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Sticky Thoughts: Self-Referential Processing and Memory Recall Accuracy in Depression

Bachelor's Project Thesis

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Abstract: This study investigates the interactions between depression, self-referential processing (SRP), stickiness of mind-wandering, and their combined effects on memory recall accuracy within complex working memory (CWM) tasks. Depression has been linked to increased "stickiness" in mind-wandering, defined as difficulty in diverting attention from spontaneous, self-generated thoughts. These sticky thoughts are often associated with impaired cognitive performance, particularly in tasks demanding high cognitive engagement. To explore these interactions, we utilized an existing dataset of English speakers from Siwen Sheng et al. (in preparation). The study examined how varying levels of depressive symptoms influence cognitive performance. Based on our literature review, we hypothesized that individuals with higher levels of depressive symptoms would exhibit lower memorization accuracy in complex working memory tasks due to increased stickiness of mind-wandering. We further hypothesized that this effect would be more pronounced in tasks involving the self condition compared to the shoebox condition. Our findings indicate that higher levels of depressive symptoms are associated with increased stickiness, which negatively impacts memory performance. However, in contrast to our hypothesis, the self condition did not significantly decrease recall accuracy compared to the shoebox condition. This suggests that while depression increases the stickiness of thoughts, it may not necessarily be specific to self-referential content. Future research should explore SRP's influence in more diverse and relevant populations (more depressed individuals) to better understand its impact on cognitive function. Additionally, examining if these results differ for individuals with a different native language could provide further insights into the linguistic influences on cognitive performance. This approach allows for a more comprehensive understanding of how SRP and its inherent stickiness affect memory performance across varying levels of depressive symptoms.

Keywords: depression, mind-wandering, memory performance, complex working memory, stickiness, self-referential, processing

1 Introduction

Mind-wandering, the experience of thoughts drifting away from a task at hand, often occurs during long and monotonous activities (Vries, 2021). Initially termed task-unrelated thought, this phenomenon was later called mind-wandering by Smallwood & Schooler (2013). Recent studies in cognitive psychology have increasingly focused on mind-wandering, particularly its implications for mental health and cognitive performance (Mooneyham & Schooler, 2013). During mind-wandering, individuals frequently struggle to return to the task at hand, often becoming stuck in their thoughts. This fascinating aspect of mind-wandering is known as "stickiness"—the difficulty in disengaging from such thoughts (Joormann et al., 2011), which has been positively associated with tendencies for depression (Van Vugt & Broers, 2016).

When characterized by "stickiness", mind-wandering presents significant challenges in disengaging from unrelated thoughts. This "sticky" thinking can turn into rumination, making individuals vulnerable to mental disorders such as depression and anxiety (Huijser, 2022), impacting both task performance and psychological well-being. Depression is associated with a tendency to respond to negative mood states and life events with ruminative thinking (Nolen-Hoeksema et al., 2008). Studies have underscored the relationship between depression and increased "sticky thinking," where individuals with depression are more prone to persistent, intrusive thoughts that are difficult to dismiss. This pattern of rumination, characterized by repeated and prolonged engagement with negative thoughts, intensifies challenges in working memory tasks.

Research by Joormann et al. (2011) has shown that individuals with depression struggle considerably with disengaging from negative stimuli, leading to an impaired ability to handle emotional material effectively within working memory. The ability to decrease stickiness on negative stimuli and make more flexible shifts between stimuli with different emotional valence is crucial for emotional regulation—the capacity to manage and respond to emotional experiences in a healthy way. For instance, the ability to reframe a negative situation in a more positive light (cognitive reappraisal) relies on the efficient handling of emotional material in working memory (Joormann & Gotlib, 2010). The sticky thoughts, as described by Van Vugt & Broers (2016), significantly disrupt cognitive processes, leading to measurable decrements in task performance. The high prevalence of sticky thinking in depressed individuals highlights a critical area of concern, as it impacts overall mental efficiency and exacerbates depressive symptoms by maintaining negative emotional states. This underscores the importance of developing therapeutic strategies that enhance the ability to manage emotional material within working memory, thereby improving emotional regulation and reducing the cognitive burden of depression.

Self-referential processing (SRP), which involves thoughts and cognitive activities that focus on the self, such as self-evaluation, self-criticism, or rumination about one's feelings and actions, has been identified as a risk factor for depression (Allison et al., 2023). Prior studies have found that SRP can instigate more spontaneous thoughts and impair memory performance compared to processing non-self-information during goal-directed cognitive tasks (Sheng et al., in preparation). Research has shown that self-focused processing is particularly pronounced in individuals with depression (Brockmeyer et al., 2015), leading to increased spontaneous thoughts that interfere with their ability to focus on and perform current tasks. This heightened self-focus often results in "sticky thinking"—persistent and intrusive thoughts that are hard to dismiss (Yoon et al., 2019).

Sticky thinking, characterized by the difficulty in disengaging from self-referential thoughts, is closely related to rumination. Rumination involves the repetitive focus on negative emotions and their causes, further exacerbating cognitive and emotional challenges (Joormann et al., 2011; Van Vugt & Broers, 2016). This pattern of thought disrupts cognitive processes, impairs working memory, and can lead to persistent negative mood states. SRP can trigger these self-generated thoughts during idle moments within tasks, prioritizing them over task-related cognitive processes, thereby exacerbating the cycle of rumination and depression (Nejad et al., 2013).

Thus, SRP contributes to the prevalence of sticky thinking, monopolizing cognitive resources that would otherwise be directed towards the task at hand. Understanding the relationship between

SRP, sticky thinking, and rumination is crucial, as these cognitive patterns exacerbate the symptoms of depression. This underscores the importance of addressing these patterns in therapeutic interventions for depression, aiming to reduce the dominance of self-focused thoughts and improve cognitive and emotional functioning. SRP heightens the competition between task-relevant processes and self-generated thoughts, leading to "sticky thinking" that disrupts cognitive functions and impairs working memory (Joormann et al., 2011; Van Vugt & Broers, 2016). While sticky thinking is known to negatively impact task performance and increase off-task thoughts, its direct effect on complex memory (CWM) tasks and the specific role of depressive symptoms on memory performance in these tasks remain underexplored. This study seeks to address this gap by examining how individuals' self-reported experiences of mind-wandering stickiness affect memory performance across varying levels of depressive symptoms in a CWM task.

