Mind over Memory: Exploring the Association between Anxiety and Suppression-Induced Forgetting

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Abstract

Challenges associated with suppressing unwanted memories are intricately connected to deficits in executive control, which, in turn, are implicated in intrusive thoughts and anxiety disorders, particularly Generalized Anxiety Disorder (GAD). To investigate this relationship, a replication of Anderson and Green's (2001) Think/No-Think (TNT) paradigm was conducted. The TNT experiment aimed to explore whether actively suppressing memories leads to Suppression-Induced Forgetting (SIF). Participants initially learned word pairs and were subsequently instructed to suppress words using either Thought Avoidance (TA) or Thought Substitution (TS). SIF was then tested under two conditions: Same Probe (SP), and Independent Probe (IP), to test cue-independent forgetting. While the study found partial evidence supporting SIF for TS in SP, results for TA and IP were inconclusive. This raises questions about the role of inhibition in the suppression process, lending support to an alternative explanation involving interference. Following the experiment, participants' GAD levels were assessed. Correlations between GAD levels and SIF were inconclusive, suggesting a more complex relationship between anxiety and memory suppression. Clinical implications advocate for incorporating TS in therapeutic interventions targeting effective memory suppression. The study underscores the need for further research on anxiety and SIF, acknowledging the methodological challenges faced in the current study.

Keywords: anxiety, generalized anxiety disorder, executive control, suppression, Suppression-Induced Forgetting, Think/No-Think

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"Of this at least, I feel assured, that there is no such thing as forgetting possible to the mind;" (De Quincey, 1821). While Thomas De Quincey's assertion challenges the notion of forgetting, this paper delves into the intricate realms of memory suppression as studied through the Think/No-Think (TNT) paradigm by Anderson and Green (2001), and its potential links to anxiety. Understanding this dynamic becomes particularly relevant within the context of clinical phenomena, shedding light on how the inability to forget may contribute to the development and maintenance of anxiety. Anxiety is a prevalent mental health issue in the Netherlands with a significant lifetime DSM-5 prevalence of 28.6% and a 12-months prevalence of 15.2% (ten Have et al., 2023). Specifically, there is a need for further research on the causes of Generalized Anxiety Disorder (GAD), which has a lifetime prevalence of 9.5% and a 12-month prevalence of 3.8% in the Netherlands. This crucial for developing more effective treatments and interventions to address the specific challenges associated with this prevalent anxiety disorder.

Anxiety and Executive Control

The Executive Deficit Hypothesis (EDH) posits that difficulties in suppressing unwanted memories are linked to deficits in executive control mechanisms (Levy & Anderson, 2008). Executive control involves higher-order cognitive processes responsible for regulating cognitive functions. Specifically, deficits in cognitive control are associated with difficulties in suppression, contributing to the occurrence of intrusive thoughts (Chen et al., 2022; Erskine et al., 2007; Warren et al., 2021). Intrusive thoughts are particularly relevant to anxiety disorders, where they are a primary source of distress (König et al., 2021; Magee et al., 2012). In the context of Generalized Anxiety Disorder (GAD), the inability to control

worrisome thoughts is associated with increased comorbidity and greater disorder severity (Hallion & Ruscio, 2013; Hallion et al., 2017).

Attentional Control Theory. The Attentional Control Theory (ACT) presents an alternative perspective (Eysenck et al., 2007). It emphasizes the role of individual differences in executive control and their correlation with cognitive instability. Anxious individuals exhibit a bias in allocating attentional resources to threat-related stimuli, both internal (worrisome thoughts) and external (threatening distractors). In contrast to the EDH, ACT suggests that anxiety itself may contribute to impaired executive control mechanisms and thus difficulties in suppressing memories, reversing the direction of influence.

Exploring Executive Control Mechanisms in Memory Suppression

Anderson and Green's (2001) laid the foundation for investigating executive control processes involved in suppressing unwanted memories with the TNT paradigm, opening doors to explore the potential clinical implications of intentional forgetting. Rooted in the theories of Freud (1969), interpreted by Anderson and Green (2001), the TNT paradigm is influenced by the concept of repressing unpleasant memories. Repression is characterized by the unconscious process of avoiding distressing memories. Although these memories are not actively accessible in conscious awareness, they persist in the latent layers of the mind. In contrast, the TNT paradigm operationalizes the concept of suppression, a conscious effort to inhibit the recall of memories, resulting Suppression-Induced Forgetting (SIF). In the TNT experiment, a combination of a learning phase, a suppression phase, and memory tests in the final phase are utilized to examine the impact of attempting to prevent awareness of unwanted memories on their later retrieval (Table 1). The findings from these experiments suggested a controllable inhibition process that selectively impairs the recall of unwanted memories, shedding light on the interplay between executive control and memory accessibility (Anderson & Hanslmayr, 2014; Anderson & Huddleston, 2012; Stramaccia et al., 2021).

SIF effects were found in the final test phase through a comparison between Baseline, that is, items that were initially learned, but not manipulated during the TNT phase, and No-Think items, which were suppressed during the TNT phase. Baseline items were expected to weaken in trace strength during this phase due to their absence, No-Think items were expected to show an even more pronounced weakening in trace strengths due to the repeated attempts at suppression. Furthermore, a positive control effect was found in the TNT paradigm; Think items, due to the repeated retrieval practice during the TNT phase, exhibited an increase in recall performance compared against Baseline items (Anderson & Green, 2001; Anderson & Huddleston, 2012; Stramaccia et al., 2021).

Table 1

Illustration of the Original TNT Experiment

	Learning Phase	TNT Phase	Final Test Phase	
			Same Probe	Independent Probe
TA	Cue: Beach	Beach → Africa	Beach	Continent-A
	Target: Africa	Beach → X	→ Africa	→ Africa

Note. This table is a representation of the Think/No-Think (TNT) experiment. TA stands for Thought Avoidance, indicating the instructions to suppress. In the learning phase, participants memorize cue-target pairs. During the TNT phase, participants suppress red-cued target words and recall green-cued target words. In the final test, during the Same Probe (SP) test, participants recall all previously learned target words. In the Independent Probe (IP) test, they recall all target words after encountering new, loosely related association words.

Same Probe Test and Independent Probe Test. Two types of tests, the Same Probe (SP) test and the Independent Probe (IP) test, were introduced to investigate the mechanisms underlying suppression effects (Anderson & Green, 2001). In the SP test, participants were prompted to recall information using the same cues presented during the TNT phase. This test, however, posed a challenge in distinguishing inhibitory mechanisms from non-inhibitory

ones, as the suppression effect could result from various factors, such as the generation of distracting thoughts or weakened cue-target associations through repeated avoidance. To address this issue, the IP test was devised. In this test, the original cues were replaced by semantic categories (e.g., “continent” for the original target “Africa”). This design aimed to isolate inhibitory processes, as an observed suppression effect would be attributed more convincingly to inhibition rather than interference or unlearning (Anderson & Huddleston, 2012; Bergström et al., 2009). Comparable results between the SP and IP tests were found, leading to interpret all outcomes in terms of inhibition, indicating a reduced activation of the memory trace itself (Anderson & Green, 2001). An analysis of TNT experiments that were conducted by Wessel and colleagues showed that there was only mixed support for SIF in SP, with significant findings in some instances, while the evidence for IP was inconclusive (Wessel et al., 2020; see also Wiechert et al., 2023). This challenges the assumption that suppressing memories results in a deactivation of memory representation, particularly in the context of cues unrelated to the study context, underscoring the complexities of inhibitory mechanisms in the TNT paradigm and emphasizing the need for further research, especially focusing on the less-explored domain of IP.

