

UNIVERSITY OF CALGARY

Electrophysiological Correlates of Naturally Occurring Thought Patterns

by

YeEun Park

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES  
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE  
DEGREE OF MASTER OF SCIENCE

GRADUATE PROGRAM IN PSYCHOLOGY

CALGARY, ALBERTA

JANUARY, 2024

© YeEun Park 2024

## Abstract

Humans engage in a continuous flow of thoughts throughout the day. These thoughts change depending on the context in which they occur and correspond with unique patterns of connectivity within and between neural networks. Notably, less is known about the electrophysiological signatures of these thought patterns. To address this question, this study examined the interplay between thought patterns and electrophysiological activity in internally and externally oriented contexts. Forty-one participants were asked to attend internally to their own thoughts (thought focus condition) and externally to a set of videos (video focus condition), during which they were asked to report various dimensions of their ongoing thoughts. We implemented principal component analysis on the ratings of these multiple thought dimensions and identified three thought patterns (representing co-occurring thought dimensions): present external thought, goal-oriented future thoughts, and freely moving external positive thoughts. We found that these three thought patterns differentially associated with the experimental conditions and EEG measures. Present external thought was more closely associated with the video focus condition and showed increased frontal alpha and posterior alpha. Goal-oriented future thoughts increased during the thought versus video focus condition but was not significantly linked to any EEG measures. Freely moving external positive thoughts were more strongly associated with the video focus condition and showed decreased frontal alpha activity. Taken together, our results highlight the complex relationship between thought patterns and electrophysiological activity in different contexts.

## **Acknowledgements**

I wish to express my deepest gratitude to my supervisor, Dr. Julia Kam. Her incredible patience and unwavering support were what made it possible for me to complete my thesis. I have learned the most valuable lessons under her guidance, both as a scientist and as a person. I hold great respect and genuinely appreciate the time and effort she spent in working with me. I also want to say thank you to the members of Internal Attention Lab, for their help and friendship along the way, and times we struggled together to get better. Finally, I am forever grateful for the love and support from my dad and brother. Knowing they were there for every step of my journey, even from a distance, is the reason I persevere.

## **Dedication**

I dedicate my thesis to my mother, JS Song, my inspiration.

## Table of Contents

Abstract.....	II
Acknowledgements .....	III
Dedication.....	IV
Table of Contents .....	V
List of Tables .....	VII
List of Figures .....	VIII
Introduction.....	1
1.1 Patterns of Ongoing Thoughts .....	1
1.2 Multi-Dimensional Experience Sampling .....	2
1.3 Extrapolating Thought Patterns via Principal Component Analysis .....	3
1.4 Thought Patterns in Resting State and Naturalistic Setting .....	4
1.5 Functional Role of EEG Frequency Band Activity .....	6
1.6 The Current Study .....	8
Methods.....	10
2.1 Participants.....	10
2.2 Procedure and Experimental Paradigm.....	10
2.2.1 Thought focus condition.....	12

2.2.2 Video focus condition.....	12
2.2.3 Multi-Dimensional Experience Sampling (MDES) .....	12
2.3 EEG Data Acquisition and Preprocessing.....	14
2.4 Statistical Analysis .....	16
2.4.1 Principal Component Analysis (PCA) .....	16
2.4.2 Linear Mixed Effects Analyses (LME) .....	16
Results .....	18
3.1 Thought Patterns Identified from PCA .....	18
3.2 Linear Mixed Effects (LME) Model Analyses .....	20
3.2.1 Examining the Relationship between Thought Patterns and Conditions .....	20
3.2.2 Thought Patterns by EEG Measures .....	22
3.2.3 EEG Measures by Condition .....	25
Discussion .....	26
4.1 Limitations and Future Directions.....	30
4.2 Conclusion .....	32
References .....	33
Appendices.....	46

## List of Tables

Table 1. Statements Presented at Each Thought Probe via Multi-Dimensional Experience	
Sampling .....	13
Table 2. Fixed Effects of Condition on Thought Patterns (as indexed by PCs).....	21
Table 3. Fixed Effects for EEG Measures on PCs (Thought Patterns).....	23
Table 4. Fixed Effects for EEG Measures on Conditions.....	25
Appendix 2. Component Loadings for Each Thought Dimension.....	46

## List of Figures

Figure 1. An Example of a Block .....	11
Figure 2. Scree Plot from PCA.....	18
Figure 3. Word Clouds for Identified Thought Patterns and Violin Plots for Thought Patterns by Condition.....	19
Figure 4. Comparisons of Power Spectral Density Plots of EEG Measures for Each Condition..	26
Appendix 1. Mean Thought Probe Responses for Thought Dimensions.....	46

## Introduction

Our conscious experience is represented by a continuous flow of thoughts. These naturally occurring thoughts vary in their content and form, from generating creative ideas, making plans for the weekend to dwelling on personal conflicts. These heterogeneous patterns of thoughts differ as a function of the task or context in which they occur. While recent functional neuroimaging studies have begun to reveal unique brain network activity and connectivity patterns that are associated with different thought patterns, their electrophysiological signatures remain unknown. This study therefore examined the electrophysiological patterns that correspond to patterns of naturally occurring thoughts.

### 1.1 Patterns of Ongoing Thoughts

Our naturally occurring thoughts are inherently heterogeneous and can be characterized by numerous dimensions (Andrews-Hanna et al., 2013; Gorgolewski et al., 2014; Seli et al., 2017; Smallwood et al., 2016; Wang et al., 2018a). For example, they may vary along dimensions relating to content (e.g., temporal focus – past or future (Baird et al., 2011); emotional valence – positive or negative (Ruby et al., 2013); goal-orientedness (Klinger, 2013)). They can also vary in form (e.g., off-task versus on-task thought (Smallwood & Schooler, 2015); internally oriented thought versus externally oriented thought (Murphy et al., 2019a); freely moving versus constrained thoughts (Christoff et al., 2016); intentionality (Seli et al., 2017)). Importantly, these thought dimensions do not exist in isolation but rather frequently co-occur, giving rise to patterns of thoughts that represent combinations of single dimensions of thoughts (Mulholland et al., 2023; Smallwood et al., 2021). Recent studies have reported several commonly occurring thought patterns. One example thought pattern is “episodic social

cognition”, which usually consists of thoughts about “others”, “self”, “past”, and “future”, potentially reflecting autobiographical memory involving other people (Konu et al., 2020; Mckeown et al., 2020; Mulholland et al., 2023; Simola et al., 2023). Another prevalent thought pattern is “task focus”, characterized by dimensions such as “task”, “deliberate”, “detailed”, and “words” (Konu et al., 2020; Mckeown et al., 2020; Mulholland et al., 2023; Simola et al., 2023). This thought pattern purportedly reflects the mental state when participants are fully engaged in the present moment on their ongoing task involving the verbal modality.

## **1.2 Multi-Dimensional Experience Sampling**

The primary method used to quantify the diverse types of ongoing thoughts is the multi-dimensional experience sampling (MDES) approach (Medea et al., 2018; Murphy et al., 2019a; Vatansever et al., 2020; Wang et al., 2018a). MDES involves sampling the inner experiences of participants by asking them a set of questions that capture multiple dimensions of their thoughts via thought probes. At each thought probe, participants are asked to report the extent to which these thought dimensions characterize their ongoing thoughts. For instance, several thought dimensions that are commonly assessed using MDES include: “My thoughts involved future events”, “My thoughts involved myself”, “My thoughts were in the form of images” (Murphy et al., 2019b; Vatansever et al., 2020). By capturing different dimensions of thoughts, the MDES method goes beyond the traditional approach of asking one question typically concerning whether thoughts were related to the ongoing task (Smallwood & Schooler, 2015) and acknowledges that our thoughts can be concurrently characterized by patterns consisting of various intersecting dimensions.

MDES has been implemented both retrospectively and online (i.e., in-the-moment). The retrospective method asks participants to summarize their thoughts that occurred during the testing session retrospectively at the end of the session. Studies examining thought patterns during resting state using fMRI have more commonly used the retrospective method (Mckeown et al., 2020; Vatansever et al., 2020; Wang et al., 2018b). One benefit of this approach is that participants' ongoing thoughts can naturally unfold over time during the testing session without interruption; however, this relies on the accurate recall of all the thoughts that occurred and neglects the variability of thoughts that occurred throughout the session as participants typically report the average or peak experience across the session.

In contrast, the online sampling method asks participants to report on their thoughts in the moment using thought probes that are distributed throughout a testing session (Smallwood & Schooler, 2006, 2015). An advantage of the online method is that it captures thoughts as they unfold in real time. The content and form of our thoughts can change from one second to the next, and this online method adequately captures this transient, dynamic characteristic of our ongoing thoughts. Recent studies have increasingly implemented this online approach of MDES in both experimental setting while participants complete working memory tasks (Konu et al., 2020; Simola et al., 2023; Sormaz et al., 2018; Turnbull et al., 2019) and in naturalistic settings using a smartphone app throughout the day (Ho et al., 2020; Linz et al., 2021; Mulholland et al., 2023).

### **1.3 Extrapolating Thought Patterns via Principal Component Analysis**

The large number of responses gathered by each thought probe via MDES necessitates an approach to quantify the data that accounts for the co-occurrence of different thought

dimensions. One established analysis technique that has been useful for reducing these dimensions and detecting thought patterns is principal component analysis (PCA) (Mulholland et al., 2023; Murphy et al., 2019a; Ruby et al., 2013; Simola et al., 2023; Smallwood et al., 2016; Vatansever et al., 2020; Wang et al., 2018a, 2018b). PCA detects recurring patterns across responses to multiple questions, with each ‘principal component’ capturing a core pattern composed of a similar set of responses to those questions. In other words, each component reflects the simultaneous occurrence of a given set of thought dimensions based on responses to MDES questions. Given that the diverse nature of our thoughts can be concurrently characterized by multiple dimensions such as temporal focus, goal-orientedness, modality, and task relevance, an unintended consequence of the traditional approach that focuses on one dimension at a time is that the multifaceted nature of our thoughts is not examined thoroughly and other co-occurring dimensions are overlooked. For instance, past studies have simply categorized a thought as task-unrelated and linked it with negative mood (Ruby et al., 2013); this neglects the possibility that what is associated with the negative mood is not just task-unrelated thoughts per se but other thought dimensions they tend to co-occur with, such as negatively valenced (i.e., emotional valence) thoughts about “other people’s” (i.e., other-relevance) evaluations about oneself in the “past” (i.e., temporal focus). By extrapolating thought patterns and revealing tendencies for certain dimensions of thoughts to co-occur in everyday life, PCA provides a more comprehensive view of ongoing thoughts.