CWM refers to the capacity to hold and manipulate information in the presence of interference or distraction, a critical function in daily cognitive tasks. Research has shown that CWM is distinctly affected by self-referential processing and mind-wandering, particularly under conditions that evoke personal concerns or self-related thoughts (Van Vugt & Broers, 2016). These conditions can significantly alter the efficiency with which working memory operates, either by enhancing the salience of distractions or by complicating the effort needed to maintain focus. This phenomenon is particularly found in individuals with heightened vulnerability to depression, where CWM is not only a measure of memory capacity but also an indicator of the cognitive impact of depressive symptoms. In our study, SRP was manipulated within the CWM task by having participants evaluate personality trait words (e.g., "Am I kind?") for self-referential processing, compared to evaluating neutral object words (e.g., "Can this fit in a shoebox?"). This manipulation aimed to trigger self-referential thinking, which is more frequent and impactful in individuals with depression. Such individuals are prone to greater self-focus and rumination, potentially exacerbating the cognitive load and affecting memory performance during the task (Daamen et al., 2016; Van Vugt & Broers, 2016).

This research utilizes an existing dataset collected for a study by Sheng et al. (in preparation), focusing on the vulnerability to depression and its impact on cognitive processes through a CWM task during self-referential processing. By leveraging this dataset, we specifically investigate how the self-referential stickiness of mind-wandering influences memory performance within a CWM task, while also examining the effects of varying levels of depression.

The research aims to explore the correlation between mind-wandering, specifically its "stickiness," within the context of depressive symptoms and seeks to investigate how the difficulty of disengaging from spontaneous, self-generated thoughts impacts memory. This study extends the findings of Van Vugt & Broers (2016), who used a Sustained Attention to Response Task (SART) and highlighted that higher stickiness levels are correlated with increased off-task thinking and inconsistent response times. Our study, however, uses a different task—a CWM task—to build on these findings by examining the specific effects on memory accuracy, particularly in the context of depressive symptoms, with SRP as a prevalent cognitive process in depression. By utilizing the CWM task, we aim to provide a deeper understanding of how sticky thinking influences cognitive performance in a different experimental context.

By linking cognitive processes to empirical data on depression and mind-wandering, this research aims to deepen the understanding of cognitive vulnerabilities associated with depressive states. Specifically, this thesis investigates the cognitive phenomenon of mind-wandering, with a focus on its "stickiness" and its impact on memory processes within the context of depressive symptoms during self-referential processing. By examining how varying levels of depressive symptoms influence individuals' engagement in mind-wandering and its consequent impact on memory performance, this study aims to offer valuable insights into the cognitive dynamics within the CWM.

The study investigates how task conditions (self-referential vs. control) affect memory accuracy within a CWM task. Initially, we examine whether these conditions influence memory recall ability, particularly in individuals with depressive states. Building on this, we assess if individuals with higher levels of depression experience more sticky thinking—persistent and intrusive

thoughts—compared to those with lower levels of depression, and how this varies between task conditions. Finally, we evaluate the combined effect of stickiness and depression on memory recall accuracy, examining their interaction across both self-referential and control conditions.

By integrating these elements, we could gain further understanding on to the research question of this study: *"How does the self-reported stickiness of mind-wandering CWM tasks affect the memorization accuracy in individuals with varying levels of depressive symptoms?"*.

Based on the previous findings, in the current study, it is hypothesised that: individuals with higher levels of depression will show worse recall accuracy in CWM tasks due to their increased stickiness on mind-wandering. Additionally, as indicated by existing work on related fields, enhanced self-referential processing with more "sticky mind-wandering" (i.e., persistent and intrusive) would be shown among those with severer depressive symptoms. Furthermore, this stickiness, which is suggested to negatively affect cognitive performance, is expected to result in decreased recall accuracy in the CWM task.

2 Methods

This study leverages an existing dataset previously collected and described in the study by Sheng et al. (in preparation), which examined the vulnerability to depression and its impact on cognitive processes through a complex working memory task. The methodology detailed below is adapted from their experimental procedures.

Participants

This study utilizes an existing dataset, originally collected to evaluate depression vulnerability among young adults aged 18 to 35 years. Initially, 111 participants completed three online questionnaires designed to assess their levels of depression vulnerability. The questionnaires lasted about 10-15 minutes, with an incentive of a chance to win a €20 gift card.

After screening for eligibility criteria, 111 participants were included in the study. Participants were then ranked based on the total Z-scores obtained from the questionnaires. Only those within the top and bottom 25 percent of the distribution were initially considered for further experimental tasks. This selection process aimed to focus on individuals at the extremes of depression vulnerability.

From this process, 46 participants completed the follow-up laboratory session, after excluding nine due to non-responsiveness. The final sample consisted of 31 females, 11 males, and 4 others, with an average age of 23.65 years (SD = 3.659). It included 38 non-native and 8 native English speakers. Each participant received €8 as compensation for the approximately 45-minute lab session.

The original data collection received ethical approval from the Research Ethics Review Committee (CETO) of the Faculty of Arts at the University of Groningen and was conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from all 46 participants who took part in the study.

Apparatus and Setting

The entire experiment was conducted in a lab room within the Bernoulliborg building, located on the Zernike Campus of the University of Groningen. The setup, in the quiet lab room, included a table and a chair for the participant, along with a computer that displayed the task. An experimenter was present in the room to address any questions during the task. The experimenter was also seated in the room on a chair behind a desk. A cupboard was positioned between both desks of the participant and the experimenter, to prevent the participant being distracted by the presence of the experimenter.

Instruments

Depression Vulnerability

The dataset includes responses from participants, who were evaluated to determine their levels of depression vulnerability using three validated self-report questionnaires (Yang et al., 2022). These questionnaires, collectively, were designed to assess various aspects of depression vulnerability.

1. *The Perseverative Thinking Questionnaire (PTQ)* (Ehring et al., 2011)

   This questionnaire measures repetitive negative thinking. It consists of 15 items rated on a 5-point Likert scale from 0 (never) to 4 (almost always). The total score ranges from 0 to 60. Higher scores indicate more severe depressive tendencies.

2. *The Ruminative Response Scale (RRS)*(Nolen-Hoeksema & Morrow, 1991)

   This questionnaire is designed to measure rumination; how individuals respond to their depressive symptoms. It consists of 22 items scored on a 4-point scale from 1 (almost never) to 4 (almost always). The total score ranges from 22 to 88. Higher scores indicate a stronger tendency to engage in depressive rumination.