Thought Avoidance and Thought Substitution. When confronted with reminders, individuals employ at least two strategies to prevent the resurgence of memories: Thought Avoidance (TA), and Thought Substitution (TS) (Benoit & Anderson, 2012). TA involves the deliberate stopping of the retrieval process for an unwanted memory, aimed at either impeding its access to conscious awareness or expelling it once it has entered awareness. On the other hand, TS entails the exclusion of an undesirable memory from conscious awareness by actively retrieving an alternative thought, image, or idea, thereby redirecting the mind away from the undesired content. TS was observed in many TNT replications (Levy & Anderson, 2008). Explicit instructions to use either TA or TS were subsequently added in

multiple replications of the TNT study (Table 2). Under the TS instructions, participants were given a substitute, assisting them in their efforts to suppress the target words, reducing the cognitive control demands compared to the TA instructions where they were required to suppress the target words without the option of replacing it with another word or thought (Hertel & Calcaterra, 2005; del Prete, 2015).

Table 2

Illustration of the TNT Experiment with Added Thought Substitution Instructions

	Learning Phase	TNT Phase	Final Test Phase	
			Same Probe	Independent Probe
TA	Cue: Beach	Beach → Africa	Beach	Continent-A
	Target: Africa	Beach → X	→ Africa	→ Africa
TS	Cue: Beach	Beach → Africa	Beach	Continent-A
	Target: Africa	Beach → Snorkel	→ Africa	→ Africa
	Substitute: Snorkel			

Note. This table is a representation of the Think/No-Think (TNT) experiment. In the learning phase, participants with Thought Substitution (TS) instructions memorize cue-target pairs, incorporating substitute words for No-Think items. During the TNT phase, the TS group recalls the substitutes for red words and says the corresponding target words for green words. The final test does not differ between Thought Avoidance (TA) and TS instructions.

Relevance

Stramaccia et al. (2021) conducted a meta-analysis on replications of the TNT paradigm, revealing that high levels of anxiety seem to correlate with difficulties in SIF. There is a noticeable gap in the existing literature concerning the assessment of instructional variants in samples with anxious individuals. Additionally, the IP test is absent in all published studies (Table 3). The studies frequently report non-significant SIF effects; the used items are oftentimes negative in valence. Only one study focused specifically on GAD. These

identified gaps underscore the need for further research to address the nuanced interplay between instructional variant, levels of GAD, and inhibitory tests with material neutral in valence.

Table 3

Think/No-Think Replications Focusing on Anxiety-Related Disorders

	Material	TA/TS	SP/IP	Valence	Anx. M.	SIF	Anxiety
Catarino et al. (2015)	Object-scene pairs	TA	SP	-	PTSD diagnosed vs control	S (control) NS (PTSD)	S
Dieler et al. (2014)	Face-picture pairs	TA	SP	-, 0	HADS-A, PANAS, STAI	NS	S (-) NS (0)
Diwadkar et al. (2017)	Word pairs, fmri	TA	SP	0	GAD diagnosed vs control	S	S
Marzi et al. (2014)	Word-scene pairs	TA	SP	+, -, 0	STAI	S	S
Waldhauser et al. (2011)	Word pairs	TA	SP	0	STAI	NS	S

Note. This table presents an overview of Think/No-Think replication studies with a focus on anxiety-related disorders. The Material column indicates the type of stimulus pairs used, while TA/TS specifies whether Thought Avoidance (TA) or Thought Substitution (TS) instructions were employed. SP/IP denotes the study's final test, either Same Probe (SP) or Independent Probe (IP). In the Valence column, symbols (+, -, 0) represent whether stimuli had positive, negative, or neutral valence, respectively. The Anx. M. column specifies the instruments used to measure anxiety. The Hospital Anxiety and Depression Scale - Anxiety (HADS-A) and the Positive and Negative Affect Schedule (PANAS) measure anxious symptoms, while the State-Trait Anxiety

Inventory (STAI) measures state and trait anxiety (Dieler et al., 2014 for further details). SIF indicates whether Suppression-Induced Forgetting (SIF) was observed. Results are denoted as S for significant and NS for non-significant findings at an alpha level of .05. The Anxiety column indicates whether statistically significant effects of anxiety were observed.

Aim

Deficits in executive functions, especially in cognitive control, lead to difficulties in SIF, especially for the TA instructions. The resultant intrusive thoughts are associated with greater disorder severity in GAD. Furthermore, anxious individuals may have impaired executive control mechanisms due to their exhibited bias in allocating attentional resources to threatening stimuli, reversing the direction of influence, emphasizing the association between anxiety and SIF.

The objective of this study is to investigate whether active suppression leads to SIF, employing a replication of the TNT task. The study uses word pairs neutral in valence and employs the two different instructional variants and two different final tests. Additionally, the research aims to explore the relationship between anxiety and SIF.

Hypothesis 1a. In the TNT task in the SP condition, participants will report significantly fewer words they have suppressed (No-Think items) than Baseline items. This effect will not occur in the IP condition.

Hypothesis 1b. To examine the presence of a positive control effect, the second part of the first hypothesis is formulated as follows: In the TNT task in the SP condition, participants will recall significantly more words they have thought about (Think items) than Baseline items. This effect will not occur in the IP condition.

Hypothesis 2. Addressing the association between anxiety and SIF, the formulated hypothesis is: Participants with higher anxiety levels will report significantly more memories they have suppressed than participants with lower anxiety levels. Using thought substitution

potentially leads to different outcomes than using thought avoidance, this will be investigated exploratively.

Method

Statement of Transparency

In accordance with transparent research principles, this study followed open science practices to enhance reproducibility and reliability. Detailed information on methodology, data collection, and analysis techniques are provided. The research is part of a larger multi-site replication study and consists of the TNT experiment (Anderson & Green, 2001) and multiple questionnaires; however, only the TNT task and Generalized Anxiety Disorder-7 (GAD-7) questionnaire (Spitzer et al., 2006) are discussed here. We pre-registered hypotheses and analysis plans with our supervisor. Raw data and analysis scripts are deposited in publicly accessible repositories (Open Science Framework and Memorial University of Newfoundland) for scrutiny and replication by interested researchers, available upon request. The project link is not available yet as it has not been made public.

