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Exploring Executive and Thought Control Processes as  
an Explanatory Framework for Suppression-Induced  
Forgetting

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I declare that this thesis has been composed entirely by myself and has not been submitted for any degree or professional qualification other than the Master of Science in Clinical Psychology at the University of Groningen.

## **Abstract**

When faced with reminders, especially intrusive ones, forgetting is central to our everyday life and mental health. Anderson and Green (2001) constructed the Think/No-Think (TNT) to investigate people's ability to consciously suppress material, resulting in suppression-induced forgetting (SIF). During the TNT task, individuals first learn word pairs, e.g., Roach – Ordeal. Then they are presented with the hint word (e.g., Roach) and instructed not to think about the response word (e.g., Ordeal) by actively trying to avoid thinking about it. SIF is tested in two conditions, one testing for the recall of the response word when given the hint word (Same Probe, SP), the other using a category word related to the response word to test for cue independent forgetting (Independent Probe, IP).

The current study aimed to investigate SIF in TNT and its proposed connection to executive and thought control processes by assessing the connection between the SIF scores, a self-report executive function questionnaire (Webexec), and a self-report thought control ability questionnaire (TCAQ). The final sample consisted of 150 participants who partook in an online administered TNT task. The data analysis showed no statistically significant results for SIF in TNT, as well as no statistically significant effects for executive control on SIF. However, results for thought control ability on SIF in IP showed a weak positive statistically significant correlation. Further research is necessary to evaluate the robustness of SIF and its connection to executive control, as the current results should be considered in light of the study's online administration.

*Keywords:* Suppression, Repression, Suppression-Induced Forgetting (SIF), Think/No-Think (TNT), Executive Control, Executive Functioning, Thought Control Ability

## **Introduction**

*“Change your thought and you will change your world. Change your thought correctly and everything will change into inner peace, happiness and personal power”*

*(Peale, 2003, p.233)*

How we do in life is determined by what we can remember. In our lifetime, we will repeatedly be confronted with memories and thoughts that make us feel angry, sad, anxious, ashamed or guilty (Baddeley et al., 2015). Most people experience intrusive thoughts and memories that involuntarily enter an individual's awareness (Muris et al., 1996; Wessel et al., 2010). The act of forgetting is often seen as a weakness, but Stramaccia et al. (2021) suggests that forgetting is part of intentional control by taking advantage of deliberate blocking processes. Therefore, forgetting could also be seen as an adaptive force that helps us shape our memories, maintain mental health, and regulate emotions and cognition in order to protect the self and focus on what needs to get done (Anderson & Hanslmayr, 2014; Chen et al., 2022; Lambert et al., 2010; Stramaccia et al., 2021).

The concept of conscious or unconscious forgetting has been the topic of deliberation in courtrooms, and in the scientific and clinical world, as it holds crucial value for overall mental well-being. Especially after the 1990s, when several people reported recollected traumatic memories after undergoing psychotherapy (Dodier et al., 2022; Geraerts & McNally, 2008; Patihis et al., 2014). Memory suppression/repression has a crucial impact on treatment of mental health disorders like PTSD, generalized anxiety disorder, depression and other psychological disorders (Chen et al., 2022; Stramaccia et al., 2021; Wang et al., 2015). The available literature on this topic mostly uses suppression and repression interchangeably.

In the current paper, repression and suppression will be differentiated as the following: Repression is an automatic, unintentional, unconscious, and protective process of forgetting. Repressed memories are said to not be part of an individual's conscious awareness but still are

stored in the back of their mind. This leads to the assumption that repressed memories unconsciously influence an individual's experiences, thoughts, and behaviours, which can lead to psychopathological symptoms (Anderson & Hanslmayr, 2014; Baddeley et al., 2015; Kihlstrom, 2002; Wessel et al., 2020). Conversely, suppression is considered an intentional, conscious goal-directed effort to eliminate memories by taking advantage of inhibitory control processes leading to suppression-induced forgetting (SIF) (Anderson & Hanslmayr, 2014; Baddeley et al., 2015; Chen et al., 2022). General research on SIF indicates that it can be achieved through two main mechanisms, thought substitution and direct suppression.