#### **1.4 Thought Patterns in Different Experimental Setting**

One of the most effective ways to empirically examine naturally occurring thoughts is to study thoughts that occur during resting state. The absence of cognitive or motor task demands

during the resting state allows for thoughts to naturally unfold over time without influence by external demands. During resting state conditions, participants are typically instructed to let their minds wander (or think about whatever they want), either with their eyes open or closed.

A recent set of studies have consistently revealed neural networks underlying certain patterns of thoughts during rest (McKeown et al., 2020; Vatansever et al., 2020; Wang et al., 2018b). In addition to the default mode network that is strongly linked to cognitive processes at rest, other brain networks have also been shown to be engaged during different patterns of thoughts. For example, thoughts that were tied to personal importance including dimensions of “near future”, “social past”, and “family”, were associated with reduced functional connectivity compared to other thought patterns within the ventral and dorsal attention networks, which are typically implicated in external attention (Wang et al., 2018b). Furthermore, a thought pattern labelled as current concerns (as characterized by dimensions of “realistic” and “important” thoughts about the “self” and “others”) in relation to other patterns of thought was linked to increased functional connectivity within the salience network, which allocates the necessary brain resources to salient stimuli (Vatansever et al., 2020). These results demonstrate that different patterns of thoughts map onto distinct patterns of connectivity within and between various brain networks.

In addition to examining thought patterns during rest, several studies have also identified differing thought patterns at two levels of difficulty of a working memory task and their corresponding functional correlates (Konu et al., 2021; Simola et al., 2023; Turnbull et al., 2019). Given that different thought patterns emerged based on the context in which they occur (Mulholland et al., 2023), it’s conceivable that a condition such as resting state in which attention is internally oriented would elicit thought patterns that differ from conditions in which attention

is externally oriented. Thus far, past research has only compared thought patterns between two levels of difficulty in a working memory task, which is externally oriented and highly constrained in terms of experimental demands. Therefore, it remains largely unknown whether thought patterns and their corresponding electrophysiological signatures differ during internally versus externally oriented contexts that are more ecologically valid. To bridge this gap, our study compared thought patterns that emerged during a resting state condition that intends to orient attention internally and a naturalistic viewing condition that aims to orient attention externally.

### **1.5 Functional Role of EEG Frequency Band Activity**

Although functional neuroimaging studies have offered important insights into neural networks that are recruited during different patterns of thoughts, they do not inform us on how neuronal activity facilitates thoughts as they unfold over time. Electroencephalogram (EEG) has the higher temporal resolution that enable us to address this question and better capture the transient and dynamic fluctuations in naturally occurring thoughts (Cohen, 2014; Liao et al., 2002). In particular, spectral activity in different frequency bands derived from EEG has been implicated in numerous high level cognitive processes (Ismail & Karwowski, 2020; Keller et al., 2023) and thus may play an important role in supporting various thought patterns.

Theta band (4-7Hz) activity is known to be associated with several forms of internal cognition. Specifically, several scalp and intracranial EEG (iEEG) studies found enhanced theta activity during internally oriented states such as autobiographical memory retrieval (Foster et al., 2013; Kam et al., 2022a; Pastötter & Bäuml, 2014; Solomon et al., 2019) and rest (Foster & Parvizi, 2012). Critically, theta oscillations have also been extensively linked to other high level internally oriented cognitive functions such as memory and cognitive control (Cavanagh &

Frank, 2014; Herweg et al., 2020; Klimesch, 1999; Klimesch et al., 1997; Sauseng et al., 2010), both of which reflect different dimensions of naturally occurring thoughts. For instance, studies have shown that a large proportion of our thoughts are spent on the past and future (Berntsen & Jacobsen, 2008; Smallwood et al., 2009; Tulving, 2002), which engage memory processes (Herweg et al., 2020; Solomon et al., 2019). Theta band activity has been implicated in numerous memory processes, including encoding new information in the hippocampal area (Kirov et al., 2009; Klimesch, 1999) as well as episodic retrieval (Doppelmayr et al., 1998; Hsieh & Ranganath, 2014) and working memory (Hsieh & Ranganath, 2014; Popov et al., 2018; Riddle et al., 2020; Schack et al., 2005). Similarly, other dimensions of thought such as goal-orientedness or intentionality would likely engage cognitive control processes. Frontal midline theta has been implicated in cognitive control (Cavanagh & Shackman, 2015; Mitchell et al., 2008). Collectively, these studies suggest that theta band is involved in various internally oriented processes and thus is likely to be engaged during various dimensions of internal thoughts.

Alpha band (8-14Hz) activity is also strongly linked to internal attention (Benedek et al., 2014; Kritzman et al., 2022). The most robust change in alpha activity is observed when participants close their eyes, during which posterior alpha increases. For this reason, traditional accounts of alpha suggest that alpha synchronization is an active suppression mechanism of external visual stimuli, especially when they are irrelevant to an ongoing task (Jensen et al., 2012; Kelly et al., 2006). In contrast, recent studies found that alpha power increased as internal cognitive demand increased and did not directly relate to the suppression of distractor stimuli (Antonov et al., 2020; Benedek et al., 2014). Moreover, alpha power decreased when attention was directed towards external environment compared to internal attention and was increased to the levels similar to resting state during internally oriented tasks (Magosso et al., 2019). These

results suggest that the major function of alpha activity may concern internally oriented cognition rather than the mere suppression of external stimuli. This recent account of alpha activity is also in line with our recent systematic review, which suggests that increased alpha activity especially over posterior scalp locations is most prominently observed during internally oriented task-unrelated thoughts compared to externally oriented states (Kam et al., 2022b). In addition, thoughts that freely move from one topic to another were linked to increased alpha power in frontal regions of the brain compared to non-freely moving thoughts (Kam et al., 2021). Frontal alpha is also highly related to creativity and divergent thoughts (Fink & Benedek, 2014; Lustenberger et al., 2015), which share similar characteristics with freely moving thoughts.

Lastly, gamma band (31-50Hz) activity is related to active attentional processes (Fitzgibbon et al., 2004; Müller et al., 2000). Gamma band activity is involved in selective and focused attention (Fell et al., 2003; Ishii et al., 2014), and increases as participants' attention becomes more engaged to a visuospatial task. In addition, posterior gamma band activity is related to the cognitive processing of perceived visual information during working memory and short-term memory tasks (Kaiser & Lutzenberger, 2005) and spontaneous visual imagery during meditation (Luft et al., 2019). These results suggest that gamma activity might be an indicator of both focused attention on visual external stimuli as well as internally oriented thoughts that involve visual imagery.

## **1.6 The Current Study**

The current study aims to examine the electrophysiological patterns that correspond to naturally occurring thought patterns in different contexts. To address this, we asked participants to report their ongoing thoughts throughout two conditions while their EEG is being recorded.

One condition resembles the resting state, in which participants were instructed to attend internally to their own thoughts (i.e., thought focus condition), while another condition resembles a naturalistic task, in which participants were instructed to attend externally to a series of short videos (i.e., video focus condition). Using multi-dimensional experience sampling, we asked participants to rate their thoughts on multiple dimensions in the moment at each thought probe presented at pseudo random intervals throughout the two conditions. We then examined whether these two conditions elicited different thought patterns, and whether these thought patterns have unique electrophysiological signatures.

Our first hypothesis was that unique thought patterns will emerge between the thought focus and video focus conditions. Based on prior studies that have revealed distinct thought patterns across conditions with varying levels of external task demands (Konu et al., 2021; Simola et al., 2023; Turnbull et al., 2019), we predict that our two conditions that were designed to elicit opposing directions of attention – internal and external – will give rise to different thought patterns. Second, we hypothesized that these thought patterns will be associated with unique EEG correlates. Although a recent study identified the P3 event-related potentials as a marker of certain thought patterns during a working memory task (Simola et al., 2023), they did not examine the spectral component of the EEG signal. Given the functional role of spectral activity in high level cognitive processes, we predicted that each thought pattern will be tied to unique spatially distributed EEG activity in different frequency bands. Grounded in past literature on various thought dimensions such as task-unrelated thought, goal-oriented functions and unconstrained cognitive processes, our analysis focused on frontocentral theta (Cavanagh & Shackman, 2015), frontal alpha (Kam et al., 2021), posterior alpha (Kam et al., 2022b), and posterior gamma (Luft et al., 2019).

## Methods

### 2.1 Participants

Forty-one participants ( $M = 24.6$ ,  $SD = 7.4$ , range = 17-50 years; 36 females and 5 males; 7 left-handed, 33 right-handed) were recruited through an online recruitment website as well as flyers posted at the University of Calgary. They consisted of students at the University of Calgary as well as individuals from the community. Participants had normal or corrected-to-normal vision and no history of neurological disorders. Written informed consent was obtained for all participants and the study was approved by the University of Calgary Conjoint Faculties Research Ethics Board.