3. *The Center for Epidemiologic Studies Depression Scale (CES-D)* (Radloff, 1977)

   This questionnaire measures the severity of depressive symptoms. It consists of 20 items rated on a 4-point scale from 0 (rarely or none of the time) to 3 (most or all of the time). Four items are reverse scored. The total score ranges from 0 to 60. Higher scores indicate more severe depressive symptoms.

To evaluate depression vulnerability, scores from each questionnaire were first standardized into Z-

scores. The Z-score for a questionnaire was calculated by subtracting the mean score of that questionnaire from the participant's score and then dividing the result by the standard deviation of scores for that questionnaire. Subsequently, the final Z-score for each participant was computed by summing the Z-scores of all three questionnaires. This combined Z-score was then used to assess the overall depression vulnerability of each participant. Using Z-scores allows for standardization, making it possible to compare scores from different questionnaires on a common scale. This method ensures that each questionnaire contributes equally to the overall depression vulnerability measure and helps in identifying individuals with high or low vulnerability by placing them in the upper or lower 25th percentile of the Z-score distribution. Those within the upper and lower 25th percentile of the total z-score distribution were categorized into either the more depressed group or the less depressed group. The results of this method can be found in the Results section.

Complex Working Memory Task

The Complex Working Memory (CWM) task is used to assess memory performance and level of stickiness under different conditions. The general details of the task are as follows:

1. Task Presentation: A computer-based task where participants are required to recall information presented on the screen and answer to multiple thought-probes.

2. Self and Shoebox Conditions: The task includes self-referential prompts (e.g., assessing personal traits) and control prompts (e.g., evaluating neutral objects).

3. Memory Accuracy Measurement: Accuracy is measured by the number of correctly recalled items.

4. Stickiness of thoughts Measurement: Thought probes are used to measure the stickiness of mind-wandering. Participants rate the difficulty of disengaging from spontaneous thoughts on a scale from 1 to 5.

Procedure

Prior to starting with the complex working memory (CWM) task, participants received detailed instructions in English, by the experimenter, to ensure they fully understood the task. The session began with one practice block, consisting of 4 trials, during which participants could ask questions to the experimenter to clarify any uncertainties about the process. After ensuring clarity, the experiment could start. The CWM task was adapted from another study (Huijser et al., 2018) where it was used to examine how self-referential processing affects self-generated thought during demanding cognitive tasks. By testing a computational cognitive model, the researchers aimed to determine if self-referential thoughts increased cognitive distractions and impacted performance. For our study, the CWM task was used to assess memory performance and stickiness in both the SRP condition and shoebox condition.

The CWM task was structured into three blocks, each containing 16 trials. Participants had the flexibility to take breaks within these blocks, to maintain focus throughout the session. Within each trial, the "X" appeared three or four times (span), and participants were asked to memorize the locations of the "X" on a 4x4 grid. Following each "X", a decision-making task was presented. After all "X's" had been presented, participants entered the recall stage which was often followed by four thought-probe questions (see Figure 2.1. During one trial the participants were expected to remember the locations of the letter "X" in sequential order for later recall and also to respond to the decision-making task as fast and as accurately as they can.

In the decision-making task, the participants were presented with two conditions. The self and the shoebox condition. The participants were expected to respond to the task by either responding 'yes' or 'no' by clicking on the corresponding key on the keyboard. The self condition focused on evaluating how individuals respond to stimuli that require them to reflect on themselves. In this condition, participants were presented with personality trait words and were asked to assess whether these traits describe them (e.g., "Am I kind?"). This method stimulates participants to engage in self-

reflection, thereby activating self-referential thinking processes. The shoebox condition served as a control to the self condition. In this setup, participants were presented with object words and were asked to decide if the item could fit inside a shoebox. This task is designed to engage cognitive processes without eliciting self-referential thoughts, thereby providing a baseline measure of cognitive performance and spontaneous thinking that is not influenced by self-reflection. By comparing performance and spontaneous thought patterns between these two conditions, the study aims to uncover how self-referential processing might influence cognitive functions.

To examine the spontaneous thoughts of the participants, four thought-probe questions were randomly presented during the blank period prior to the recall stage (Huijser et al., 2018). The four different thought-probes were the following:

1. *What were you thinking about right before you had to answer?* This is used to access the content of thoughts during the blank period prior to the recall phase in order to categorize the responses as "on-task" or "off-task" thinking.

2. *To what extent were your thought self-focused?* This question is used to assess the self-focus of thought. Responses could range from 1 (completely other-focused) to 5 (completely self-focused).

3. *How difficult was it to disengage from the thought?* This was used to assess the stickiness of thought. Responses could range from not sticky to very sticky, from 1 (very easy) to 5 (very difficult).

4. *How positive or negative were your thoughts?* This was used to assess the valence of thought. Responses could range from 1 (very negative thoughts) to 5 (very positive thoughts).

In this study, we are only interested in the stickiness of thought. Therefore we only focused on the third thought probe question: "How difficult was it to disengage from the thought?"

In the CWM task, there was a total of 48 trials. This included 24 trials for each span length (three and four) and 24 trials for each condition (SRP and shoebox). In each block, 8 of the 16 trials were followed by thought probe questions. Thus, out of the 48 trials, 24 were followed by a thought probe.

Statistical Analysis

All analyses were conducted using R software (version 4.4.1). Solely the trials followed by a thought probe were included, resulting in the exclusion of half of the trials from the analysis.

Linear mixed-effects models were utilized to examine the interplay between variables, specifically using the lmer function to analyze continuous dependent variables (recall accuracy, stickiness) against the independent variables (stickiness, condition, span and depression level). Linear mixed-effects models were chosen due to their ability to account for both fixed and random effects, providing a more robust analysis. In these models, the individual subjects were treated as random effects to account for the variability between participants. Additionally, t-tests were employed to compare the means of different groups and assess significant differences between conditions. Interaction effects were also examined in the different models to understand how the relationship between variables might change under different conditions. Four specific models were developed:

- Model 1: This model assessed the effect of cognitive load on accuracy, including the interaction between cognitive load(span) and condition (self/shoebox)

- Model 2: This model assessed the effects of depression level (less/more) and condition (self/shoebox) on memory recall accuracy, including the interaction between these variables.

- Model 3: This model assessed the effect of depression(less/more) and condition(self/shoebox) on stickiness, including the interaction between these variables.

- Model 4: This model examined how self-reported stickiness during the complex working memory task influenced recall accuracy in individuals with varying depression levels.