Participants

Participants were 47 first year students from the Dutch psychology bachelor track of the University of Groningen (RUG). They were recruited via SONA (https://www.sona-systems.com; https://rug-en.sona-systems.com/Default.aspx?ReturnUrl=%2f), with color blindness and lack of fluency in Dutch as exclusion criteria. Participants received SONA credits for their participation. A further 11 students participated but were excluded due to various reasons. Specifically, three were excluded for not adhering to the experimenter's instructions accurately, six participants were excluded due to a cheater score of four or higher. The cheater score assessed whether participants suspected that their memory for response items would be tested later, even when instructed not to think about these items. Furthermore, one participant failed to meet the minimum threshold for recalled words in the learning phase

of the experiment, leading to their exclusion from the analysis, and data of one included participant were not available at the time of data analysis. Participants had a mean age of 19.55 (SD=1.653); 38 identified as female, eight as male, and one as other/diverse. Four participants reported ADHD, four a learning disability, four another unspecified condition, and one declined to say (multiple choices were allowed for this question).

Design

This experimental study employed a mixed between-within subjects design. Dependent variables were number of words reported in the final test phase (subcategorized in Think, No-Think and Baseline), independent variables were instructional variant (TA versus TS), and IP and SP. Anxiety levels were analyzed within a correlational design.

Materials

Post-Experimental Questionnaire

GAD-7. A Dutch version of the GAD-7 (Spitzer et al., 2006) was applied to assess participants' level of anxiety. The GAD-7 proves to be reliable and effective for identifying and evaluating the severity of GAD in both clinical settings and research. Possible responses on the seven items of the GAD-7 varied on a scale from 0-3, where 0 signified not being bothered at all and 3 indicating almost daily confrontation with the specific item during the last two weeks. Examples of items are "Trouble relaxing" and "Feeling nervous, anxious, or on edge". The sum of the items could thus range from 0-21, with 21 indicating severe anxiety symptoms. In the current study, Cronbach's alpha was determined to be .791, which is found to be an acceptable value for internal consistency.

Experimental Word List

This experiment utilized 54 cue-target English word pairs that were neutral in valence from Benoit and Anderson (2012), translated into Dutch. Each pair included matching independent probes and thought substitutes. The items were organized into counterbalanced

lists for No-Think, Think, and Baseline conditions. To facilitate practice during the task, three additional lists of 6 items each were created for the three conditions. Importantly, these practice items were not counterbalanced, lacked independent probes, and only the practice No-Think items had accompanying thought substitutes. Complete counterbalancing across the lists was implemented, ensuring a robust experimental design, with each condition represented by an equal number of participants.

Learning Phase. In this phase, 54 word pairs were presented on the screen for 2500ms each, preceded by a 500ms fixation stimulus ("+"). The presentation order was block randomized, guaranteeing representation from Think, No-Think, and Baseline conditions in every three trials. Filler words were incorporated as the first and last nine cues in each cycle.

Test-Feedback Phase. Cue words were presented on the screen for 4000ms each, with a 500ms fixation stimulus between cues. Again, the first and last nine cue words served as filler items.

Criterion Phase. This phase replicated the previous one. Participants failing to correctly recall at least 66% of the words were excluded from the analysis.

Substitute Learning Phase. New cue-substitute pairs were presented for 4000ms with a 500ms fixation stimulus between pairs. To account for primacy and recency effects, three randomly selected No-Think filler substitutes were introduced at the start and conclusion of this phase.

Think/No-Think Phase. Participants encountered two-thirds of the earlier critical cue words, presented in either green (Think items) or red font (No-Think items). Each trial started with a 500ms fixation stimulus, followed by a 3000ms presentation of the red or green hint word. Trials were pseudo-randomized, ensuring each cue word was presented at least once before repetition. Each trial included two repetitions of each red and green word.

Final Test Phase.

Context Reinstatement Phase. During this phase, six filler Baseline, three filler Think, and three filler No-Think items were used.

Same Probe Test and Independent Probe Test. In the Same Probe Test (SP) each single cue word was presented for 3000ms after a 400ms fixation cross. The Independent Probe Test (IP) mirrored the SP test with re-randomized critical item order and novel association cues for each trial, accompanied by the initial letter of a corresponding target word.

Procedure

Participants arrived at the laboratory and were verbally and by an information letter informed about the study's objectives. The letter, intentionally deceiving, portrayed the experiment as focusing on attention and distraction, omitting any mention of a memory test. Participants were also informed about their rights and the assurance of data anonymity. After providing informed consent and undergoing language fluency screening, the learning phase started. Participants were randomly assigned to the instructional variant, the item counterbalancing and the order of SP and IP in the final test phase. All experiment instructions were read aloud by the experimenter to ensure uniformity across participants.

Learning Phase

Participants studied all word pairs once without providing responses. In the following Test-Feedback phase, they recalled target words associated with presented cues. Responses were scored by the experimenter, and feedback was given by presenting the correct target word afterwards. This cycle continued until participants either achieved 66% accuracy or completed three cycles. The subsequent Criterion Phase was identical to the previous phase, but without feedback. In the following Substitute Leaning Phase, TS participants learned substitutes for No-Think items, while TA participants did not undergo this phase.

Think/No-Think Phase

In the Think/No-Think (TNT) phase, for the green trials, participants were instructed to verbally retrieve and keep the associated target words in mind. In red trials, instructions based on conditions; TA involved keeping the target word from coming to mind by maintaining their attention on the red cues without substituting the target with another word, thought or idea, while TS entailed thinking about the previously learned substitute and vocalizing its retrieval. Participants completed 288 trials, with 12 repetitions of each cue word, divided into six rounds. Participants had the opportunity to take breaks between rounds and completed a Diagnostic Questionnaire (DQ) after the third round, to ensure participants understood and followed TNT instructions accurately, allowing for correction when necessary (Nardo & Anderson, 2023). Previous to the TNT phase, participants completed two practice rounds with 12 filler items each, and a DQ was administered between practice rounds.

Final Test Phase

After completing the TNT phase, the final test phase started with the context reinstatement phase as a practice test. Participants were presented with cue words and had to recall the original target words. No feedback was given, and responses were scored by the experimenter on paper. The SP test was very similar to the context reinstatement phase, participants were presented with a single cue word and had to recall the original target word for a total of 36 trials. Again, no feedback was given, and responses were scored by the experimenter on paper. The IP mirrored the SP test but with new association words (Table 1 for an example).

Post-Experimental Questionnaire

After finishing the experiment participants were asked to fill out the post-experimental questionnaire.

Debriefing

Lastly, participants received a brief written and oral debriefing. It was communicated that participants were randomly assigned to one of the two instructional variants. Details were intentionally limited to ensure that future participants would remain unaware of the experiment's true purpose. Participants were emphasized not to discuss their experiences during the experiment with other students. Our contact information was provided for any participant question or concern. Additionally, participants will receive a comprehensive debriefing through SONA once the master theses are completed, outlining the true experiment's objectives and the results at the RUG.