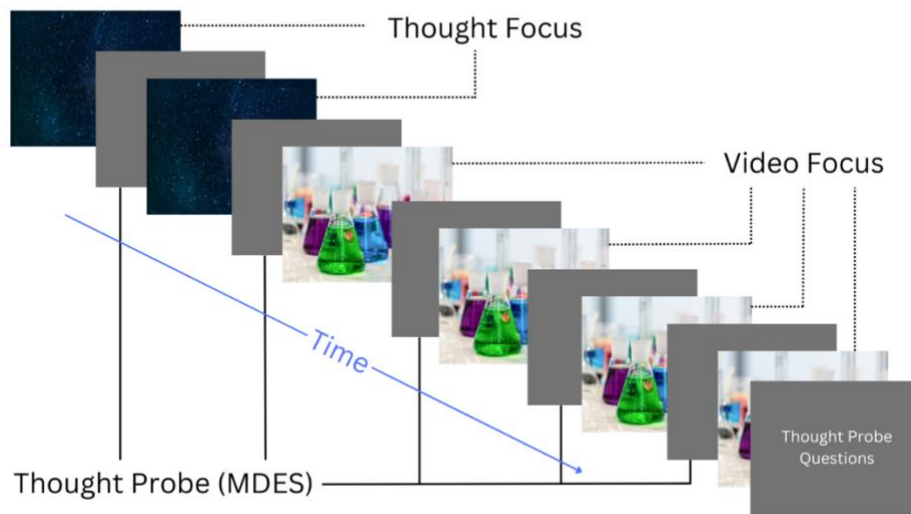
### 2.2 Procedure and Experimental Paradigm

Participants sat in an armchair in front of a computer screen in a quiet room with dimmed lights. They were asked to complete two conditions, thought focus and video focus, throughout the recording session that lasted approximately 1.5 hours. The task paradigm is illustrated in Figure 1. The experiment was separated into six blocks, with each block lasting on average 22.5 minutes (range: 15 to 30 minutes, depending on the number of trials per block). Every block started with the thought focus condition, followed by the video focus condition. Within each block, we presented an average of three trials (range: two to four trials) of each of the two conditions. Each trial lasted on average 90 seconds (range = 80 to 100 seconds). At the end of each trial, participants were explicitly instructed to report their ongoing thoughts immediately before the appearance of a thought probe, rather than the thoughts during the whole duration of the video, via multi-dimensional experience sampling (MDES; further detailed below). The

duration of each trial and the number of trials within each block were pseudo-randomized to prevent participants from anticipating when a thought probe would emerge and when the block ends. At the end of each block, participants were asked to rate on a 5-point Likert scale how often were they able to follow the instructions for each condition (described below), with the response ranging from 1 (never) to 5 (always). Trials in which their responses to this question were 1 (never) were excluded from subsequent analysis, as this suggests they did not follow the instructions and thus did not perform the condition as instructed.

### Figure 1

*An Example of a Block*



*Note.* This example block consisted of two trials in the thought focus condition and four trials in the video focus condition. An MDES thought probe appeared at the end of each trial, which lasted on average 90s.

**2.2.1 Thought focus condition** - This condition resembled the resting state, in which participants were instructed to look at the monitor but focus their attention internally and think about whatever comes to mind. To ensure the external stimuli are relatively consistent across conditions, they were presented with a slow-paced video with mini star-shaped objects gradually moving against a black background, which mimicked a night sky with slowly drifting stars. In other words, instead of asking participants to close their eyes or using a static fixation cross typically seen during resting state, we instead presented a “starry night” video so that both experimental conditions involved video stimuli. This ensures that any electrophysiological differences observed between conditions could not be solely attributed to the static versus moving nature of the stimuli between conditions.

**2.2.2 Video focus condition** – For this condition, participants were instructed to pay attention externally to a collection of short, fast-paced videos of scientific experiments presented on the monitor. This video focus condition was designed as a passive viewing task, which aimed to mimic a naturalistic task setting. The selection of scientific experiment videos was intended to engage participants’ external attention and was based on feedback from 25 pilot subjects who watched various other types of videos. In summary, the main purpose was to engage internally oriented and externally oriented attention in the thought focus and video focus conditions respectively.

**2.2.3 Multi-Dimensional Experience Sampling (MDES)** – Participants were asked to report their ongoing thoughts at the end of each trial via multi-dimensional experience sampling

(MDES) (Ho et al., 2020; Konu et al., 2021; Medea et al., 2018; Smallwood et al., 2016).

Thought probes containing a standard set of 14 statements appeared on the computer screen at the end of each trial (as shown in Table 1). These statements were designed to assess the content and nature of participants' ongoing thoughts along multiple dimensions in the moment. These specific dimensions have been assessed in previous studies of ongoing thoughts (FERNYHOUGH et al., 2018; Kam et al., 2021; Mckeown et al., 2020; Smallwood et al., 2016; Vatansever et al., 2020). For each statement, participants responded by selecting a value using the mouse on a continuous scale ranging from 0 (not at all) to 100 (extremely) that best described their momentary experience. Across the six blocks, we presented a total of 36 thought probes, with 18 thought probes in each of the two conditions.

In order to ensure participants have a clear understanding of the meaning of the thought dimensions assessed at each thought probe, we implemented several steps prior to data acquisition. First, participants were provided with an elaborate explanation of each statement and its corresponding response scale (i.e., what a "not at all" or "extremely" response mean in the context of that statement). We also provided real-life examples of each thought dimension to facilitate the understanding of how they may occur in the context of an experiment. Participants were also given an opportunity to ask clarification questions.

**Table 1**

*Statements Presented at Each Thought Probe via Multi-Dimensional Experience Sampling*

---

MDES Statements
My thoughts involved myself.
My thoughts involved other people.

---

My thoughts involved past events.

My thoughts involved future events.

My thoughts were focused on the present moment.

My thoughts were in the form of images.

My thoughts were in the form of words.

My thoughts were positive.

My thoughts were negative.

My thoughts were focused on the external environment.

My thoughts were focused on my internal world.

My thoughts were related to goals.

My thoughts were freely moving.

My thoughts were stuck on one topic.

---

### **2.3 EEG Data Acquisition and Preprocessing**

EEG data was recorded continuously and digitized at 500 Hz from 64 electrodes placed on a cap with 10-10 international layout using the BrainVision EEG system (ActiCap64 system, Brain Products GmbH, Gilching, Germany). Four electrodes placed around the eyes (electrooculograms; EOG) were used to detect eye movements. Two EOGs were placed on the left and right temple and another two electrodes were placed above and below the left eye to record both horizontal and vertical eye movements respectively.

EEG data was preprocessed using MATLAB (The MathWorks Inc., 2022) and the FieldTrip toolbox (Oostenveld et al., 2011). Continuous data was band-pass filtered between 1 to 55Hz. A 1Hz high pass filter was shown to be ideal for independent component analysis (ICA)

decomposition (Klug & Gramann, 2021) and we implemented a low pass filter of 55Hz filter to avoid contamination by line noise at 60Hz. ICA was performed to detect and remove artifacts, such that components associated with eye blinks, saccades, muscle artifacts and other types of noise were removed from the data. Electrodes with excessively high noise were identified through visual inspection and interpolated from neighbouring electrodes using spherical spline interpolation (Perrin et al., 1989). Any remaining artifactual segments were manually identified and removed from subsequent analyses. EEG data were segmented into non-overlapping 2s epochs. Although the main interval of interest is two seconds, we extracted an additional one second before and after this main interval for padding purposes for subsequent time frequency decomposition. Subsequent analyses only focused on the seven epochs, equivalent to 14s, preceding the thought probe (as described below). Finally, a common average reference was applied to the clean, segmented data.

To compute the power spectral density of EEG data, a Fast Fourier Transform (FFT) with a Hanning taper was applied for frequencies between 2 and 55Hz at 1Hz intervals. We then extracted the spectral activity within each canonical frequency band of interest: theta (4-7Hz), alpha (8-14Hz), and gamma (31-50Hz). For each frequency band, several EEG channels from a specific region were chosen based on prior literature and our hypothesis. This included four EEG measures, encompassing frontocentral theta (FC1, FC2, F1, F2, Fz), frontal alpha (Fz, F1, F2, F3, F4), posterior alpha (O1, O2, Oz, PO7, PO3, POz, PO4, PO8), and posterior gamma (P1, P2, Pz, PO3, PO4, POz). The mean power of each EEG measure was computed across channels of interest and frequencies within each frequency band for each two-seconds epoch for subsequent analysis. Our analysis specifically focused on the aforementioned EEG spectral measures within the fourteen seconds of data (equivalent to seven epochs) prior to each thought probe. The time

window of 10-15s has been commonly used and suggested to reliably capture the reported attentional states in previous studies (Baldwin et al., 2017; Martel et al., 2019; Polychroni et al., 2022) and falls within the most commonly used time interval as reported in a systematic review (Kam et al., 2022b). This time window reflects a trade-off between accumulating sufficient data to obtain reliable estimates of EEG measures and maintaining the integrity of the report of ongoing experiences (Smallwood & Schooler, 2006).

## **2.4 Statistical Analysis**

### ***2.4.1 Principal Component Analysis (PCA)***

We implemented principal component analysis (PCA) on the MDES data obtained through each thought probe in order to consolidate the 14 thought dimensions into a fewer number of principal components, which reflect the latent patterns of co-occurring thoughts. PCA with varimax rotation was implemented in line with previous studies (Konu et al., 2021; Mckeown et al., 2020; Mulholland et al., 2023; Simola et al., 2023; Turnbull et al., 2019)-

### ***2.4.2 Linear Mixed Effects (LME) Model Analyses***

All LME analyses were conducted using R 4.2.2 (R Core Team, 2022) and RStudio (version 2023.3.0.386). The Restricted Maximum Likelihood estimation method was used in the models. After eliminating artifactual segments during EEG preprocessing and removing trials in which participants responded with the lowest rating of 1 (never) to the control question, we retained a total of 1458 observations for the LME models. To account for variability across participants in their response to thought probes, participants were included as a random intercept in all of the following models.

**Principal Components by Condition.** To assess whether unique thought patterns emerged across the two conditions, we implemented separate LMEs for each of the selected principal components to determine whether they varied between the thought focus or video focus conditions. In each model, condition (video focus vs thought focus as reference level) was a fixed effect independent variable, and a given principal component was specified as the dependent variable.

**Principal Components by EEG Measures.** To assess whether the thought patterns as indexed by principal components were uniquely associated with EEG spectral measures, we implemented separate LMEs for each of the four EEG measures (i.e., frontocentral theta, frontal alpha, posterior alpha, and posterior gamma). These models consisted of principal component as the independent variable and EEG measures as the dependent variable, allowing us to assess whether any given thought pattern could predict each EEG measure. Separate analyses were conducted for each principal component and each EEG measure, as model comparisons indicated no significant improvement when including all three principal components to predict EEG measures.

In order to evaluate whether thought patterns can explain variance in observed EEG measures, we performed model comparison analyses using the Likelihood Ratio Test. These analyses aimed to determine whether the inclusion of thought patterns significantly enhanced model fit compared to a baseline model, which included only the intercept term as a predictor. We compared this baseline model to a more complex model that incorporated all relevant principal components as predictors to assess whether the inclusion of principal components as predictors led to a significant improvement in overall model fit.

**EEG Measures by Condition.** To assess whether the experimental conditions were uniquely associated with EEG spectral measures, we implemented separate LMEs for each of the four EEG measures to determine whether they differentially correspond with each condition. In these models, condition was included as an independent variable and each EEG measure was included as a dependent variable, to assess whether the EEG measures differed during the thought focus versus video focus condition.

