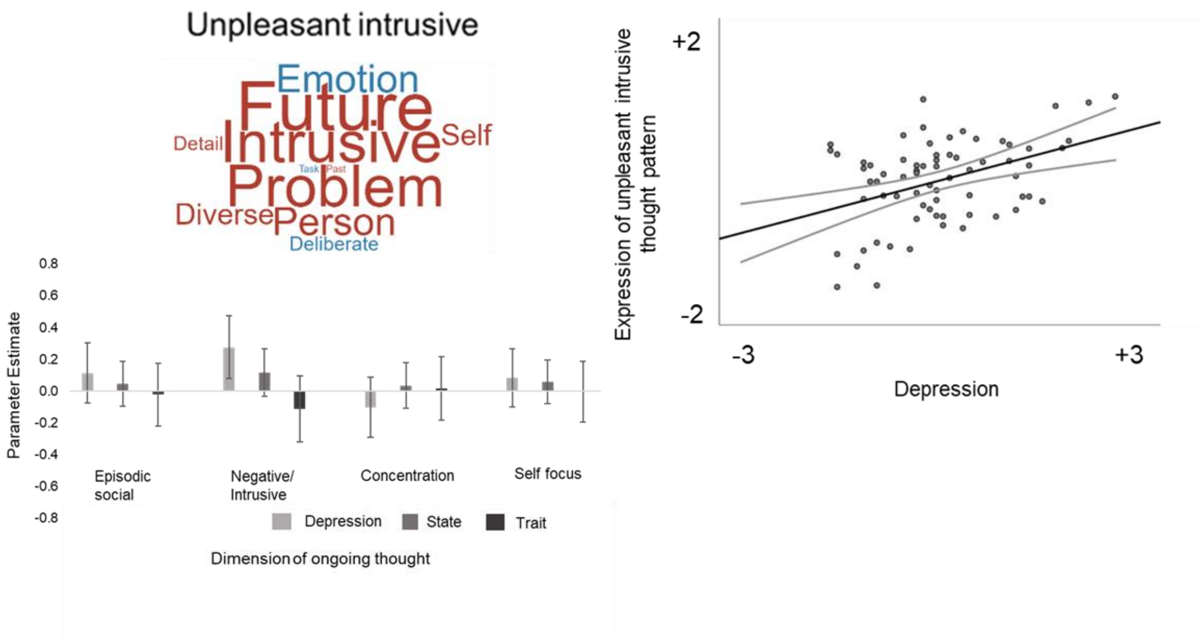


Figure 3. **The association between patterns of thought and measures of affective disturbance (symptom scores of depression, state and trait anxiety).** The bar graph summarises the beta weights from the model describing the average contribution of depression, state and trait anxiety as described by 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.

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 One) 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., 2019a). 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) 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 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; Paul Seli 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, Dikker, Huth, & Perrodin, 2019; Smilek, Eastwood, Reynolds, & Kingstone, 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 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 (P. Seli, Cheyne, Xu, Purdon, & Smilek, 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., 2019a; Turnbull, Wang, Schooler, et al., 2019b). 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, Proctor, Lloyd, & Baddeley, 1993). Notably, however, affectively toned TV programmes also involved a relative absence of episodic social thought (See Figure 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 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, Koster, Klinger, & Alloy, 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.

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.

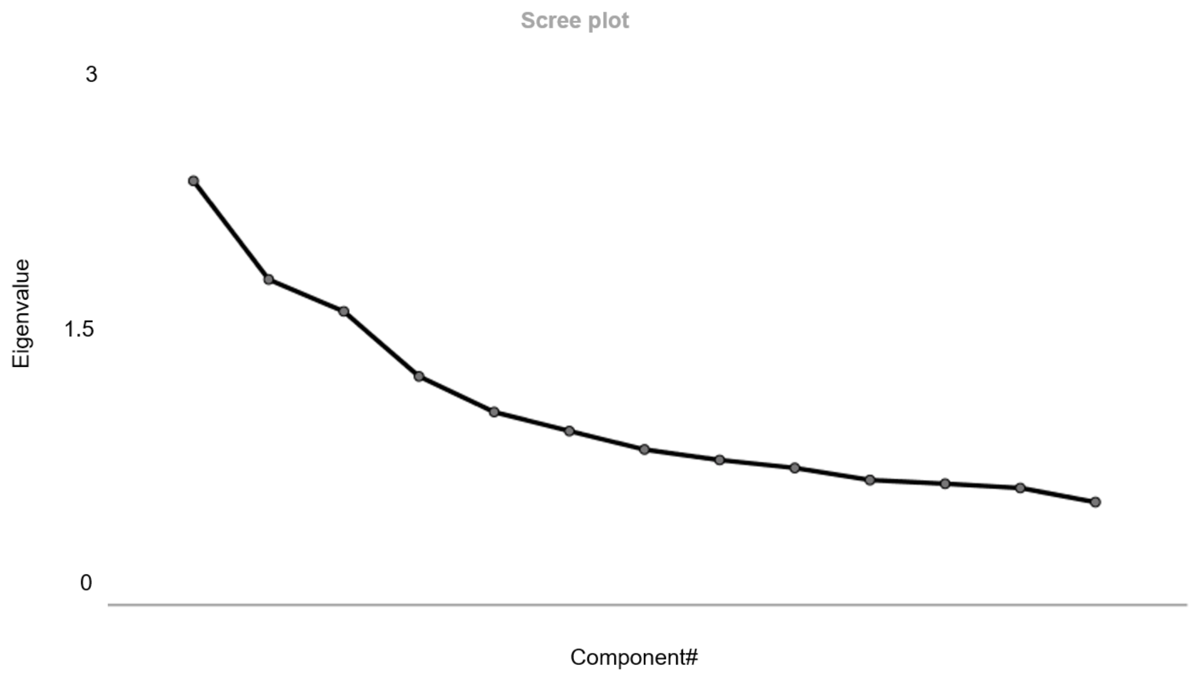
Fifth, although the use of TV-clips as a task environment enables us to test for patterns of thought in a more naturalistic setting, there is still room to develop more naturalistic task environments. In this regard, it is important to note that our selection of the questions to assess ongoing thoughts, 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, Somer, & Regis, 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, Schooler, & Seli, 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 et al., 2021).