The Bayesian model comparison method was used to assess the fit of the linear mixed-effects models (see Table 3.2). Bayes Factors (BF) were

estimated to assess the models' relevance using the 'ImBF' function from the 'BayesFactor' package. BFs can measure one model's superiority over another (for example, using the elements of interest). In terms of BF interpretation, a BF less than 1 indicates support for the null or simpler model; a BF between 1 and 3 suggests weak evidence for the alternative or more complex model; a BF between 3 and 10 indicates moderate evidence in favor of the alternative model; and a BF greater than 10 indicates strong evidence supporting the alternative model. The significance of factors within models was determined based on p-values (< 0.05) and effect sizes, derived from the 'lmer' function of the 'lme4' package in R.

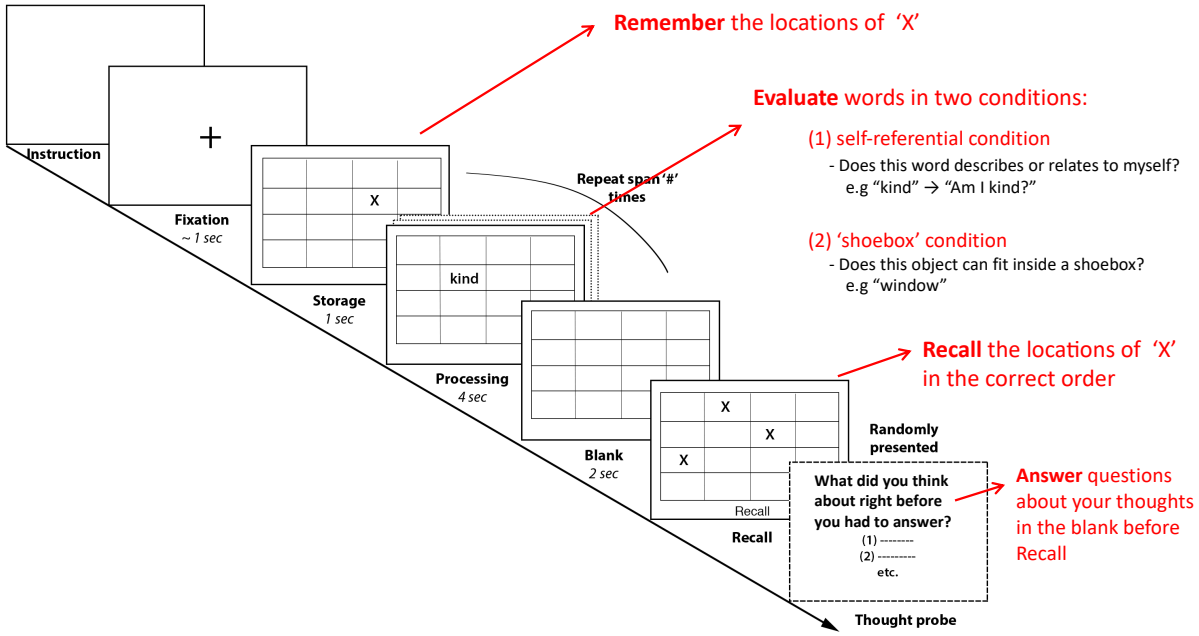


Figure 2.1: Overview of one trial of the complex working memory task. The trial in this figure represents a self condition trial. The diagonal arrow shows the progression of a trial in time.

3 Results

3.1 Verification of less and more depressed groups

To verify whether there was a significant difference between the two groups (less and more depressed) on depression-related symptoms, Yang et al. (2022) examined this group difference on the composite Z-score of three self-report questionnaires using an independent t-test. Table 3.1 shows the mean composite Z-scores and standard deviations for both groups. The results indicate that participants in the more depressed group scored significantly higher on all individual questionnaires and the summed Z-score than the less depressed group ($p < 0.001$, $t = 16.9$, $BF = 3.4e{+}17$), with extremely strong evidence according to the Bayes Factors. Therefore, we can verify that the setup used to categorize the two groups into less and more depressed has succeeded due to significant differences between the groups.

3.2 The effect of cognitive load and SRP on accuracy

Prior to analysing the impact of self-referential processing on memory accuracy, we initially confirmed whether the participants' memory performance decreased as the task difficulty increased. The memory accuracy differences were analysed by examining the changes in spans (3, 4) under both conditions (self vs. shoebox).

The analysis indicated that there was a significant main effect of span on memory accuracy ($\chi^2(1) = 5.74, p = 0.017, \text{BF} = 0.52$), demonstrating that increasing the span from 3 to 4 led to a significant decrease in recall accuracy. In span 3 trials, the mean recall accuracy was 0.867 (SD = 0.188), while in span 4 trials, it was 0.837 (SD = 0.193). This result suggests that the difficulty level, as manipulated by span length, affected participants' ability to recall target items. Nevertheless, the Bayes factor (BF) yielded a weak indication in favour of this model (BF = 0.51922), suggesting that although there is statistical significance, the support for a higher span decreasing recall accuracy was not strong.

Next, we investigated whether memory accuracy was affected by the condition (shoebox vs. self). There was no significant main effect of condition on recall accuracy, according to the ANOVA test comparing the models ($\chi^2(1) = 0.04, p = 0.82, \text{BF} = 0.03$). This suggests that the specific type of the task (whether participants were asked to consider self-referential thoughts or neutral object-related thoughts) does not significantly influence how well they remember information in this context.

The interaction between span and condition on recall accuracy also showed no significant effect, ($\chi^2(1) = 0.47, p = 0.49, \text{BF} = 0.08$), suggesting that the combined influence of span and condition did not significantly impact recall accuracy.

3.3 The effect of SRP on recall accuracy for more and less depressed individuals

In order to further explore the impact of self-referential thinking on accuracy, it is necessary to examine whether this effect varies among persons with higher levels of depression. Analysis revealed that depression does not significantly impact recall accuracy, with the results showing no main effect of depression ($\chi^2(1) = 0.52, p = 0.47, \text{BF} = 0.09$). Additionally, there was no significant main effect of condition (self-referential vs. control) on recall accuracy ($\chi^2(1) = 0.04, p = 0.82, \text{BF} = 0.03$). Importantly, the interaction effect between condition and depression on recall accuracy was also not significant ($\chi^2(1) = 2.2, p = 0.14, \text{BF} = 0.18$). These results indicate that neither the level of depression nor the self condition significantly influenced memory performance in the complex working memory task.