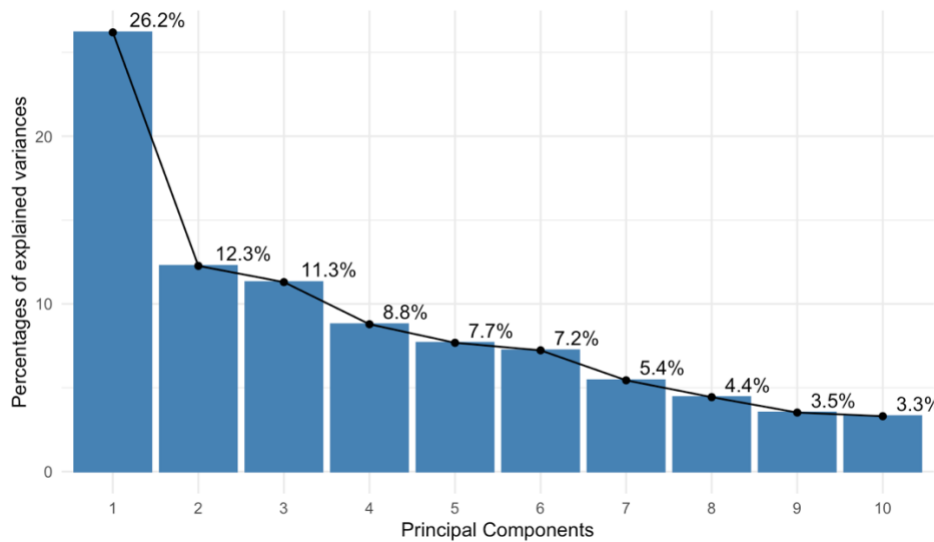
## **Results**

### **3.1 Thought Patterns Identified from PCA**

We utilized principal component analysis (PCA) to decompose the trial-level MDES responses, to uncover patterns of thought across both conditions. The scree plot resulting from PCA is depicted in Figure 2. Guided by the inflection point of scree plot and considering the variances explained by each PC (Mulholland et al., 2023; Simola et al., 2023; Sormaz et al., 2018), we extracted three principal components for subsequent analysis. Collectively, these three components explained 49.8% of the total variance.

#### **Figure 2**

*Scree Plot from PCA*

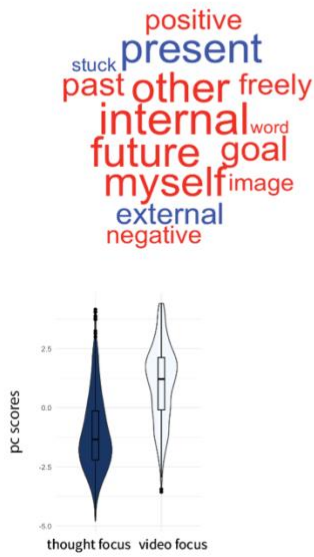


The first principal component (PC1) exhibited high loadings on thought dimensions such as “present”, “external”, and “stuck”, which we labeled as ‘present external thought’. The second component (PC2) encompassed dimensions like “goal”, “word”, “future”, and “myself”, and was labelled as ‘goal-oriented future thought’. The third component (PC3) included dimensions of “freely”, “external”, “positive”, “present”, and was labelled as ‘freely moving external positive thought’. These three extracted thought patterns are visualized in Figure 3 as word clouds, created from their PCA loadings for each thought dimension. Detailed component loadings for each thought dimension are available in the Appendix (Appendix 2).

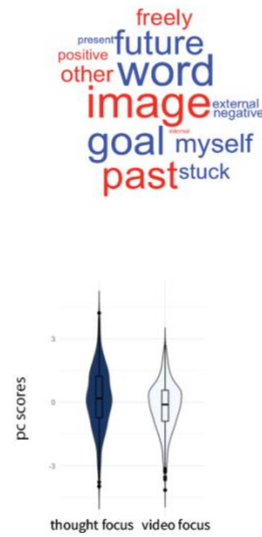
**Figure 3**

*Word Clouds for Identified Thought Patterns and Violin Plots for Thought Patterns by Condition*

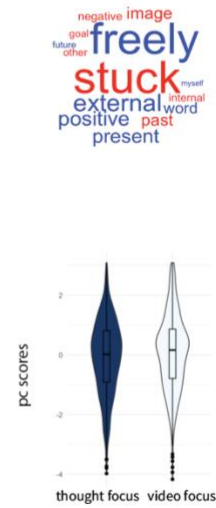
A. Present external thought



B. Goal-oriented future thought



C. Freely moving external positive thought



*Note.* Word clouds and violin plots for a) present external thought b) goal-oriented future thought and c) freely moving external positive thought. Top panel: Word clouds for each thought pattern. Font size corresponds to higher loadings, whereas colour indicates the direction of the loadings (blue = positive, red = negative) of the respective thought dimension onto the principal component. Bottom panel: violin plots of the principal component scores of each thought pattern as a function of thought focus and video focus condition.

### 3.2 Linear Mixed Effects (LME) Model Analyses

Next, we conducted Linear Mixed Effects (LME) analyses to examine the relationship between conditions (thought focus vs. video focus) and the three thought patterns (as indexed by each principal component), the association between thought patterns with EEG measures, and the influence of EEG measures on conditions.

#### 3.2.1 Examining the Relationship between Thought Patterns and Conditions

We first examined the impact of the experimental condition on the various thought patterns. Results of these analyses are illustrated in Figure 3 and statistical values are reported in Table 2.

**Present external thought (PC1).** – There was a significant main effect of condition on present external thought. Specifically, participants in the video focus condition showed a significant increase in scores on the present external thought compared to those in thought focus condition ( $b = 2.11, p < .001$ ).

**Goal-oriented future thought (PC2).** – The main effect of condition on goal-oriented future thought was significant, characterized by an increase in goal-oriented future thought during the thought focus condition compared to the video focus condition ( $b = -0.37, p < .001$ ).

**Freely moving external positive thought (PC3).** – The model revealed a significant main effect of condition on freely moving external positive thought, such that there was an increase in freely moving external positive thought during the video focus condition compared to the thought focus condition ( $b = 0.16, p = .005$ ).

**Table 2**

*Fixed Effects of Condition on Thought Patterns (as indexed by PCs)*

		Estimate	95% CI	SE	<i>df</i>	<i>t</i>
Present external thought	(Intercept)	-1.06	-1.31, -0.81	0.12	49.64	-8.53***
	Condition	2.11	1.96, 2.25	0.07	1417.17	28.16 ***
Goal-oriented future thought	(Intercept)	0.19	-6.55, 0.38	0.94	51.58	2.00
	Condition	-0.37	-4.96, -0.25	0.06	1417.19	-6.05 ***
	(Intercept)	-0.08	-0.29, 0.14	0.11	47.12	-0.70

Freely moving external positive thought	Condition	0.16	0.05, 0.27	0.06	1417.04	2.79 **
---	-----------	------	------------	------	---------	---------

Note. Reference condition = video focus condition. \*\*\*  $p < .001$  \*\*  $p < .01$  \*  $p < .05$ .

### 3.2.2 Thought Patterns by EEG Measures

Next, we examined the EEG correlates of these thought patterns. Results for these analyses are reported in Table 3.

**Frontocentral Theta.** For frontocentral theta activity, there were no significant main effects of any of the three thought patterns: present external thought ( $b = -0.01, p = .456$ ); goal-oriented future thought ( $b = 0.01, p = .528$ ); freely moving external positive thought ( $b = 0.00, p = .821$ ). We also assessed whether the model with three predictors of thought patterns accounted for more variance than the model without using an analysis of variance (ANOVA). There was no significant difference between the two models ( $\chi^2(4) = 3.07, p = .546$ ), in line with the three null effects reported above.

**Frontal Alpha.** Our analyses showed significant main effects of present external thought and freely moving external positive thought on frontal alpha. There was a significant negative effect of present external thought on frontal alpha ( $b = -0.01, p = .014$ ). This indicates that when engaged in present external thoughts, individuals tend to exhibit lower levels of frontal alpha. Similarly, freely moving external positive thought also had a significant negative effect on frontal alpha ( $b = -0.01, p = .038$ ), suggesting that engaging in freely moving positive thoughts about the external environment is associated with reduced frontal alpha levels. The effect of goal-oriented future thoughts on frontal alpha was not statistically significant ( $b = 0.00, p = .720$ ). Model comparisons revealed that the inclusion of three principal components significantly enhanced the model fit compared to the baseline model ( $\chi^2(3) = 10.03, p = .018$ ),

indicating that the joint influence of the three thought patterns explained significantly more variance in frontal alpha than the baseline model.

**Posterior Alpha.** Present external thought had a significant negative effect on posterior alpha ( $b = -0.02, p = .006$ ), such that when directing their attention to the current external moment, individuals tend to display lower levels of posterior alpha. However, goal-oriented future thought ( $b = 0.00, p = .862$ ) and freely moving external positive thought ( $b = -0.02, p = .104$ ) did not significantly predict posterior alpha. Model comparisons demonstrated a significant enhancement in model fit with the inclusion of three principal components compared to the baseline model ( $\chi^2(3) = 9.78, p = .020$ ).

**Posterior Gamma.** None of the three thought patterns showed a statistically significant effect on posterior gamma (present external thought:  $b = 0.00, p = 0.98$ ; goal-oriented future thought:  $b = 0.00, p = 0.855$ ; freely moving external positive thought:  $b = 0.00, p = .614$ ). Model comparisons indicated no significant difference in model fit ( $\chi^2(3) = 0.28, p = .964$ ), suggesting that the inclusion of the three principal components did not significantly improve the overall fit compared to the baseline model.