Data Analysis Plan

For this analysis the statistical computations were conducted using SPSS version 28. The SIF variables were derived by subtracting the No-Think score from the Baseline score for both SP and IP. A new anxiety variable was computed by summing all items of the GAD-7. To analyze the first hypothesis, a paired samples t-test and a Wilcoxon signed-rank test were carried out due to the non-normality of the data. The original significance level was .05, and after Bonferroni correction, the adjusted level was .006 for this hypothesis. For the second hypothesis, a correlation analysis was performed (Kendall's Tau-b due to the violation of assumptions). Significance levels were adjusted to .013. Exploratory analyses involved paired samples t-tests and a Wilcoxon signed-rank test to explore differences between instructions on SIF. The data integrity and manipulation check was analyzed by the use of the Kruskal-Wallis test (again, due to evidence of non-normally distributed data).

Results

Hypothesis 1a

In the SP condition (N=47), data normality was assessed using the Shapiro-Wilk test, indicating non-normality (W=.88, p<.001). Visual examination of a histogram and boxplot confirmed this. After removing two outliers, a paired samples t-test showed a statistically

significant difference between Baseline and No-Think; $t(44)=4.88$, $p<.001$, $d=0.73$ (Table 4 contains an overview of all conducted t-tests for SIF). Additionally, a parallel analysis using a non-parametric test was performed on the complete dataset. A Wilcoxon signed-rank test supported the findings ($Z=61$, $p<.001$), and thereby strengthens the robustness of the result (see Appendix A, Figure A1 for a graphical illustration).

In the IP condition, normality testing ($W=.82$, $p<.001$) and visual inspection revealed non-normality. After removing two outliers, a paired samples t-test revealed no significant difference between Baseline items and No-Think items; $t(44)=1.06$, $p=.295$, $d=0.16$. Non-parametric analysis (Wilcoxon signed-rank test) on the entire dataset yielded consistent results ($Z=405$, $p=.411$), indicating no significant shift in variable scores (Appendix A, Figure A2).

Table 4

Results of t-tests Examining the SIF Effects for the Different Final Tests and Instructions

	No-Think		Baseline		*t(df)*	*p*	Cohen's
	M	*SD*	*M*	*SD*			*d*
Same Probe	.89	0.12	.97	0.05	4.88(44)	<.001	0.73
Same Probe TA	.97	0.06	.99	0.05	1.63(18)	.121	0.37
Same Probe TS	.85	0.11	.97	0.05	-5.37(21)	<.001	-1.15
Independent Probe	.80	0.11	.82	0.09	1.06(44)	.295	0.16
Independent Probe TA	.83	0.11	.82	0.09	-0.11(20)	.916	-0.02
Independent Probe TS	.78	0.12	.82	0.10	1.43(23)	.166	0.29

Note. Suppression-Induced forgetting (SIF) effects examined through t-tests for different final tests and instructional variants (TA represents Thought Avoidance and TS is Thought Substitution). M represents Mean, SD is Standard Deviation, t(df) is the t-value with degrees of freedom in parentheses, p is the p-value, and Cohen's d indicates effect size.

Hypothesis 1b

To analyze the positive control effect in the SP condition (N=47), once again we assessed the normality of the data through the Shapiro-Wilk test, indicating a deviation from normal distribution (W=.64, p<.001), confirmed by histogram and boxplot. Due to the substantial departure from normality, outliers could not be filtered. A Wilcoxon signed-rank test on the full dataset showed no significant alteration in variable scores; Z=10.5, p=.045 (Appendix B, Figure B1).

For the positive control effect in the IP condition, normality testing showed no deviation (W=.98, p=.637). Visual inspection detected an outlier, and after its exclusion, a paired samples t-test found no significant differences between Baseline and Think items; t(45)=1.19, p=.239, d=0.18 (Table 5 contains an overview of all conducted t-tests for the positive control effect). Non-parametric analysis (Wilcoxon signed-rank test) on the entire dataset confirmed this result; Z=591.5, p=.152 (Appendix B, Figure B2).

Table 5

Results of t-tests Examining the Positive Control Effects for the Independent Probe Test and Different Instructions

	Think		Baseline		*t(df)*	*p*	Cohen's *d*
	M	*SD*	*M*	*SD*			
Independent Probe	.80	0.09	.82	0.09	1.19(45)	.239	0.18
Independent Probe TA	.79	0.10	.83	0.08	1.43(22)	.166	0.30
Independent Probe TS	.81	0.09	.82	0.10	0.59(23)	.562	0.12

Note. Positive Control effects examined through t-tests for the Independent Probe test and different instructional variants (TA represents Thought Avoidance and TS is Thought Substitution). M represents Mean, SD is Standard Deviation, t(df) is the t-value with degrees of freedom in parentheses, p is the p-value, and Cohen's d indicates effect size.

Hypothesis 2

For TA (N=23) in the SP condition, the total responses on the GAD-7 varied from 0-12 (see Table 6 for descriptives). Linearity and normality assumptions between anxiety and SIF were violated, as observed in a scatterplot and boxplots (see Appendix C, Figure C1 for a graphical presentation of the data). Visual inspection indicated a non-monotonic pattern, suggesting that the relationship between anxiety and SIF did not follow a simple, consistent trend. Instead, it exhibited fluctuations and variations that were not easily characterized by a linear association. Given this pattern, Kendall's Tau-b showed a weak, non-significant negative association (τb=-.11, p=.534).

In the IP condition, similar violations were found in linearity and normality assumptions for anxiety and SIF (Appendix C, Figure C2). Kendall's Tau-b indicated a very weak, non-significant negative association (τb=-.08, p=.612).

For the TS instructions (N=24) in the SP condition, the total responses on the GAD-7 varied from 0-13. Violations in linearity and normality assumptions were evident (Appendix C, Figure C3). Kendall's Tau-b suggested a weak, non-significant positive association (τb=.19, p=.208).

In the IP condition, a violation of linearity assumption was noted, while normality assumption violations were only observed in the anxiety variable (Appendix C, Figure C4). The boxplot of the SIF variable showed normally distributed data. Kendall's Tau-b revealed a weak, non-significant negative association (τb=-.03, p=.841).

Table 6

Descriptive statistics for SIF and GAD-7 scores

	M	SD
SIF Same Probe TA	0.02	0.11
SIF Same Probe TS	0.16	0.17
SIF Independent Probe TA	-0.03	0.26

	M	SD
SIF Independent Probe TS	0.05	0.15
GAD-7 (TA)	4.3	2.9
GAD-7 (TS)	4.9	4

Note. Descriptive statistics for the Suppression-Induced Forgetting (SIF) effects and Generalized Anxiety Disorder 7 (GAD-7) scores. M represents the mean; SD represents the standard deviation. For SIF effects in de different final tests and instructional variants (TA for Thought Avoidance; TS for Thought Substitution), positive values indicate a recall of more Baseline words compared to No-Think words, while negative values suggest the opposite. GAD-7 scores are reported for both TA and TS instructions, indicating the level of anxiety, with higher scores suggesting greater anxiety.