Figure 3.1 illustrates the relationship between more and less depressed individuals and recall accuracy under two different conditions: shoebox (control condition) and self (self-referential condition). In both conditions, the findings depicted that memory recall accuracy was similar for both less and more depressed individuals. The plot shows that recall accuracy does not significantly differ between less and more depressed groups across both conditions. This is consistent with our statistical findings

Table 3.1: Means and standard deviations (between brackets) of self-report questionnaires scores across the less and more depressed groups. (Sheng et al, in preparation)

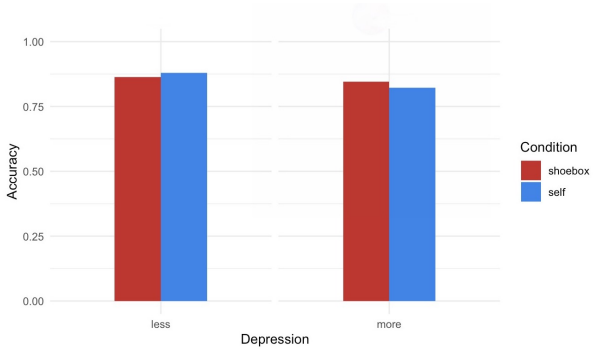
	Less Depressed	More Depressed	t	BF
PTQ	16.43 (6.18)	40.87 (7.55)	12.0***	2.2e+12
RRS	34.35 (6.07)	60.09 (7.65)	12.6***	1.1e+13
CES-D	8.22 (3.94)	31.04 (9.16)	11.0***	1.2e+11
Total Z score	-3.07 (0.88)	3.65 (1.69)	16.9***	3.4e+17

Note: *p < 0.05; **p < 0.01; ***p < 0.001

Table 3.2: Chi-square Goodness of Fit Test and Bayes Factors Results

	$\chi^2(p)$	$p = df$	P - value	Bayes Factor (BF)
Span on accuracy	5.7	1	$< 0.05^*$	0.52
Condition on accuracy	0.04	1	0.82	0.03
Depression on accuracy	0.5	1	0.47	0.09
Stickiness on accuracy	17.7	1	$< 0.001^{***}$	118.42
Depression on stickiness	11.3	1	$< 0.001^{**}$	96.6

Note: *p < 0.05; **p < 0.01; ***p < 0.001



Note: *p < 0.05; **p < 0.01; ***p < 0.001

Figure 3.1: Effect of depression on memory recall accuracy across the two conditions (self vs. shoebox)

3.4 The difference in the average level of sticky thinking between less and more depressed individuals

Our previous analysis indicated that neither task condition nor depression significantly impacted recall accuracy. Consequently, the next step is to investigate whether individuals with higher levels of depression have stickier thoughts compared to those with lower levels of depression under both the self-referential and control conditions. This could clarify if thought stickiness explains the observed lack of significant effects on recall accuracy.

The analysis revealed that depression significantly influences stickiness ($\chi^2(1) = 11.3, p < 0.001, \text{BF} = 96.6$), indicating strong evidence for this effect. Similarly, condition also significantly affects stickiness ($\chi^2(1) = 14.5, p < 0.001, \text{BF} = 182.4$).

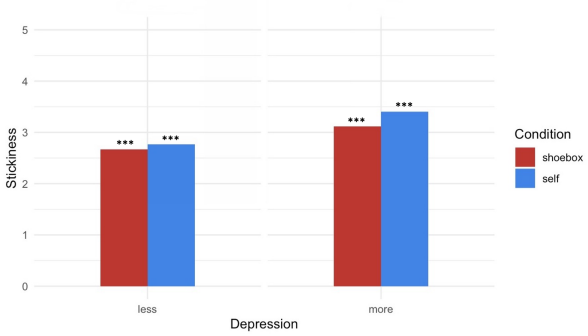
The analysis showed that individuals with higher levels of depression reported stickier thoughts compared to those with lower levels of depression. Specifically, the mean stickiness score for individuals with higher depression was 3.26 (SD = 0.76), whereas the less depressed individuals reported less sticky thoughts, with a mean score of 2.72 (SD = 0.81).

When inspecting the impact of condition on stickiness, the findings suggest that the self-referential condition resulted in stickier thoughts, compared to the shoebox condition. The mean stickiness score in the shoebox condition was 2.90 (SD = 0.82), while in the self-referential condition, it was higher at 3.08 (SD = 0.83).

Additionally, the analysis revealed weak evidence

for the interaction effect of depression and condition on stickiness ($\chi^2(1) = 3.7, p = 0.05, \text{BF} = 1.4$), suggesting that the relationship between depression and stickiness varies by task type, with individuals with higher depressive symptoms finding self-referential tasks especially challenging, leading to greater stickiness compared to the shoebox condition.

Figure 3.2 illustrates the impact of depression on stickiness, as described above. The graph shows that individuals with higher levels of depression reported greater stickiness in both conditions. Notably, the increase in stickiness is more pronounced in the self-referential condition.



Note: *p < 0.05; **p < 0.01; ***p < 0.001

Figure 3.2: Effect of depression severity on stickiness across the two conditions (self vs. shoebox)

3.5 What is the effect of stickiness and depression on memory recall accuracy for individuals in both the self condition and shoebox condition?

The analysis investigated the interaction effects of stickiness and depression, as well as stickiness and condition, on memory recall accuracy in both the self and the shoebox condition. The results indicated that the interaction effect of stickiness and depression on recall accuracy was not significant ($\chi^2(1) = 2.5, p = 0.11, \text{BF} = 0.141$), suggesting weak evidence against the model including this interaction. Interaction Effects of Stickiness and Depression on Memory Recall Accuracy The analysis investigated the interaction effects of stickiness and depression, as well as stickiness and condition, on memory recall accuracy in both the self and shoebox conditions. Initially, the results indicated that the interaction effect of stickiness and depression on recall accuracy was not significant($\chi^2(1) = 2.5, p = 0.11, \text{BF} = 0.141$), suggesting weak evidence against the model including this interaction.

Further analysis separated the interaction effects of stickiness and depression for each condition. In the self condition, the interaction effect was found to be non-significant ($\chi^2(1) = 0.087, p = 0.77, \text{BF} = 0.052$), indicating very weak evidence for the inclusion of this interaction in the model (see Figure 3.3. Similarly, in the shoebox condition, the interaction effect was also non-significant ($\chi^2(1) = 1.7969, p = 0.18, \text{BF} = 0.129$), suggesting weak evidence for the interaction model (see Figure 3.4. These results suggest that the interaction between stickiness and depression does not significantly influence memory recall accuracy in either the self or shoebox condition. Similarly, the interaction effect of stickiness and condition on recall accuracy also did not yield significant results ($\chi^2(1) = 0.01, p = 0.91, \text{BF} = 0.031$).