CRediT Authorship Contribution Statement

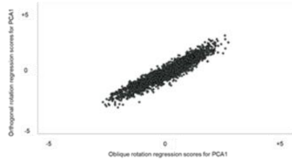
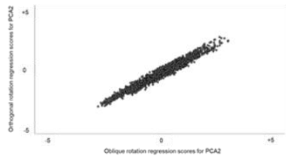
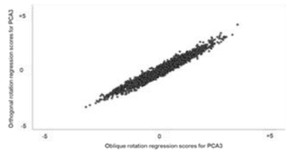
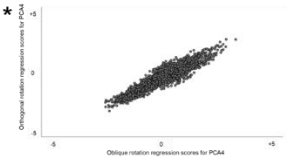
Delali Konu: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing - original draft, Writing - review & editing. Brontë Mckeown: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, 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.

Supplementary Materials

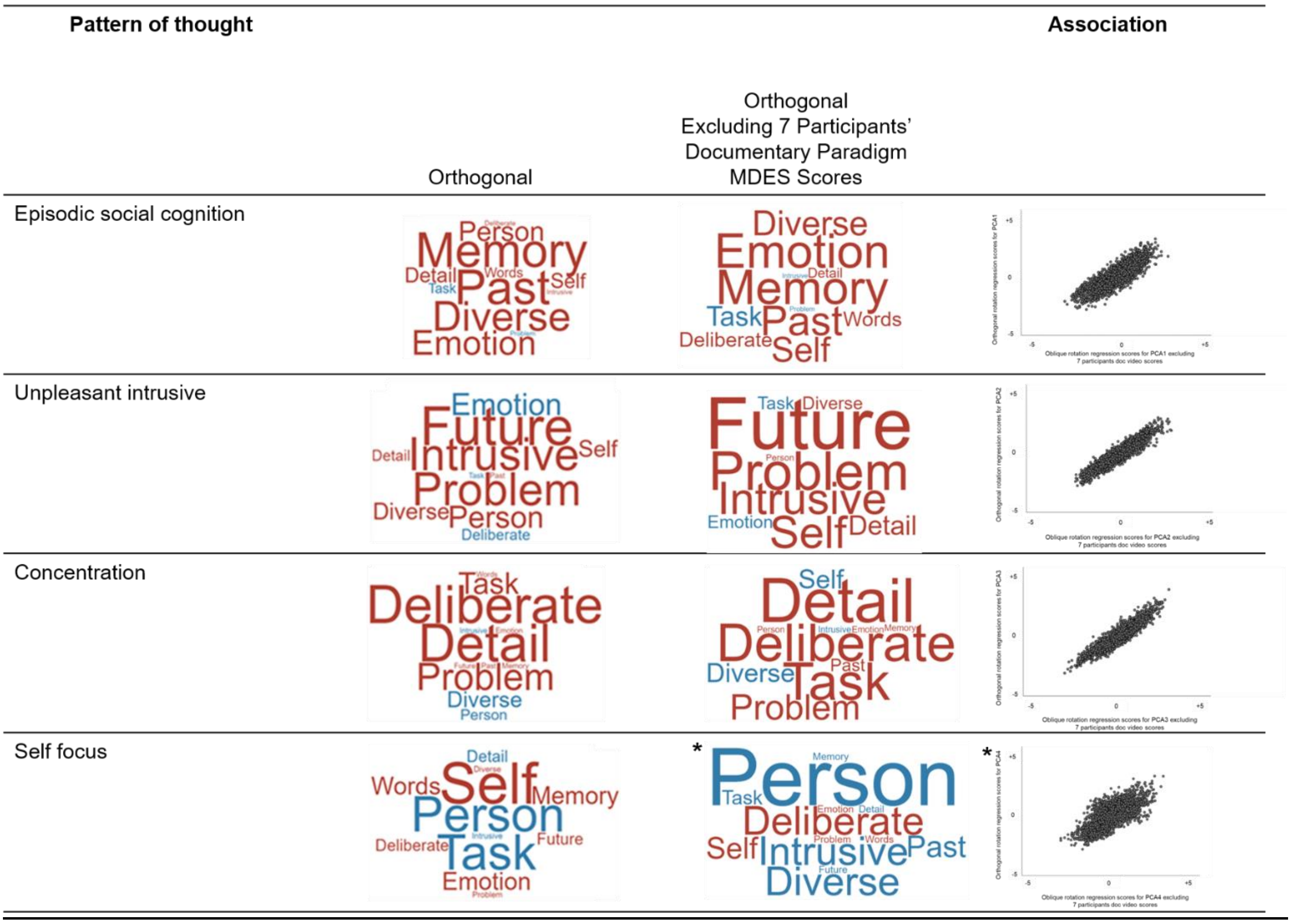
Supplementary Figure 1. Word clouds summarising the decomposition of the experience sampling data collected using oblique direct oblimin rotation which also revealed four components across all conditions. For presentation purposes the component loadings for PCA4 have been inverted to demonstrate its 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.