Exploratory Analyses

We explored SIF differences between instructional variants. For the TA group in the SP condition, assessment of normality through testing and visual inspection indicated non-normal distribution (Table 7). Following the exclusion of four outliers, a paired samples t-test was conducted, revealing no statistically significant difference between Baseline and No-Think (Table 4). Consistent results were obtained through non-parametric analysis (Wilcoxon signed-rank test) with included outliers. Similar results were found for IP in TA. For TS in the SP test, normality testing revealed a deviation from normal distribution. Both the paired samples t-test with two removed outliers and the Wilcoxon signed-rank test revealed statistically significant differences between Baseline and No-Think. Results for IP in the TS group were non-significant for SIF (Appendix A, Figure A1).

Table 7

Results of Shapiro-Wilk test and Wilcoxon signed-rank test Examining SIF for the Different Final Tests and Instructions

	Shapiro-Wilk		Mdn		Wilcoxon Signed-Rank	
	W	*p*	No-Think	Baseline	*Z*	*p*
Same Probe	.88	<.001	.92	1	61	<.001
Same Probe TA	.87	.002	1	1	18.5	.358
Same Probe TS	.87	.006	.83	1	7	<.001
Independent Probe	.82	<.001	.82	.83	405	.441
Independent Probe TA	.77	<.001	.83	.82	121	.848
Independent Probe TS	.98	.795	-	-	-	-

Note. Suppression-Induced Forgetting effects examined through normality tests, and non-parametric tests across the different types of final tests and instructions. The Shapiro-Wilk tests assessed the normality of the data, providing W-statistics and associated p-values. Mdn represents the median, Wilcoxon Signed-Rank tests examined the significance of differences, reporting Z-statistics and corresponding two-tailed p-values. When the data demonstrated a normal distribution, the non-parametric Wilcoxon signed-rank test was deemed unnecessary.

Similarly, the positive control effect was separately analyzed for TA and TS. None of the parametric (Table 5) and non-parametric tests (Table 8) revealed statistically significant differences between Think and Baseline for SP or IP (Appendix B, Figure B1 and B2).

Table 8

Results of Shapiro-Wilk test and Wilcoxon signed-rank test Examining the Positive Control Effects for the Different Final Tests and Instructions

	Shapiro-Wilk		Mdn		Wilcoxon Signed-Rank	
	W	*p*	Think	Baseline	*Z*	*p*
Same Probe	.64	<.001	1	1	10.5	.045
Same Probe TA	.57	<.001	1	1	1	.08

	Shapiro-Wilk		Mdn		Wilcoxon Signed-Rank	
	W	*p*	Think	Baseline	*Z*	*p*
Same Probe TS	.71	<.001	1	1	15.5	.292
Independent Probe	.98	.637	.82	.83	591	.152
Independent Probe TA	.97	.755	-	.82	-	-
Independent Probe TS	.97	.717	-	-	-	-

Note. Positive Control effects examined through normality tests, and non-parametric tests across the different types of final tests and instructions. The Shapiro-Wilk tests assessed the normality of the data, providing W-statistics and associated p-values. Mdn represents the median, Wilcoxon Signed-Rank tests examined the significance of differences, reporting Z-statistics and corresponding two-tailed p-values. When the data demonstrated a normal distribution, the non-parametric Wilcoxon signed-rank test was deemed unnecessary.

Data Integrity and Manipulation Checks

Due to the previously shown violation of normality assumptions for SIF in SP and IP, non-parametric tests were conducted to explore potential differences in SIF based on the researcher who conducted the experiment. A Kruskal-Wallis H test indicated that there were no statistically significant differences between the researchers for SIF in SP, H(2)=1.89, p=.390, with a mean rank SIF score of 27.38 for Lara, 23.09 for Sarah, and 20.93 for Yara. For IP, results were similarly non-significant, H(2)=.05, p=.973, with a mean rank SIF score of 23.41 for Lara, 24.5 for Sarah, and 24.14 for Yara.

As a result of the non-normal distribution of the SIF variables, a non-parametric test was conducted to analyze differences between the counterbalanced word lists A, B, and C. A Kruskal-Wallis H test indicated that there were no statistically significant differences between counterbalanced items for SIF in the SP condition, H(2)=2.2, p=.333, with a mean rank SIF score of 24.81 for A, 27.2 for B, and 20.19 for C. For IP, results were similarly non-

significant, H(2)=1.17, p=.557, with a mean rank SIF score of 21.75 for A, 23.33 for B, and 26.88 for C.

Discussion

The obtained results roughly align with the formulated first hypothesis. In support of Hypothesis 1a, participants in the SP condition reported statistically significant fewer suppressed memories (No-Think items) than Baseline items, supporting the assumed presence of SIF in the TNT paradigm, with a moderate effect size. The exploratory analysis revealed that this effect holds true only for TS, where a larger effect size suggests a significantly greater difference in suppressed memories between No-Think and Baseline, indicating stronger SIF with TS instructions. Results in the TA group were inconclusive. Moreover, the IP test showed inconclusive results for both TA and TS. For Hypothesis 1b, there was no statistically significant difference in both SP and IP for the positive control effect. This holds true for both instructional variants. These findings suggest that the TNT paradigm, particularly in the SP condition, partially induced memory suppression effects. Furthermore, contrary to Hypothesis 2, no substantial correlation between anxiety levels and SIF in both final tests and instructions was found, indicating that the association between anxiety and memory suppression may be more nuanced than hypothesized. Lastly, in examining the influence of different experimenters and counterbalanced items on SIF, no significant differences were observed.

Prior Research Findings and Consistency

While Anderson and Green (2001) found significant suppression effects for both SP and IP, our study's results, aligning more closely with Wessel et al. (2020), only showed significant effects for SP. Bergström et al. (2009) reported significant SP results for TA and TS but couldn't replicate SIF for IP with TS. Stramaccia et al. (2021) suggest effective SIF for

both TA and TS but acknowledge limited evidence for IP. This emphasizes the need for further investigation into SIF mechanisms.

Comparing our results to previous studies with a focus on anxiety-related disorders (Table 3), the present study, overall, does not align with previous findings. These differences could be attributed to multiple factors, like sample characteristics, anxiety measurement tools, or stimuli valence, which underscores the importance of considering these factors in future investigations (Catarino et al., 2015; Dieler et al., 2014; Diwadkar et al., 2017; Marzi et al., 2014; Waldhauser et al., 2011).