**Table 3**

*Fixed Effects for EEG Measures PCs (Thought Patterns)*

		Estimate	95% CI	SE	<i>df</i>	<i>t</i>
Frontocentral	(Intercept)	0.40	0.27, 0.53	0.07	39,92	6.12
theta	PC1	-0.01	-0.02, 0.01	0.01	1439.00	-0.75
	(Intercept)	0.40	0.27, 0.53	0.07	39.95	6.14
	PC2	0.01	-0.02, 0.33	0.01	1444.00	0.63

	(Intercept)	0.40	0.27, 0.53	0.07	39.95	6.14
	PC3	0.00	-0.02, 0.03	0.01	1454.00	0.23
Frontal alpha	(Intercept)	0.25	0.18, 0.33	0.04	39.96	6.70***
	PC1	-0.01	-0.01, -0.00	0.00	628.23	-2.48*
	(Intercept)	0.25	0.18, 0.33	0.04	39.97	6.70***
	PC2	-0.00	-0.01, 0.01	0.00	1412.00	-0.36
	(Intercept)	0.25	0.18, 0.33	0.04	39.96	6.70***
	PC3	-0.01	-0.02, 0.00	0.00	1422.00	-2.07*
Posterior alpha	(Intercept)	0.39	0.29, 0.49	0.05	39.99	7.92***
	PC1	-0.02	-0.02, 0.02	0.01	666.07	-2.77**
	(Intercept)	0.39	0.30, 0.49	0.05	40.01	7.99***
	PC2	0.00	-0.02, 0.02	0.01	1437.00	0.17
	(Intercept)	0.39	0.30, 0.49	0.05	40.01	7.99***
	PC3	-0.02	-0.02, 0.02	0.01	1450.50	-1.63
Posterior gamma	(Intercept)	0.01	0.01, 0.02	0.00	40.00	3.61***
	PC1	0.00	-0.00, 0.00	0.00	1416.00	0.02
	(Intercept)	0.01	0.01, 0.02	0.00	40.00	3.61***
	PC2	-0.00	-0.00, 0.00	0.00	1386.00	-0.18
	(Intercept)	0.01	0.01, 0.02	0.00	40.00	3.61***
	PC3	0.00	-0.00, 0.00	0.00	1386.00	0.50

---

*Note.* PC1 = present external thought, PC2 = goal-oriented future thought, PC3 = freely moving external positive thought. \*\*\*  $p < .001$  \*\*  $p < .01$  \*  $p < .05$ .

### 3.2.3 EEG Measures by Condition.

Finally, we examined whether EEG measures exhibited differential patterns in response to each experimental condition. No significant effect of condition was observed for frontocentral theta ( $b = 0.02, p = .574$ ). However, there was a significant main effect of condition on frontal alpha. Participants exhibited a significant decrease in frontal alpha during the video focus condition compared to the thought focus condition ( $b = -0.03, p < .001$ ). Similarly, the model with posterior alpha demonstrated a significant main effect of condition, revealing a significant reduction in posterior alpha in the video focus condition compared to the thought focus condition ( $b = -0.14, p < .001$ ). Finally, there was also a significant main effect of condition on posterior gamma, characterized by a significant increase in posterior gamma during the video focus condition compared to thought focus condition ( $b = 0.00, p < .001$ ).

**Table 4**

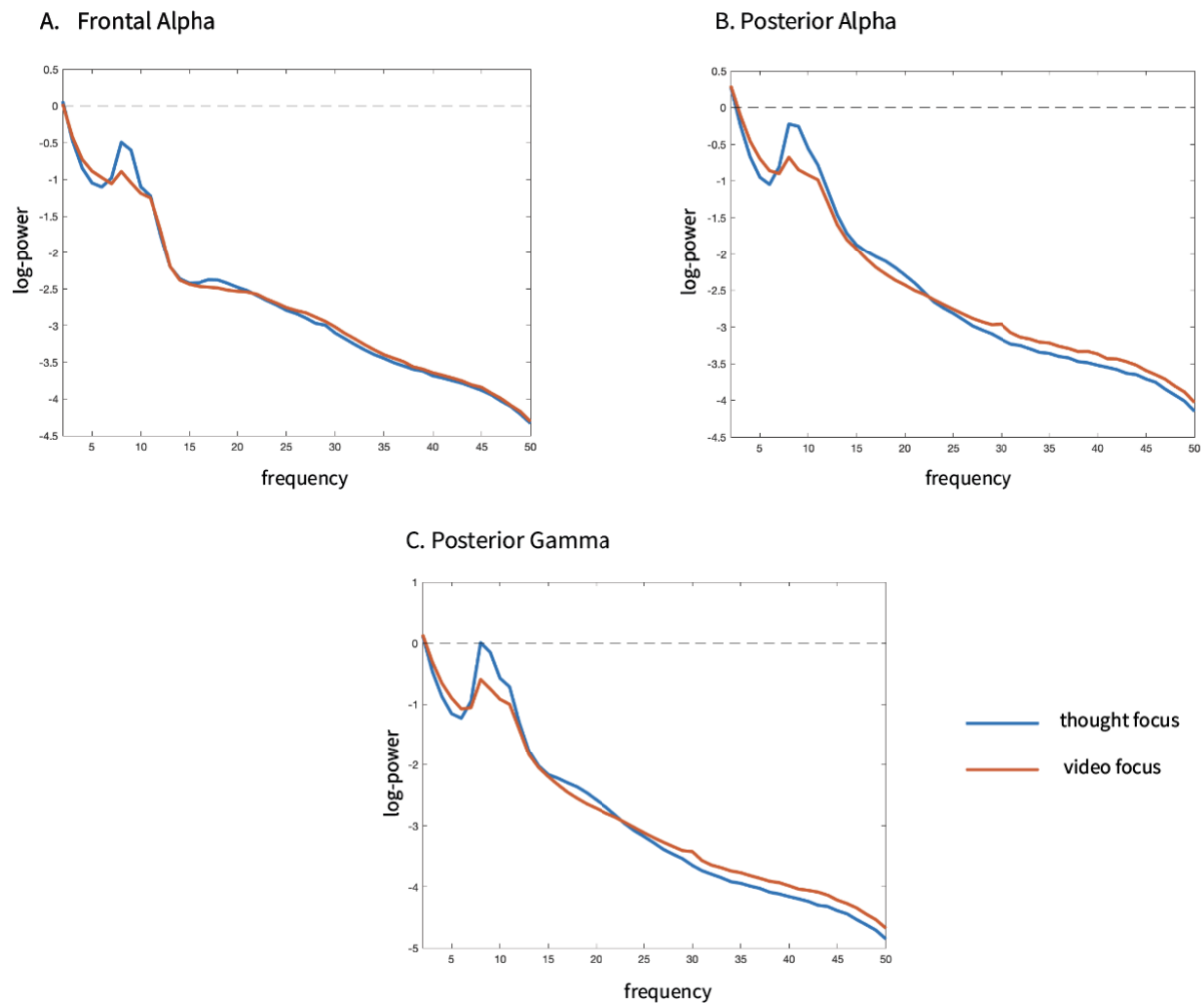
*Fixed Effects for EEG Measures on Condition*

		Estimate	95% CI	SE	<i>df</i>	<i>t</i>
Frontocentral theta	(Intercept)	0.39	0.26, 0.53	0.07	44.41	5.85***
	Condition	0.02	-0.04, 0.08	0.03	1416.08	0.56
Frontal alpha	(Intercept)	0.27	0.19, 0.34	0.04	41.07	-7.09***
	Condition	-0.03	-0.05, -0.02	0.01	1416.08	-3.76***
Posterior alpha	(Intercept)	0.46	0.36, 0.56	0.05	44.11	9.14***
	Condition	-0.14	-0.17, -0.09	0.02	1416.08	-6.22***
Posterior gamma	(Intercept)	0.01	0.00, 0.02	0.00	40.24	3.24**
	Condition	0.00	0.00, 0.00	0.00	1416.08	6.70***

Note. Reference condition = video focus condition. \*\*\*  $p < .001$  \*\*  $p < .01$  \*  $p < .05$ .

**Figure 4**

*Comparisons of Power Spectral Density Plots of EEG Measures for Each Condition*



## Discussion

The current study examined how thought patterns change with context and differentially correspond with EEG measures. We identified three distinct thought patterns using PCA: present

external thought (PC1), goal-oriented future thought (PC2), and freely moving external positive thought (PC3). Present external thought was uniquely linked to specific EEG measures, including decreased frontal alpha and posterior alpha. Freely moving external positive thought was associated with frontal alpha activity as well. Moreover, the experimental context significantly influenced the occurrence of these thought patterns and were differentially associated with EEG measures that aligned with those of thought patterns. Our findings shed light on the intricate interplay between thought patterns, experimental context, and electrophysiological activity.

The main thought pattern, characterized by a focus on external stimuli in the present moment, was closely associated with the video focus condition and decreased activity in posterior alpha and frontal alpha. The observed decline in posterior alpha during thoughts about an ongoing external task aligns with prior studies that have reported decreased posterior alpha during attention tasks (Bacigalupo & Luck, 2019; Jensen & Mazaheri, 2010). Similarly, this finding is also consistent with studies linking increased posterior alpha to internal attention (Benedek et al., 2014; Ceh et al., 2020). Our study therefore provides additional evidence supporting the relationship between the internal and external focus of thoughts and posterior alpha. Given that activity in the posterior gamma band has been associated with the processing of visual stimuli (Kaiser & Lutzenberger, 2005; Müller et al., 2000), we had anticipated that thoughts focused on the external task – video watching – would be associated with increased posterior gamma. Although this thought pattern did not significantly predict posterior gamma, there was a main effect of experimental condition as characterized by greater posterior gamma during the video focus condition. Moreover, present external thought was more strongly linked to

the video versus thought focus condition. This suggests that the experimental context may have accounted for more of the variance in posterior gamma band activity than the thought pattern itself. Finally, reduction in frontal alpha during this thought pattern may be attributed to the positive loading of the sticky thought dimension and negative loading of the freely moving thought dimension. According to the Dynamic Thought Framework (Christoff et al., 2016), sticky thoughts can be characterized as difficult to disengage from, and they operate outside conscious of cognitive control. This is conceptually opposite of freely moving thought, defined as the spontaneous, unconstrained transition between thought content and mental state. Considering past reports of increased frontal alpha during freely moving thought (Kam et al., 2021), the decrease in frontal alpha during this thought pattern corroborates past reports of the association between frontal alpha and freely moving thought.