Supplementary Figure 2. Scree plot showing oblique oblimin decomposition on the experience sampling data.

Pattern of thought			Association
	Orthogonal	Oblique	
Episodic social cognition			
Unpleasant intrusive			
Concentration			
Self focus		* 	* 

Supplementary Figure 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 bare 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.



Supplementary Figure 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 bare 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.

Supplementary Table 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

Supplementary Table 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			

Supplementary Table 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

Supplementary Table 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				

Supplementary Table 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.

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

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

Supplementary Table 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

Supplementary Table 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						

Supplementary Table 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

Supplementary Table 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

Supplementary Table 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

Supplementary Item 1

State Anxiety Inventory (Spielberger, 1983) Questions

Not at all (1)

Somewhat (2)

Moderately so (3)

Very much so (4)

Reversed items: 1, 2, 5, 8, 10, 11, 15, 16, 19, 20

Q1 I feel calm.
Q2 I feel secure.
Q3 I am tense.
Q4 I feel strained.
Q5 I feel at ease.
Q6 I feel upset.
Q7 I am presently worrying over possible misfortunes.
Q8 I feel satisfied.
Q9 I feel frightened.
Q10 I feel comfortable.
Q11 I feel self-confident.
Q12 I feel nervous.
Q13 I feel jittery.
Q14 I feel indecisive
Q15 I am relaxed.
Q16 I feel content.
Q17 I am worried.
Q18 I feel confused.
Q19 I feel steady.
Q20 I feel pleasant.

Supplementary Item 2

Trait Anxiety Inventory (Spielberger, 1983) Questions

Not at all (1)

Somewhat (2)

Moderately so (3)

Very much so (4)

Reversed items: 21, 23, 26, 27, 30, 33, 34, 36, 39

Q21 I feel pleasant.
Q22 I feel nervous and restless.
Q23 I feel satisfied with myself.
Q24 I wish I could be as happy as others seem to be.
Q25 I feel like a failure.
Q26 I feel rested.
Q27 I am "cool, calm and collected"
Q28 I feel that difficulties are piling up so that I cannot overcome them.
Q29 I worry too much over something that really doesn't matter.
Q30 I am happy.
Q31 I have disturbing thoughts.
Q32 I lack self-confidence.
Q33 I feel secure.
Q34 I make decisions easily.
Q35 I feel inadequate.
Q36 I am content.
Q37 Some unimportant thought runs through my mind and bothers me.
Q38 I take disappointments so keenly that I can't put them out of my mind.
Q39 I am a steady person.
Q40 I get in a state of tension or turmoil as I think over my recent concerns and interests.

Supplementary Item 3

Centre for Epidemiological Studies Depression Scale (Radloff, 1977) Questions

Rarely or none of the time (less than 1 day) (0)

Some or a little or the time (1-2 days) (1)

Occasionally or a moderate amount of time (3-4 days) (2)

Most or all of the time (5-7 days) (3)

Reversed items: 4, 8, 12, 16

Q1 During the past week, I was bothered by things that usually don't bother me.
Q2 During the past week, I did not feel like eating; my appetite was poor.
Q3 During the past week, I felt that I could not shake off the blues even with help from my family or friends.
Q4 During the past week, I felt that I was just as good as other people.
Q5 During the past week, I had trouble keeping my mind on what I was doing.
Q6 During the past week, I felt depressed.
Q7 During the past week, I felt that everything I did was an effort.
Q8 During the past week, I felt hopeful about the future.
Q9 During the past week, I thought my life had been a failure.
Q10 During the past week, I felt fearful.
Q11 During the past week, my sleep was restless.
Q12 During the past week, I was happy.
Q13 During the past week, I talked less than usual.
Q14 During the past week, I felt lonely.
Q15 During the past week, people were unfriendly.
Q16 During the past week, I enjoyed life.
Q17 During the past week, I had crying spells.
Q18 During the past week, I felt sad.
Q19 During the past week, I felt that people dislike me.
Q20 During the past week, I could not get "going".

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