Theoretical Contributions and Interpretation of Non-Significant Results

Significant findings in SP and inconclusive outcomes in IP suggest that TNT weakened cue-target associations without affecting independent target word accessibility, offering partial evidence for SIF (Wiechert et al., 2023). However, observed memory suppression effects during later recall may not solely result from inhibitory processes (Herbert & Sütterlin, 2012). This challenges the conventional TNT paradigm understanding, proposing that effects may arise from memory interference at both initial sampling and subsequent recovery stages. Although this notion is debated in the literature (Bäuml & Hanslmayr, 2010), the results of the exploratory analyses, suggesting that TS is an effective suppression strategy, while TA results were inconclusive, provide further insights. The effectiveness of TS may be explained by substitutes inducing forgetting through retroactive interference, altering the cue's functional meaning (Hertel & McDaniel, 2010). This perspective raises additional questions about the inhibition theory (Anderson & Green, 2001). Furthermore, our findings are in line with the assumption that cognitive control could be essential for SIF, as TA requires more cognitive control than TS (Chen et al., 2022; Hertel & Calcaterra, 2005). Lastly, directing subjects to refrain from responding during No-Think trials might function as a distracting

task, diverting processing resources that would otherwise be allocated to memory inhibition (Román et al., 2009). This could further explain the inconclusive results in TA.

The inconclusive results observed in our study regarding the association between anxiety and SIF, where stimuli were neutral in valence, suggest the potential influence of material that is emotional in valence on the observed effects. A distinctive sensitivity to and excessive focus on negative information plays a pivotal role in affective disorders like anxiety (Bar-Haim et al., 2007; Teachman et al., 2012). Consequently, the capacity to forget negative memories could serve as a cognitive foundation for mental well-being, while the absence of this ability might be linked to affective disorders like GAD (Hallion & Ruscio, 2013; Hallion et al., 2017). The ACT complements this understanding by emphasizing individual differences in executive control and their correlation with cognitive instability (Eysenck et al., 2007). Particularly under stressful conditions (e.g., while presented with cue-target pairs with emotionally negative valence), high anxiety levels intensify the effects on attentional control, reinforcing the preference of anxious individuals to allocate attentional resources to threat-related stimuli, whether internal or external. This aligns with studies employing cue-target pairs with negative valence in the Think/No-Think (TNT) paradigm (Catarino et al., 2015; Dieler et al., 2014; Marzi et al., 2014), which has consistently demonstrated a significant association between anxiety and SIF.

Methodological Concerns and Future Research Implications

Key methodological concerns in our study primarily revolve around the TNT paradigm, with a focus on task design and participants' prior knowledge. Clear instructions are crucial for valid results. Three participants were excluded because they did not accurately follow the instructions for the IP test, and it is plausible that more participants had difficulty with the instructions, which is not checked. Additionally, control for prior knowledge is essential due to its potential impact on task engagement. If participants hear from peers that

the experiment involves a memory test for suppressed words, there is a risk that they may go against instructions and practice anyway. The cheater score is intended to check for this, and a too high score is an exclusion criterion. However, participants may provide socially desirable answers. Overall, people tend to suspect a memory test and may still practice suppressed words (Liu et al., 2021). Despite efforts, such as standardized verbal instructions and post-experimental familiarity assessments aimed at improving internal validity, recognizing these concerns is crucial for a thorough interpretation. Addressing these considerations will guide future research towards improved task designs and increased reliability.

Due to our participation in the multi-site replication project, adherence to project guidelines constrained our ability to conduct an a-priori power analysis to determine the necessary sample size for achieving statistically significant results. Consequently, only our local dataset was analyzed for this Master's thesis. Future research endeavors should consider incorporating power analyses to enhance methodological rigor.

We did not exclude participants with any current psychiatric disorders or even high levels of depression (or sleep difficulties) measured with different questionnaires. Depression or sleep-related disorders could be confounding factors considering their high prevalence of comorbidity. Although the presence of suppression deficits in anxiety might be influenced by this comorbidity, with existing evidence suggesting that depressive symptoms contribute to deficits in SIF (Stramaccia et al., 2021), Catarino et al. (2015) revealed that depression may not be the predominant factor in SIF impairments for higher anxiety levels.

Using a sample solely composed of first-year psychology students raises concerns about sample homogeneity and the generalizability of findings. The uniform academic background and limited life experience of this group may limit the applicability of results to a broader population. The specific characteristics and mindset associated with first-year students could influence performance on the TNT paradigm, potentially affecting external

validity. While this choice ensures consistency, caution is warranted in generalizing beyond this demographic. Future research should explore the TNT paradigm's replication in diverse populations to enhance external validity and understand the robustness of observed suppression effects.

Finally, drawing causal conclusions about the relationship between SIF and anxiety was not feasible with the current experimental setup. Future research could employ a randomized controlled trial, exemplified by a study protocol article on binge drinking and Memory Inhibition (Almeida-Antunes et al., 2022). This longitudinal study will include cognitive training and transcranial direct current stimulation interventions, with potential outcomes like improved capacity to suppress alcohol-related memories and insights for treating alcohol misuse.

Clinical Implications

The impact of long-term suppression on symptom severity is not well-explored. In anxiety disorders, avoidance of memories can manifest in two distinct forms (Catarino et al., 2015). Firstly, it involves the avoidance of situations reminiscent of the unpleasant memory. Secondly, it involves a more proactive approach, attempting to suppress the memory itself when confronted with triggering stimuli. The former strategy may contribute to the preservation of memories, as individuals have fewer opportunities to naturally forget them. Conversely, actively suppressing the memory when confronted with it can prove advantageous if executed effectively. In this context, TS in therapeutic interventions emerges as potentially more efficacious than TA, offering promising implications for the treatment of anxiety disorders.

In our sample, five participants exhibited a GAD-7 score that can be identified as indicative of GAD (Spitzer et al., 2006). However, this screening tool alone is insufficient for establishing a GAD diagnosis. The absence of a significant correlation between anxiety levels

and the SIF effect in our study may indicate complex interactions between anxiety and the ability for memory suppression. If individuals with clinical anxiety were included in the study, the conclusions drawn from our research might have been more robust and the implications for treatment could have been more pronounced.

Conclusion

In conclusion, our findings revealed significant SIF effects in the SP condition, particularly with TS instructions, roughly aligning with prior literature. Together with the inconclusive results for TA and IP, our findings could be explained by memory interference instead of inhibition. Furthermore, the absence of a substantial correlation between anxiety and SIF suggests an inconclusive, more complex relationship. Methodological considerations and the need for diverse population samples were underscored, emphasizing the importance of refining memory-focused interventions.