The thought pattern characterized by goal-oriented thoughts about the future was decreased during the video focus condition and were not associated with any EEG markers. As theta activity has been linked to cognitive control (Cavanagh & Frank, 2014; Eisma et al., 2021; Harris et al., 2017; Sauseng et al., 2010), which conceptually aligns with goal-oriented processes, we had anticipated that frontocentral theta would be associated with this thought pattern. The lack of significant relationship between frontocentral theta and this thought pattern might be because the nature of goal-oriented thoughts in a naturalistic setting (such as during video watching) differs from that in highly constrained cognitive tasks (e.g., mental arithmetic tasks, spatial attention task, visuospatial planning task) (Harris et al., 2017; Katahira et al., 2018; Spreng et al., 2010). For example, participants may be focused on thinking about plans for the upcoming weekend, which they label as goal and future-oriented thought; this type of thought

would seem phenomenologically different from the types of thoughts that emerge during a cognitive control task, during which participants are asked to move disks between rods, adhering to specific rules on the number of disks moved and stacking order. Given that task setting seems to play a role in the relationship between theta activity and task-unrelated thought (Kam et al., 2022b), which can include goal-oriented, future thoughts, it is conceivable that frontocentral theta may be a context-dependent marker that emerges only in certain contexts for this thought pattern as well. Our results contribute to the growing understanding that frontocentral theta activity may vary across different experimental contexts, highlighting the need for further exploration of the electrophysiological correlates of goal-oriented thought in more naturalistic settings.

Characterized by freely moving, positive, external, and present thoughts, the third thought pattern (PC3) was more likely to occur during the video focus condition and was associated with decreased frontal alpha. The unexpected negative relationship between frontal alpha and a thought pattern that is characterized by freely moving thought may reflect a misalignment between our provided definition and participants' interpretation of this thought dimension. Despite providing elaborate definitions and real-life examples of this thought dimension, it is plausible that participants categorized the rapid switching between external stimuli switching (as is the case for the short, quick-paced videos presented to them during the video focus condition) as freely moving. In contrast, the definition provided to participants primarily concerns the freedom of internally oriented thought to move from one topic to another. This definition aligns with the conceptual framework (Christoff et al., 2016), which was originally created within the context of spontaneously occurring thought. Notably, participants'

potential interpretation of attention quickly switching from one video to another, though not part of the original framework, is a plausible interpretation of this terminology and would explain why this thought pattern is more closely linked to the video focus condition. Another possible interpretation for the relationship of frontal alpha and the third thought pattern is that frontal alpha may serve as a marker for some other cognitive dimension, or it might be different when various thought dimensions are combined together as a pattern, as opposed to when each dimension is considered in isolation. This implies that the interplay and integration of multiple cognitive dimensions within this thought pattern might contribute to the observed modulation of frontal alpha, indicating a need for a more intricate understanding of the neural correlates of thought patterns. Despite this unexpected observation, the co-occurring thought dimensions in this thought pattern is in line with previous literature associating freely moving thought with positive affect (Mills et al., 2021; Thiemann et al., 2023). Importantly, the lower variance explained by the goal-oriented future thought (PC2; 12.3%) and freely moving positive present thought (PC3; 11.3%) compared to the present external thought (PC1; 26.2%) might suggest that these two thought patterns are less robust, potentially explaining the weaker or absence of modulation of electrophysiological activity.

#### **4.1 Limitations and Future Directions**

Our study's interpretation is subject to certain considerations, with one notable limitation being the significant gender imbalance in our participant sample, predominantly consisting of 36 females and 5 males. This skewed representation raises concerns regarding the generalizability of our findings, as gender-related cognitive differences might be incompletely captured. Given this limitation, it is imperative to explicitly acknowledge that the identified relationships between

thought patterns and neural activity may not fully represent both genders. Future research endeavors should prioritize a more balanced gender distribution in participant samples to ensure that the insights derived from the study are applicable across diverse demographic groups. This approach aligns with the broader call for inclusivity in cognitive research and enhances the external validity of our findings.

Moreover, the observed complexities in our findings could be influenced by specific characteristics of the video-watching task and individual differences in thought patterns. For instance, variations in the set of videos during the video focus condition could introduce changes in the EEG measures associated with thought patterns. Additionally, our study did not control for or examine individual differences in characteristics that may impact thought patterns, such as Attention Deficit Hyperactivity Disorder (ADHD). Given that individuals with ADHD have been shown to report excessive off-task thoughts (Franklin et al., 2016) compared to neurotypical individuals, the thought patterns and their associated neural activity within this population may differ. These factors, which are not explicitly measured in our study, introduce additional nuances to the relationship between thought patterns, experimental context and neural activity. Future research could explore additional contextual factors and a broader range of participant groups, providing a more nuanced and comprehensive understanding of thought patterns and their corresponding electrophysiological signatures.

## **4.2 Conclusion**

In conclusion, our study contributes to the growing body of literature on the complex relationship between thought processes and electrophysiological activity in different contexts. The robust influence of conditions on thought patterns, particularly present external thought,

highlights the malleability of thought processes due to experimental contexts. Furthermore, these results underscore the nuanced interplay between context-dependent thought patterns and EEG measures. Taken together, our findings offer valuable insights into the contextual modulation of thought and neural dynamics, paving the way for future research in this domain.

## References

- 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/10.3389/fpsyg.2013.00900>
- Antonov, P. A., Chakravarthi, R., & Andersen, S. K. (2020). Too little, too late, and in the wrong place: Alpha band activity does not reflect an active mechanism of selective attention. *NeuroImage, 219*, 117006. <https://doi.org/10.1016/j.neuroimage.2020.117006>
- Bacigalupo, F., & Luck, S. J. (2019). Lateralized Suppression of Alpha-Band EEG Activity As a Mechanism of Target Processing. *The Journal of Neuroscience, 39*(5), 900–917. <https://doi.org/10.1523/JNEUROSCI.0183-18.2018>
- 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>
- Baldwin, C. L., Roberts, D. M., Barragan, D., Lee, J. D., Lerner, N., & Higgins, J. S. (2017). Detecting and Quantifying Mind Wandering during Simulated Driving. *Frontiers in Human Neuroscience, 11*, 406. <https://doi.org/10.3389/fnhum.2017.00406>
- Benedek, M., Schickel, R. J., Jauk, E., Fink, A., & Neubauer, A. C. (2014). Alpha power increases in right parietal cortex reflects focused internal attention. *Neuropsychologia, 56*, 393–400. <https://doi.org/10.1016/j.neuropsychologia.2014.02.010>

- Berntsen, D., & Jacobsen, A. S. (2008). Involuntary (spontaneous) mental time travel into the past and future. *Consciousness and Cognition, 17*(4), 1093–1104.  
<https://doi.org/10.1016/j.concog.2008.03.001>
- Cavanagh, J. F., & Frank, M. J. (2014). Frontal theta as a mechanism for cognitive control. *Trends in Cognitive Sciences, 18*(8), 414–421. <https://doi.org/10.1016/j.tics.2014.04.012>
- Cavanagh, J. F., & Shackman, A. J. (2015). Frontal midline theta reflects anxiety and cognitive control: Meta-analytic evidence. *Journal of Physiology-Paris, 109*(1–3), 3–15.  
<https://doi.org/10.1016/j.jphysparis.2014.04.003>
- Ceh, S. M., Annerer-Walcher, S., Körner, C., Rominger, C., Kober, S. E., Fink, A., & Benedek, M. (2020). Neurophysiological indicators of internal attention: An electroencephalography–eye-tracking coregistration study. *Brain and Behavior, 10*(10), e01790. <https://doi.org/10.1002/brb3.1790>
- Christoff, K., Irving, Z. C., Fox, K. C. R., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews Neuroscience, 17*(11), 718–731. <https://doi.org/10.1038/nrn.2016.113>
- Cohen, M. X. (2014). *Analyzing Neural Time Series Data: Theory and Practice*. The MIT Press.  
<https://doi.org/10.7551/mitpress/9609.001.0001>
- Doppelmayr, M., Klimesch, W., Schwaiger, J., Auinger, P., & Winkler, T. (1998). Theta synchronization in the human EEG and episodic retrieval. *Neuroscience Letters, 257*(1), 41–44. [https://doi.org/10.1016/S0304-3940\(98\)00805-2](https://doi.org/10.1016/S0304-3940(98)00805-2)
- Eisma, J., Rawls, E., Long, S., Mach, R., & Lamm, C. (2021). Frontal midline theta differentiates separate cognitive control strategies while still generalizing the need for cognitive control. *Scientific Reports, 11*(1), 14641. <https://doi.org/10.1038/s41598-021-94162-z>

- Fell, J., Fernández, G., Klaver, P., Elger, C. E., & Fries, P. (2003). Is synchronized neuronal gamma activity relevant for selective attention? *Brain Research Reviews*, *42*(3), 265–272. [https://doi.org/10.1016/S0165-0173\(03\)00178-4](https://doi.org/10.1016/S0165-0173(03)00178-4)
- Fernyhough, C., Alderson-Day, B., Hurlburt, R. T., & Kühn, S. (2018). Investigating Multiple Streams of Consciousness: Using Descriptive Experience Sampling to Explore Internally and Externally Directed Streams of Thought. *Frontiers in Human Neuroscience*, *12*, 494. <https://doi.org/10.3389/fnhum.2018.00494>
- Fink, A., & Benedek, M. (2014). EEG alpha power and creative ideation. *Neuroscience & Biobehavioral Reviews*, *44*, 111–123. <https://doi.org/10.1016/j.neubiorev.2012.12.002>
- Fitzgibbon, S. P., Pope, K. J., Mackenzie, L., Clark, C. R., & Willoughby, J. O. (2004). Cognitive tasks augment gamma EEG power. *Clinical Neurophysiology*, *115*(8), 1802–1809. <https://doi.org/10.1016/j.clinph.2004.03.009>
- Foster, B. L., Kaveh, A., Dastjerdi, M., Miller, K. J., & Parvizi, J. (2013). Human Retrosplenial Cortex Displays Transient Theta Phase Locking with Medial Temporal Cortex Prior to Activation during Autobiographical Memory Retrieval. *Journal of Neuroscience*, *33*(25), 10439–10446. <https://doi.org/10.1523/JNEUROSCI.0513-13.2013>
- Foster, B. L., & Parvizi, J. (2012). Resting oscillations and cross-frequency coupling in the human posteromedial cortex. *NeuroImage*, *60*(1), 384–391. <https://doi.org/10.1016/j.neuroimage.2011.12.019>
- 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), e97176.  
<https://doi.org/10.1371/journal.pone.0097176>
- Harris, A. M., Dux, P. E., Jones, C. N., & Mattingley, J. B. (2017). Distinct roles of theta and alpha oscillations in the involuntary capture of goal-directed attention. *NeuroImage*, 152, 171–183. <https://doi.org/10.1016/j.neuroimage.2017.03.008>
- Herweg, N. A., Solomon, E. A., & Kahana, M. J. (2020). Theta Oscillations in Human Memory. *Trends in Cognitive Sciences*, 24(3), 208–227. <https://doi.org/10.1016/j.tics.2019.12.006>
- Ho, N. S. P., Poerio, G., Konu, D., Turnbull, A., Sormaz, M., Leech, R., Bernhardt, B., Jefferies, E., & Smallwood, J. (2020). Facing up to the wandering mind: Patterns of off-task laboratory thought are associated with stronger neural recruitment of right fusiform cortex while processing facial stimuli. *NeuroImage*, 214, 116765.  
<https://doi.org/10.1016/j.neuroimage.2020.116765>
- Hsieh, L.-T., & Ranganath, C. (2014). Frontal midline theta oscillations during working memory maintenance and episodic encoding and retrieval. *NeuroImage*, 85, 721–729.  
<https://doi.org/10.1016/j.neuroimage.2013.08.003>
- Ishii, R., Canuet, L., Ishihara, T., Aoki, Y., Ikeda, S., Hata, M., Katsimichas, T., Gunji, A., Takahashi, H., Nakahachi, T., Iwase, M., & Takeda, M. (2014). Frontal midline theta rhythm and gamma power changes during focused attention on mental calculation: An MEG beamformer analysis. *Frontiers in Human Neuroscience*, 8.  
<https://doi.org/10.3389/fnhum.2014.00406>
- Ismail, L. E., & Karwowski, W. (2020). Applications of EEG indices for the quantification of human cognitive performance: A systematic review and bibliometric analysis. *PLOS ONE*, 15(12), e0242857. <https://doi.org/10.1371/journal.pone.0242857>