Additionally, the three-way interaction between depression, stickiness and condition was also not significant, ($\chi^2(2) = 1.9, p = 0.40, \text{BF} = 0.010$) indicating that the combined effect of stickiness and depression on recall accuracy does not significantly differ between the self-referential and control tasks.

These findings suggest that while stickiness and depression individually impact memory recall accuracy, their combined effect does not significantly alter the outcome. This means that the presence of both high stickiness and high depression does not intensify the decline in recall accuracy more than each factor does on its own. Similarly, the type of task condition (self-referential vs. shoebox) does not significantly interact with stickiness to influence recall accuracy. This indicates that the negative impact of sticky thoughts on memory recall is consistent across different types of tasks, and the depressive symptoms do not amplify the stickiness effect in any specific task condition.

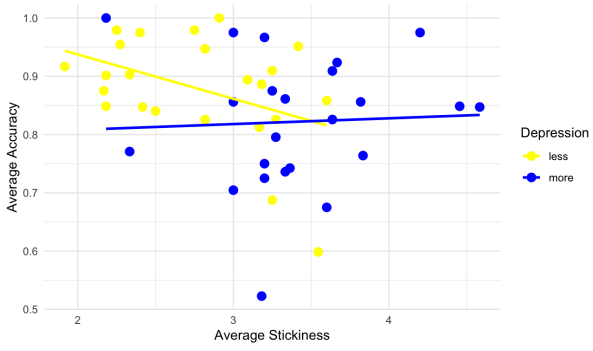
Despite the lack of significant interaction effects, the data reveal some notable trends. In the self-referential condition, less depressed individuals with stickier thoughts tend to have poorer accuracy, while more depressed individuals show no sig-

nificant difference in accuracy based on stickiness. This suggests a potential trend where less depressed individuals are more affected by the stickiness of their thoughts when engaged in self-referential processing.

In the shoebox condition, both less and more depressed individuals with higher stickiness exhibit poorer recall accuracy compared to those with lower stickiness. This trend indicates that regardless of depression level, stickier thoughts in the shoebox condition are associated with decreased recall accuracy.

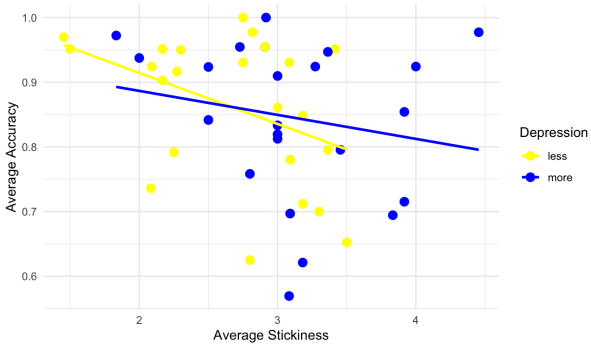
Figures 3.3 and 3.4 illustrate these relationships. In both figures, the trends suggest that for less depressed groups, as stickiness increases, recall accuracy decreases significantly compared to the more depressed group. However, the statistical tests do not support these interactions as significant.

The overall findings indicate that stickiness significantly decreases recall accuracy, while depression significantly increases stickiness. However, the interaction effects between stickiness and depression, as well as the three-way interaction with condition, are not statistically significant. This suggests that while stickiness negatively impacts recall accuracy and depression exacerbates stickiness, their combined effect does not significantly influence memory recall accuracy, regardless of the condition.



Note: *p < 0.05; **p < 0.01; ***p < 0.001

Figure 3.3: Interaction effect of stickiness and depression on recall accuracy in the self condition



Note: *p < 0.05; **p < 0.01; ***p < 0.001

Figure 3.4: Interaction effect of stickiness and depression on recall accuracy in the shoebox condition

4 Discussion

By utilizing a dataset from Sheng et al. (in preparation), the current study examined the interactive effects of depression, self-referential processing and stickiness of mind-wandering on recall accuracy under a complex working memory task

We hypothesized that individuals with higher levels of depressive symptoms would exhibit lower memory recall accuracy due to increased stickiness of mind-wandering, particularly in tasks involving SRP.

First of all, our results found a significant impact of task span on recall accuracy. Specifically, increasing the task span from 3 to 4 led to a significant decrease in recall accuracy. This indicates that the difficulty level, as manipulated by span length, effectively impacts participants' ability to recall target items. This finding aligns with existing literature suggesting that greater cognitive load reduces working memory performance (Barrouillet et al., 2007).

However, our results did not show significant main effects of depression or SRP condition on recall accuracy. This suggests that the specific task condition (whether it involves self-referential processing or not) and the level of depression do not significantly influence memory. This could suggest that the cognitive load imposed by the task might overshadow the specific influence of self-referential processing. Additionally, the interaction effects between depression and the self condition

were not statistically significant, indicating that the expected exacerbation of cognitive load by SRP in individuals with higher depressive symptoms was not observed in this study.

When examining the nature of sticky thoughts, our study revealed that depression was significantly associated with increased stickiness. Participants with higher depressive symptoms reported greater difficulty disengaging from spontaneous, off-task thoughts. This aligns with previous research indicating that depressed states enhance the persistence of negative, self-referential thoughts(Nolen-Hoeksema et al., 2008).

Unlike our study, which utilized a complex working memory task to assess the impact of depressive symptoms on cognitive performance, Nolen-Hoeksema et al. (2008) employed a rumination induction method. In their study, participants focused on the meanings, causes, and consequences of their feelings, which is a more direct measure of rumination. Additionally, Nolen-Hoeksema et al. (2008) did not use a cognitive task to assess stickiness. Instead, they measured rumination through self-report questionnaires and observational methods during induced rumination periods.

Despite these methodological differences, both studies found that increased stickiness of thoughts negatively impacted cognitive performance. In our study, this increased stickiness led to lower recall accuracy in self and shoebox conditions. However, the interaction between stickiness levels and task conditions (self vs. shoebox) on recall accuracy was not statistically significant. This indicates that while stickiness affects memory performance, the specific task condition (whether it involves self-referential processing or not) does not influence this effect. Additionally, the interaction of depression with task conditions on recall accuracy was also not statistically significant. Thus, results for more depressed individuals did not lead to significantly less accuracy, as we hypothesised.