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Appendix A

Graphical illustration of the SIF effect for hypothesis 1a

Figure A

Percentage recalled items (Baseline and No-Think) per participant for the complete data set

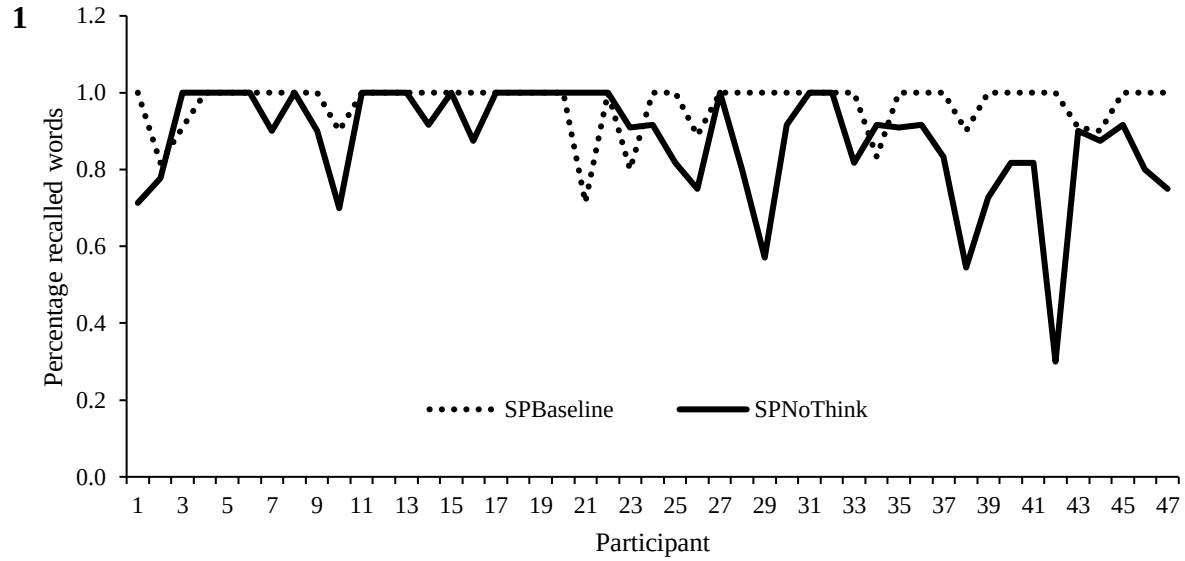


Figure A1 depicts individual scores of participants for Baseline and No-Think items in the Same Probe (SP) condition. Datapoints 1-23 on the x-axis represent participants with Thought Avoidance (TA) instructions, while datapoints 24-47 represent participants with Thought Substitution (TS) instructions. The graph roughly aligns with the hypothesis proposing a higher recall percentage for Baseline items compared to No-Think items, this pattern appears evident for TS. However, this distinction does not appear to hold true for TA.

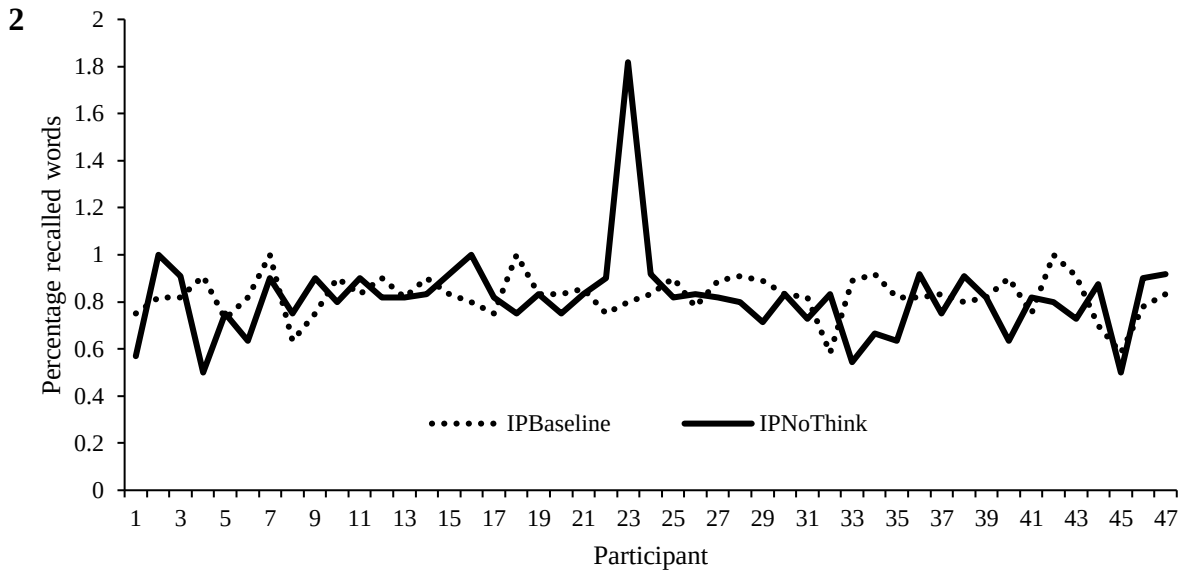


Figure A2 presents individual scores of participants for Baseline and No-Think items in the Independent Probe (IP) condition. Participants with Thought Avoidance (TA) instructions are represented by datapoints 1-23 on the x-axis, whereas participants with Thought Substitution (TS) instructions are represented by datapoints 24-47. In contrast to the hypothesis proposing a higher recall percentage for Baseline items compared to No-Think items, this pattern does not seem apparent in the displayed graph, neither for TA nor for TS. In the graph, it is evident that participant 23 exhibits a notable outlier in the No-Think scores compared to other participants. This outlier can be attributed to a data entry error by the experimenter. It is crucial to note that this deviation does not reflect participant behavior but rather an occasional error during data input. Furthermore, it's worth mentioning that this outlier has been excluded from the parametric analysis to ensure the accuracy of the statistical examination.

Appendix B

Graphical illustration of the positive control effect for hypothesis 1b

Figure B

Percentage recalled items (Baseline and Think) per participant for the complete data set

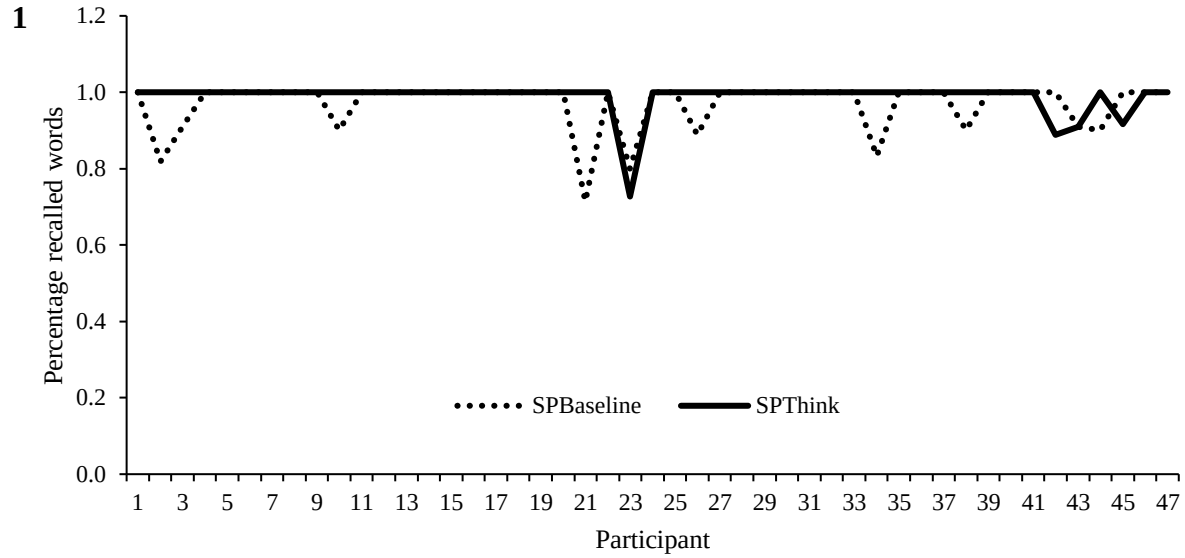


Figure B1 displays individual scores of participants for Baseline and Think items in the SP condition. Datapoints 1-23 on the x-axis correspond to participants following Thought Avoidance (TA) instructions, while datapoints 24-47 represent participants instructed with Thought Substitution (TS). The hypothesis posited that participants would recall a higher percentage of Think items compared to Baseline items, and this pattern seems not to be evident in this graph, neither for TA nor for TS.