- Jensen, O., Bonnefond, M., & VanRullen, R. (2012). An oscillatory mechanism for prioritizing salient unattended stimuli. *Trends in Cognitive Sciences*, *16*(4), 200–206.  
<https://doi.org/10.1016/j.tics.2012.03.002>
- Jensen, O., & Mazaheri, A. (2010). Shaping Functional Architecture by Oscillatory Alpha Activity: Gating by Inhibition. *Frontiers in Human Neuroscience*, *4*.  
<https://doi.org/10.3389/fnhum.2010.00186>
- Kaiser, J., & Lutzenberger, W. (2005). Human gamma-band activity: A window to cognitive processing. *NeuroReport*, *16*(3).  
[https://journals.lww.com/neuroreport/fulltext/2005/02280/human\\_gamma\\_band\\_activity\\_a\\_window\\_to\\_cognitive.1.aspx](https://journals.lww.com/neuroreport/fulltext/2005/02280/human_gamma_band_activity_a_window_to_cognitive.1.aspx)
- 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*, *118*(4), e2011796118.  
<https://doi.org/10.1073/pnas.2011796118>
- Kam, J. W. Y., Mittner, M., & Knight, R. T. (2022a). Mind-wandering: Mechanistic insights from lesion, tDCS, and iEEG. *Trends in Cognitive Sciences*, *26*(3), 268–282.  
<https://doi.org/10.1016/j.tics.2021.12.005>
- Kam, J. W. Y., Rahnema, T., Park, Y. E., & Hart, C. M. (2022b). Electrophysiological markers of mind wandering: A systematic review. *NeuroImage*, *258*, 119372.  
<https://doi.org/10.1016/j.neuroimage.2022.119372>
- Katahira, K., Yamazaki, Y., Yamaoka, C., Ozaki, H., Nakagawa, S., & Nagata, N. (2018). EEG Correlates of the Flow State: A Combination of Increased Frontal Theta and Moderate

- Frontocentral Alpha Rhythm in the Mental Arithmetic Task. *Frontiers in Psychology*, 9, 300. <https://doi.org/10.3389/fpsyg.2018.00300>
- Keller, S. M., Reyneke, C., Gschwandtner, U., & Fuhr, P. (2023). Information Contained in EEG Allows Characterization of Cognitive Decline in Neurodegenerative Disorders. *Clinical EEG and Neuroscience*, 54(4), 391–398. <https://doi.org/10.1177/15500594221120734>
- Kelly, S. P., Lalor, E. C., Reilly, R. B., & Foxe, J. J. (2006). Increases in Alpha Oscillatory Power Reflect an Active Retinotopic Mechanism for Distracter Suppression During Sustained Visuospatial Attention. *Journal of Neurophysiology*, 95(6), 3844–3851. <https://doi.org/10.1152/jn.01234.2005>
- Kirov, R., Weiss, C., Siebner, H. R., Born, J., & Marshall, L. (2009). Slow oscillation electrical brain stimulation during waking promotes EEG theta activity and memory encoding. *Proceedings of the National Academy of Sciences*, 106(36), 15460–15465. <https://doi.org/10.1073/pnas.0904438106>
- Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: A review and analysis. *Brain Research Reviews*, 29(2–3), 169–195. [https://doi.org/10.1016/S0165-0173\(98\)00056-3](https://doi.org/10.1016/S0165-0173(98)00056-3)
- Klimesch, W., Doppelmayr, M., Schimke, H., & Ripper, B. (1997). Theta synchronization and alpha desynchronization in a memory task. *Psychophysiology*, 34(2), 169–176. <https://doi.org/10.1111/j.1469-8986.1997.tb02128.x>
- Klinger, E. (2013). Goal Commitments and the content of thoughts and dreams: Basic principles. *Frontiers in Psychology*, 4. <https://doi.org/10.3389/fpsyg.2013.00415>

- Klug, M., & Gramann, K. (2021). Identifying key factors for improving ICA-based decomposition of EEG data in mobile and stationary experiments. *European Journal of Neuroscience*, *54*(12), 8406–8420. <https://doi.org/10.1111/ejn.14992>
- Konu, D., Mckeown, B., Turnbull, A., Siu Ping Ho, N., 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*, 103139. <https://doi.org/10.1016/j.concog.2021.103139>
- Konu, D., Turnbull, A., Karapanagiotidis, T., Wang, H.-T., Brown, L. R., Jefferies, E., & Smallwood, J. (2020). A role for the ventromedial prefrontal cortex in self-generated episodic social cognition. *NeuroImage*, *218*, 116977. <https://doi.org/10.1016/j.neuroimage.2020.116977>
- Kritzman, L., Eidelman-Rothman, M., Keil, A., Freche, D., Sheppes, G., & Levit-Binnun, N. (2022). Steady-state visual evoked potentials differentiate between internally and externally directed attention. *NeuroImage*, *254*, 119133. <https://doi.org/10.1016/j.neuroimage.2022.119133>
- Liao, C. H., Worsley, K. J., Poline, J.-B., Aston, J. A. D., Duncan, G. H., & Evans, A. C. (2002). Estimating the Delay of the fMRI Response. *NeuroImage*, *16*(3), 593–606. <https://doi.org/10.1006/nimg.2002.1096>
- Linz, R., Pauly, R., Smallwood, J., & Engert, V. (2021). Mind-wandering content differentially translates from lab to daily life and relates to subjective stress experience. *Psychological Research*, *85*(2), 649–659. <https://doi.org/10.1007/s00426-019-01275-2>

- Luft, C. D. B., Zioga, I., Banissy, M. J., & Bhattacharya, J. (2019). Spontaneous Visual Imagery During Meditation for Creating Visual Art: An EEG and Brain Stimulation Case Study. *Frontiers in Psychology, 10*, 210. <https://doi.org/10.3389/fpsyg.2019.00210>
- Lustenberger, C., Boyle, M. R., Foulser, A. A., Mellin, J. M., & Fröhlich, F. (2015). Functional role of frontal alpha oscillations in creativity. *Cortex, 67*, 74–82. <https://doi.org/10.1016/j.cortex.2015.03.012>
- Magosso, E., De Crescenzo, F., Ricci, G., Piastra, S., & Ursino, M. (2019). EEG Alpha Power Is Modulated by Attentional Changes during Cognitive Tasks and Virtual Reality Immersion. *Computational Intelligence and Neuroscience, 2019*, 1–18. <https://doi.org/10.1155/2019/7051079>
- Martel, A., Arvaneh, M., Robertson, I., Smallwood, J., & Dockree, P. (2019). *Distinct neural markers for intentional and unintentional task unrelated thought* [Preprint]. Neuroscience. <https://doi.org/10.1101/705061>
- Mckeown, B., Strawson, W. H., Wang, H.-T., Karapanagiotidis, T., Vos De Wael, R., 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*, 117072. <https://doi.org/10.1016/j.neuroimage.2020.117072>
- Medea, B., Karapanagiotidis, T., Konishi, M., Ottaviani, C., Margulies, D., Bernasconi, A., Bernasconi, N., Bernhardt, B. C., Jefferies, E., & Smallwood, J. (2018). How do we decide what to do? Resting-state connectivity patterns and components of self-generated thought linked to the development of more concrete personal goals. *Experimental Brain Research, 236*(9), 2469–2481. <https://doi.org/10.1007/s00221-016-4729-y>

- Mills, C., Porter, A. R., Andrews-Hanna, J. R., Christoff, K., & Colby, A. (2021). How task-unrelated and freely moving thought relate to affect: Evidence for dissociable patterns in everyday life. *Emotion, 21*(5), 1029–1040. <https://doi.org/10.1037/emo0000849>
- Mitchell, D. J., McNaughton, N., Flanagan, D., & Kirk, I. J. (2008). Frontal-midline theta from the perspective of hippocampal “theta.” *Progress in Neurobiology, 86*(3), 156–185. <https://doi.org/10.1016/j.pneurobio.2008.09.005>
- Mulholland, B., Goodall-Halliwel, I., Wallace, R., Chitiz, L., Mckeown, B., Rastan, A., Poerio, G. L., Leech, R., Turnbull, A., Klein, A., Milham, M., Wammes, J. D., Jefferies, E., & Smallwood, J. (2023). Patterns of ongoing thought in the real world. *Consciousness and Cognition, 114*, 103530. <https://doi.org/10.1016/j.concog.2023.103530>
- Müller, M. M., Gruber, T., & Keil, A. (2000). Modulation of induced gamma band activity in the human EEG by attention and visual information processing. *International Journal of Psychophysiology, 38*(3), 283–299. [https://doi.org/10.1016/S0167-8760\(00\)00171-9](https://doi.org/10.1016/S0167-8760(00)00171-9)
- Murphy, C., Poerio, G., Sormaz, M., Wang, H.-T., Vatansever, D., Allen, M., Margulies, D. S., Jefferies, E., & Smallwood, J. (2019b). 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), e0216182. <https://doi.org/10.1371/journal.pone.0216182>
- Murphy, C., Wang, H.-T., Konu, D., Lowndes, R., Margulies, D. S., Jefferies, E., & Smallwood, J. (2019a). Modes of operation: A topographic neural gradient supporting stimulus dependent and independent cognition. *NeuroImage, 186*, 487–496. <https://doi.org/10.1016/j.neuroimage.2018.11.009>
- Oostenveld, R., Fries, P., Maris, E., & Schoffelen, J.-M. (2011). FieldTrip: Open Source Software for Advanced Analysis of MEG, EEG, and Invasive Electrophysiological Data.