Contrary to our hypothesis, the self-referential processing condition did not significantly decrease recall accuracy compared to the shoebox condition. This unexpected result could be explained by several factors. One possibility is that the self-referential and control tasks might have similar cognitive demands in the context of our study, especially given the nature of the working memory tasks used. However, this is inconsistent with previous findings by Huijser et al. (2018), which showed distinct cognitive demands between self-referential and non-self-referential tasks. Another explanation could be related to our sample composition. The participants, mainly university students, might not have experienced depressive symptoms severe enough to exhibit significant differences between conditions. Additionally, the linguistic background of participants (with a significant proportion being non-native English speakers) might have influenced their processing of self-referential and control tasks, potentially masking the true effects of self-referential processing on memory performance (Rohrer et al., 2020).

In summary, our findings confirm that depression is associated with increased stickiness of thoughts, the differential effects of self-referential processing on memory recall accuracy were not observed.

Despite the lack of significant interaction effects between task conditions (self vs. shoebox) and depression levels on memory recall, our study did find a significant impact of stickiness on recall accuracy. This could imply that while depression increases the stickiness of thoughts, it may not necessarily be specific to self-referential content. Self-referential processing, which involves evaluating information in relation to oneself, seems to increase the stickiness of thoughts in individuals with higher levels of depression. However, these self-focused thoughts did not significantly disrupt memory performance in the context of this study.

Additionally, while the CWM task included a thought probe related to how much participants' thoughts were self-related, we did not analyze this specific measure in our current analysis. Measuring the amount of self-related thoughts directly could provide further insights into the role of self-referential processing in cognitive performance. Future research should include a thorough analysis of these self-related thought probes to clarify their specific impact on cognitive tasks.

Our results indicate that depression is significantly associated with increased stickiness of thoughts and that higher levels of stickiness negatively impact memory recall accuracy. This implies that techniques aimed at reducing the stickiness of negative, self-referential thoughts could be beneficial in improving cognitive function in depressed individuals. For example, mindfulness-based interventions or other therapeutic approaches that aim

to modify self-referential processing patterns may help reduce the cognitive decline in memory recall associated with depression (Lin et al., 2018). By targeting the persistence of self-focused thoughts, these interventions could potentially mitigate the cognitive interference caused by stickiness, highlighting the need for therapeutic strategies that specifically address these cognitive patterns to improve memory performance in depressed individuals.

Several limitations should be considered when interpreting our findings.

Firstly, the study's reliance on a sample of university students, who may not exhibit severe depressive symptoms, limits the generalizability of the results to clinical populations (Andrews & Wilding, 2004). University students often experience situational depressive symptoms that might not capture the full spectrum of depression seen in clinical settings. This full spectrum includes more severe and chronic symptoms, comorbid conditions like anxiety or substance abuse, and significant impacts on daily functioning (Andrews & Wilding, 2004). These aspects are crucial for understanding the broader implications of depression on cognitive processes such as self-referential processing and memory recall accuracy.

Future research could benefit from examining the questionnaire scores to determine how closely they align with clinical thresholds for depression. Including participants with a broader range of depressive symptoms, particularly those meeting clinical criteria would provide a more comprehensive understanding of how depression affects cognitive processes.

Secondly, the linguistic background of participants, with a significant proportion being non-native English speakers, might have influenced the processing of self-referential and control tasks. Non-native speakers may face additional cognitive load when processing tasks in a non-native language, which could potentially mask the true effects of self-referential processing on memory performance (Rohrer et al., 2020). This extra cognitive load could dilute the differences between self and shoebox conditions, leading to a potential underestimation of the impact of SRP. Future research should consider only conducting the experiments on participants who are all native speakers.

Future research could also broaden the scope of this study to expand on the findings by including a second experiment with participants who are native speakers of a different language. This would allow for an exploration of whether the results observed in English speakers are consistent across different linguistic backgrounds. By investigating the cognitive processing of self-referential and control tasks in a linguistically diverse sample, future studies could assess the potential influence of language on mind-wandering stickiness and memory recall accuracy.

Additionally, in our task, which consisted of three blocks (each with 16 trials), we only focused on half of the trials which were followed by the thought probes. Since we only analyzed these trials, it could have limited our ability to detect significant differences. Future studies should consider increasing the number of trials analyzed, thereby increasing the statistical power and the overall robustness of the results. However, making the task longer could also present complications. The task is already one hour long, and extending it further could lead to participant fatigue, decreased motivation, and reduced data quality due to lapses in attention. Therefore, future studies should consider the balance between increasing the number of trials for greater statistical power and maintaining a manageable task length to ensure high-quality data. Analyzing all existing trials without extending the task duration might be a viable compromise to achieve more robust results without overburdening the participants.

Moreover, this study examined multiple relationships and causalities between variables, specifically focusing on the associations between depression, self-referential processing (SRP), stickiness, and memory recall accuracy. While we observed significant associations, we cannot fully determine the directionality of these relationships because the data was collected at a single point in time (cross-sectional study). This limitation means we can only identify correlations, not causations, making it unclear whether depression leads to increased stickiness and reduced memory recall accuracy or if the difficulty in disengaging from sticky thoughts exacerbates depressive symptoms.

To address this limitation, longitudinal studies are needed. Such studies could explore how changes in depressive symptoms over time influence SRP and memory performance. Additionally, they could

assess whether interventions targeting SRP lead to sustained improvements in cognitive function, providing deeper insights into the directionality of these effects. Longitudinal data would help to establish causal relationships by observing how variables change and interact over time.

Finally, our study did not account for the potential impact of other psychological factors, such as anxiety and stress, which often co-occur with depression and can affect cognitive performance. Anxiety and stress can introduce additional cognitive load and distraction, potentially confounding the results by making it difficult to isolate the specific effects of depression and self-referential processing. These unmeasured factors could mask or exaggerate the true effects of depression and SRP. Studies have shown that social anxiety disorder (SAD) is associated with aberrant self-referential processing (SRP) and that these neural correlates are related to clinical improvement following pharmacological and cognitive-behavioral treatments (Yoon et al., 2019). Future studies should include measures of these co-occurring psychological factors to separately examine their individual and combined effects on memory recall accuracy. However, incorporating additional variables would complicate the research design, requiring more comprehensive data collection and analysis to ensure robust and reliable results.