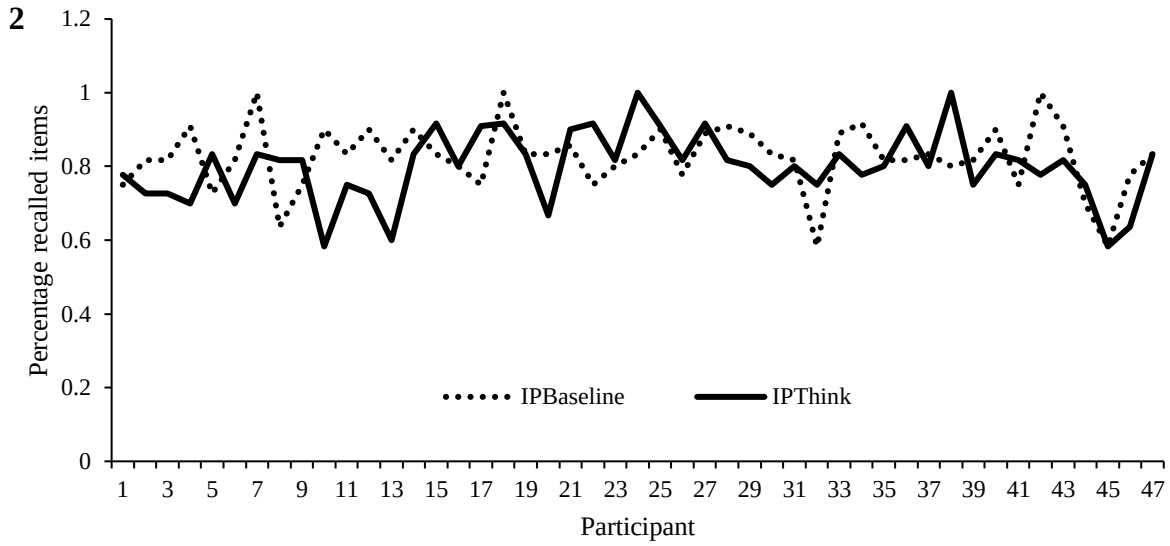


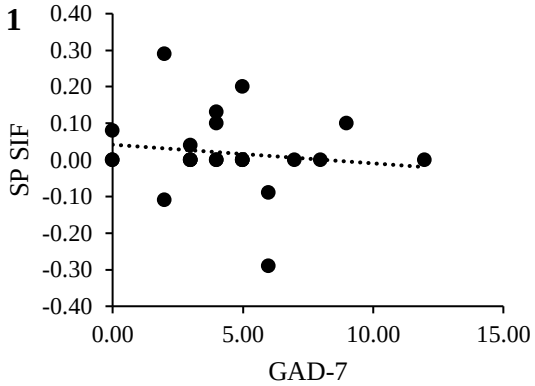
Figure B2 illustrates individual scores of participants for Baseline and Think items in the Independent Probe (IP) condition. Participants instructed with Thought Avoidance (TA) are depicted by datapoints 1-23 on the x-axis, while those with Thought Substitution (TS) instructions are represented by datapoints 24-47. Contrary to the hypothesis suggesting a higher recall percentage for Think items compared to Baseline items, this pattern does not appear evident in the presented graph.

Appendix C

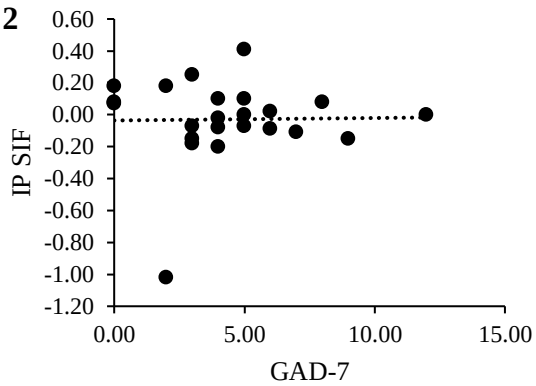
Graphical illustration of the data for hypothesis 2

Figure C

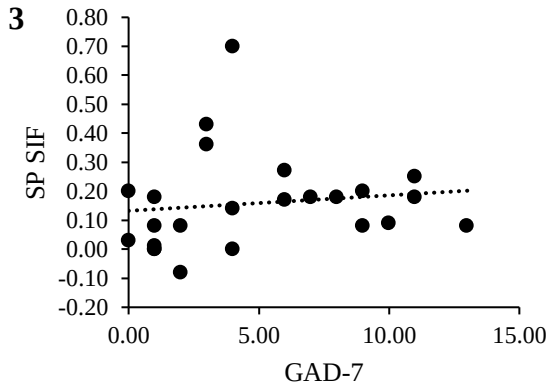
Changes in SIF scores as a function of Total GAD-7 scores



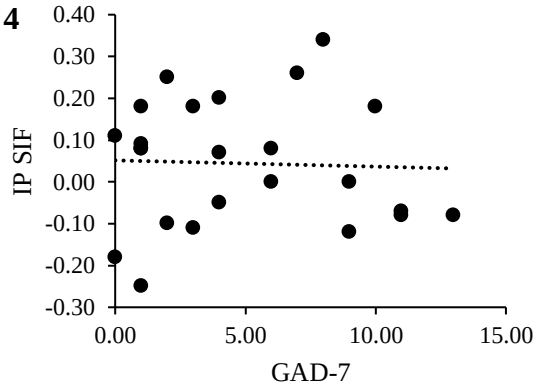
Note. This figure demonstrates the changes in SPSIF effects as a function of total GAD-7 scores in the Thought Avoidance group.



Note. This figure demonstrates the changes in IPSIF effects as a function of total GAD-7 scores in the Thought Avoidance group.



Note. This figure demonstrates the changes in SPSIF effects as a function of total GAD-7 scores in the Thought Substitution group.



Note. This figure demonstrates the changes in IPSIF effects as a function of total anxiety scores in the Thought Substitution group.

Figures C1-C4 depict scatterplots of GAD-7 scores and Suppression-Induced Forgetting (SIF) effects in both the SP and IP conditions, under both Thought Avoidance (TA) and Thought Substitution (TS) instructions. In all four scatterplots, it is evident that the data is not linearly distributed, and that the correlations between anxiety and SIF appear weak.