- Computational Intelligence and Neuroscience*, 2011, 1–9.  
<https://doi.org/10.1155/2011/156869>
- Pastötter, B., & Bäuml, K.-H. T. (2014). Distinct slow and fast cortical theta dynamics in episodic memory retrieval. *NeuroImage*, 94, 155–161.  
<https://doi.org/10.1016/j.neuroimage.2014.03.002>
- Perrin, F., Pernier, J., Bertrand, O., & Echallier, J. F. (1989). Spherical splines for scalp potential and current density mapping. *Electroencephalography and Clinical Neurophysiology*, 72(2), 184–187.
- Polychroni, N., Herrojo Ruiz, M., & Terhune, D. B. (2022). Introspection confidence predicts EEG decoding of self-generated thoughts and meta-awareness. *Human Brain Mapping*, 43(7), 2311–2327. <https://doi.org/10.1002/hbm.25789>
- Popov, T., Popova, P., Harkotte, M., Awiszus, B., Rockstroh, B., & Miller, G. A. (2018). Cross-frequency interactions between frontal theta and posterior alpha control mechanisms foster working memory. *NeuroImage*, 181, 728–733.  
<https://doi.org/10.1016/j.neuroimage.2018.07.067>
- Riddle, J., Scimeca, J. M., Cellier, D., Dhanani, S., & D’Esposito, M. (2020). Causal Evidence for a Role of Theta and Alpha Oscillations in the Control of Working Memory. *Current Biology*, 30(9), 1748-1754.e4. <https://doi.org/10.1016/j.cub.2020.02.065>
- Ruby, F. J. M., 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), e77554.  
<https://doi.org/10.1371/journal.pone.0077554>

- Sauseng, P., Griesmayr, B., Freunberger, R., & Klimesch, W. (2010). Control mechanisms in working memory: A possible function of EEG theta oscillations. *Neuroscience & Biobehavioral Reviews*, *34*(7), 1015–1022.  
<https://doi.org/10.1016/j.neubiorev.2009.12.006>
- Schack, B., Klimesch, W., & Sauseng, P. (2005). Phase synchronization between theta and upper alpha oscillations in a working memory task. *International Journal of Psychophysiology*, *57*(2), 105–114. <https://doi.org/10.1016/j.ijpsycho.2005.03.016>
- Seli, P., Ralph, B. C. W., Konishi, M., Smilek, D., & Schacter, D. L. (2017). What did you have in mind? Examining the content of intentional and unintentional types of mind wandering. *Consciousness and Cognition*, *51*, 149–156.  
<https://doi.org/10.1016/j.concog.2017.03.007>
- Simola, J., Silander, T., Harju, M., Lahti, O., Makkonen, E., Pätsi, L.-M., & Smallwood, J. (2023). Context independent reductions in external processing during self-generated episodic social cognition. *Cortex*, *159*, 39–53.  
<https://doi.org/10.1016/j.cortex.2022.11.010>
- 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), e0152272.  
<https://doi.org/10.1371/journal.pone.0152272>
- Smallwood, J., Nind, L., & O'Connor, R. C. (2009). When is your head at? An exploration of the factors associated with the temporal focus of the wandering mind. *Consciousness and Cognition*, *18*(1), 118–125. <https://doi.org/10.1016/j.concog.2008.11.004>

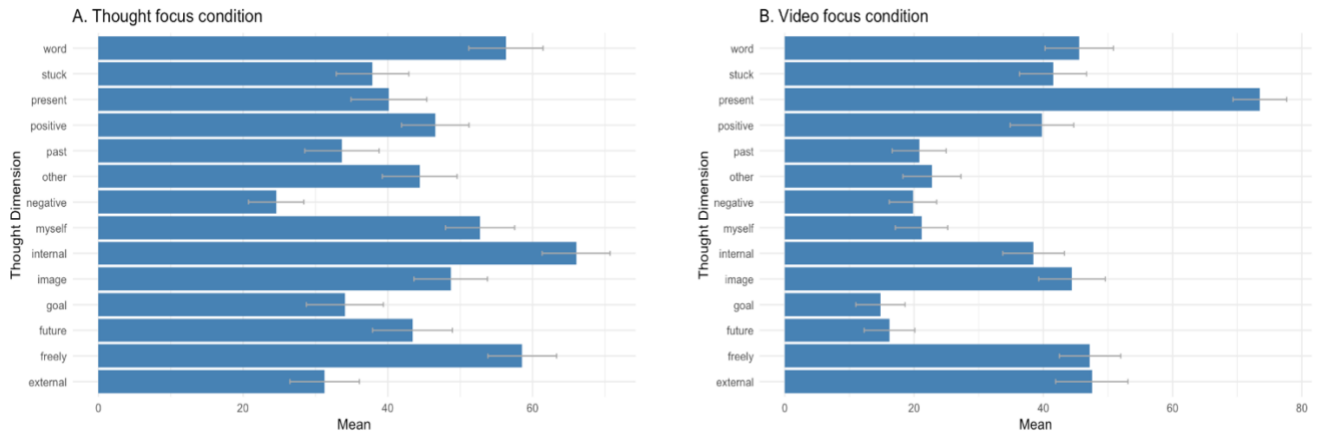
- Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, 132(6), 946–958. <https://doi.org/10.1037/0033-2909.132.6.946>
- Smallwood, J., & Schooler, J. W. (2015). The Science of Mind Wandering: Empirically Navigating the Stream of Consciousness. *Annual Review of Psychology*, 66(1), 487–518. <https://doi.org/10.1146/annurev-psych-010814-015331>
- Smallwood, J., Turnbull, A., Wang, H., Ho, N. S. P., Poerio, G. L., Karapanagiotidis, T., Konu, D., Mckeown, B., Zhang, M., Murphy, C., Vatansever, D., Bzdok, D., Konishi, M., Leech, R., Seli, P., Schooler, J. W., Bernhardt, B., Margulies, D. S., & Jefferies, E. (2021). The neural correlates of ongoing conscious thought. *iScience*, 24(3), 102132. <https://doi.org/10.1016/j.isci.2021.102132>
- Solomon, E. A., Stein, J. M., Das, S., Gorniak, R., Sperling, M. R., Worrell, G., Inman, C. S., Tan, R. J., Jobst, B. C., Rizzuto, D. S., & Kahana, M. J. (2019). Dynamic Theta Networks in the Human Medial Temporal Lobe Support Episodic Memory. *Current Biology*, 29(7), 1100-1111.e4. <https://doi.org/10.1016/j.cub.2019.02.020>
- Sormaz, M., Murphy, C., Wang, H., 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. <https://doi.org/10.1073/pnas.1721259115>
- 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>

- Thiemann, R. F., Mills, C., & Kam, J. W. Y. (2023). Differential relationships between thought dimensions and momentary affect in daily life. *Psychological Research*, *87*(5), 1632–1643. <https://doi.org/10.1007/s00426-022-01766-9>
- Tulving, E. (2002). Episodic Memory: From Mind to Brain. *Annual Review of Psychology*, *53*(1), 1–25. <https://doi.org/10.1146/annurev.psych.53.100901.135114>
- 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. *Nature Communications*, *10*(1), 3816. <https://doi.org/10.1038/s41467-019-11764-y>
- Vatansever, D., Karapanagiotidis, T., Margulies, D. S., Jefferies, E., & Smallwood, J. (2020). Distinct patterns of thought mediate the link between brain functional connectomes and well-being. *Network Neuroscience*, *4*(3), 637–657. [https://doi.org/10.1162/netn\\_a\\_00137](https://doi.org/10.1162/netn_a_00137)
- Wang, H.-T., Bzdok, D., Margulies, D., Craddock, C., Milham, M., Jefferies, E., & Smallwood, J. (2018b). Patterns of thought: Population variation in the associations between large-scale network organisation and self-reported experiences at rest. *NeuroImage*, *176*, 518–527. <https://doi.org/10.1016/j.neuroimage.2018.04.064>
- Wang, H.-T., Poerio, G., Murphy, C., Bzdok, D., Jefferies, E., & Smallwood, J. (2018a). Dimensions of Experience: Exploring the Heterogeneity of the Wandering Mind. *Psychological Science*, *29*(1), 56–71. <https://doi.org/10.1177/0956797617728727>

## Appendices

### Appendix 1

#### *Mean Thought Probe Responses for Thought Dimensions*



*Note.* Error bars represent standard error of mean in the bar graph.

### Appendix 2

#### *Component Loadings for Each Thought Dimension*

	PC1	PC2	PC3
myself	-0.32858892743511	0.259131348015753	0.0316269582452782
other	-0.346797993003284	-0.170376690080013	-0.064506220678884
past	-0.263580078145617	-0.367119564199157	-0.163366373817392
future	-0.347343858111087	0.342828758231047	0.0530624252534596
present	0.344615333999531	0.0916590067126636	0.231510415050077
image	-0.192149728784112	-0.39565415197629	-0.155672913522262
word	-0.0888576560982995	0.429293456021044	0.151697327201522

---

positive	-0.213419429950934	-0.0320401927800055	0.260812364030446
negative	-0.172055143748512	0.116588862533032	-0.0819732387107586
external	0.231195194078895	0.133180882027222	0.305370552149133
internal	-0.376427020390969	-0.0194468711787732	-0.0831065549302024
goal	-0.277452745963035	0.429239763158238	-0.0661081595003502
freely	-0.232427635753366	-0.191979415398847	0.582123328648495
stuck	0.129457902754767	0.220091362905122	-0.588517501336333

---