In summary, our study provides valuable insights into how depression, self-referential processing (SRP), and stickiness of mind-wandering interrelate and affect memory recall accuracy. We found that higher levels of depressive symptoms are associated with increased stickiness, which negatively impacts memory performance. Although we did not observe differential effects of self versus shoebox conditions, our findings highlight the significant cognitive burden of depression. Despite the study's limitations, such as the influence of co-occurring psychological factors and the need for a larger sample size, our research underscores the importance of further studies to confirm and extend these findings.

5 Conclusions

This thesis explored the relationships between depression, self-referential processing (SRP), mind-wandering stickiness, and their effects on memory recall accuracy in complex working memory (CWM) tasks. The research question addressed was: "How does the self-reported stickiness of mind-wandering during complex memory tasks affect memorization accuracy in individuals with varying levels of depressive symptoms?"

Our findings show that while depression is associated with increased stickiness of mind-wandering, which is the difficulty in disengaging from spontaneous thoughts, there was no significant direct impact of depression on memory recall accuracy. This suggests that although depressive symptoms make it harder for individuals to shift away from sticky thoughts, this did not translate to a measurable decrease in recall accuracy in our study. However, we did find that increased stickiness of thoughts negatively impacted recall accuracy. This indicates that stickier thoughts consume cognitive resources necessary for task performance, leading to reduced memory recall accuracy regardless of the level of depression.

Furthermore, we did not observe significant differences in recall accuracy between self and shoebox conditions. This indicates that the general cognitive demand of the tasks might overshadow the specific impact of self-referential content. Additionally, there were no significant interaction effects between task conditions (self vs. shoebox) and depression levels on memory recall accuracy.

Our study's limitations include a homogeneous sample of university students and linguistic diversity that might have influenced the results. Future research should consider more diverse and linguistically homogeneous samples and analyze a more comprehensive set of trials to enhance robustness and statistical power.

In conclusion, while depressive symptoms are linked to increased stickiness of mind-wandering, this stickiness did not significantly impact memory recall accuracy within the context of our study. However, increased stickiness of thoughts was found to negatively affect memory recall accuracy. These findings highlight the complexity of the relationship between depression, mind-wandering, and cognitive performance. Future research should further clarify these relationships and investigate interventions aimed at reducing sticky thoughts and improving cognitive function in individuals with depression.

References

Allison, G. O., Kamath, R. A., Carrillo, V., Alqueza, K. L., Pagliaccio, D., Slavich, G. M., ... Auerbach, R. P. (2023). Self-referential processing in remitted depression: an event-related potential study. *Biological Psychiatry Global Open Science*, *3*(1), 119–129.

Andrews, B., & Wilding, J. M. (2004). The relation of depression and anxiety to life-stress and achievement in students. *British journal of psychology*, *95*(4), 509–521.

Barrouillet, P., Bernardin, S., Portrat, S., Vergauwe, E., & Camos, V. (2007). Time and cognitive load in working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(3), 570.

Brockmeyer, T., Zimmermann, J., Kulessa, D., Hautzinger, M., Bents, H., Friederich, H.-C., ... Backenstrass, M. (2015). Me, myself, and i: self-referent word use as an indicator of self-focused attention in relation to depression and anxiety. *Frontiers in psychology*, *6*, 1564.

Daamen, J., Vugt, M. v., & Taatgen, N. (2016). Measuring and modeling distraction by self-referential processing in a complexworking memory span task. In *Proceedings of the annual meeting of the cognitive science society* (Vol. 38).

Ehring, T., Zetsche, U., Weidacker, K., Wahl, K., Schönfeld, S., & Ehlers, A. (2011). The perseverative thinking questionnaire (ptq): Validation of a content-independent measure of repetitive negative thinking. *Journal of behavior therapy and experimental psychiatry*, *42*(2), 225–232.

Huijser, S. (2022). The wandering mind: investigating what drives self-generated thinking and determines its adaptive or maladaptive consequences.

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

Joormann, J., & Gotlib, I. H. (2010). Emotion regulation in depression: Relation to cognitive inhibition. *Cognition and Emotion*, *24*(2), 281–298.

Joormann, J., Levens, S. M., & Gotlib, I. H. (2011). Sticky thoughts: Depression and rumination are associated with difficulties manipulating emotional material in working memory. *Psychological science*, *22*(8), 979–983.

Lin, Y., Callahan, C. P., & Moser, J. S. (2018). A mind full of self: Self-referential processing as a mechanism underlying the therapeutic effects of mindfulness training on internalizing disorders. *Neuroscience & Biobehavioral Reviews*, *92*, 172–186.

Mooneyham, B. W., & Schooler, J. W. (2013). The costs and benefits of mind-wandering: a review. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, *67*(1), 11.

Nejad, A. B., Fossati, P., & Lemogne, C. (2013). Self-referential processing, rumination, and cortical midline structures in major depression. *Frontiers in human neuroscience*, *7*, 666.

Nolen-Hoeksema, S., & Morrow, J. (1991). A prospective study of depression and posttraumatic stress symptoms after a natural disaster: the 1989 loma prieta earthquake. *Journal of personality and social psychology*, *61*(1), 115.

Nolen-Hoeksema, S., Wisco, B. E., & Lyubomirsky, S. (2008). Rethinking rumination. *Perspectives on psychological science*, *3*(5), 400–424.

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

Rohrer, P. L., Delais-Roussarie, E., & Prieto, P. (2020). Beat gestures for comprehension and recall: Differential effects of language learners and native listeners. *Frontiers in Psychology*, *11*, 575929.

Smallwood, J., & Schooler, J. W. (2013). The restless mind.

Van Vugt, M. K., & Broers, N. (2016). Self-reported stickiness of mind-wandering affects task performance. *Frontiers in psychology*, *7*, 189779.

Vries, S. d. (2021). *Classifying the stickiness of mind-wandering* (Unpublished doctoral dissertation).

Yang, H., Paller, K. A., & van Vugt, M. (2022). The steady state visual evoked potential (ssvep) tracks "sticky" thinking, but not more general mind-wandering. *Frontiers in Human Neuroscience*, *16*, 892863.

Yoon, H.-J., Seo, E. H., Kim, J.-J., & Choo, I. H. (2019). Neural correlates of self-referential processing and their clinical implications in social anxiety disorder. *Clinical Psychopharmacology and Neuroscience*, *17*(1), 12.