The former builds on the distraction of the original thought by substituting or overriding it with other/competing thoughts and therefore blocking its retrieval, taking advantage of interference (Anderson & Levy, 2007; Baddeley et al., 2015; Davidson et al., 2020; Levy, 2002; Wang et al., 2015). Direct suppression, on the other hand, does not involve substitution/interference but is rather a process in which individuals stop the revival of thoughts by actively and consciously avoiding them. This process proceeds either momentarily by stopping the thought as soon as a cue hits or continuously by developing strategies that help stop the thought's occurrence later (Anderson & Hanslmayr, 2014; Geraerts & McNally, 2008). Anderson and Green (2001) proposed that the underlying aspects of direct suppression deviate from the original interference approach and suggested that individuals need to exert inhibitory control over the thought that should be suppressed (Wang et al., 2015).

Suppression is a complex mechanism that requires many different control and regulation strategies to prevent thought recollection (Chen et al., 2022; Davidson et al., 2020). There has been accumulating behavioural and neurocognitive evidence on the assumption that SIF can be attributed to inhibitory control which is part of executive function (Anderson & Green, 2001; Anderson & Levy, 2007; Göbel et al., 2022). Executive function is an umbrella

term for different processes like planning, attention and impulse control, which are an essential part of the working memory, by regulating and manipulating the encoding and decoding (Buchanan et al., 2010; Raz & Fabrega, 2006). An essential executive control process for suppression is the ability of thought control. It is perceived as an inhibitory process that helps us regulate our thinking to align with our goals. Further, research indicates that individuals with lower self-perceived thought control ability tend to experience more intrusive thoughts and expend greater effort in suppression attempts, overall suggesting that individuals exhibiting greater executive control demonstrated greater SIF (Baddeley et al., 2015; Chen et al., 2022; Göbel et al., 2022; Williams et al., 2010).

Determining whether an individual successfully suppresses a memory from entering consciousness is challenging, as direct observation of awareness is impossible. Therefore, Anderson and Green (2001) modelled the Think/No-Think (TNT) task after the Go/No-Go task. The Go/No-Go task examines executive control over motor actions, indicated by the ability to stop motor actions/withhold responses which are a measure of the inhibitory control (Anderson, 2003; Anderson & Green, 2001; Anderson & Huddleston, 2012). Anderson and Green's (2001) TNT task was constructed to explore whether the act of suppression would engage in similar inhibitory control processes by examining an individuals' ability to suppress memories when confronted with reminders (Anderson & Green, 2001; Baddeley et al., 2015; Conway, 2001).

**Table 1**

The Phases and Conditions in Anderson and Green's (2001) Think/No-Think (TNT) Task

Condition	Phase 1	Phase 2	Test Phase	
	Study	Think/No-Think	Same Probe	Independent Probe
No-Think/Suppress	Ordeal-Roach	Ordeal	Ordeal - ...	Insect – R...
Think/ Recall	Steam-Train	Steam	Steam - ...	Vehicle – T...
Baseline	Rent-Week		Rent - ...	Time – W...

*Note.* This figure provides an overview of the different phases and conditions in Anderson and Green's (2001) TNT task. In Phase 1 Participants were given a hint word (e.g., Ordeal) and were asked to recall the response word (e.g., Roach). In Phase 2 participants were either presented with a red or green hint word. A red hint word indicating for the participant to avoid thinking and to not recall the response word and a green hint word indicating for the participant to recall the hint word as practiced in Phase 1. In the Test Phase participants partook in a Same Probe (same as Phase 1) and an Independent Probe task, with the latter consisting of a category word and the first letter of the response word.

Anderson and Greens (2001) TNT task consists of participants first learning 40-word pairs (e.g., Ordeal – Roach). After they are presented several times with some of the different hint words (e.g., Ordeal) and are instructed to either think and recall the response word (think condition) or not to think and not recall the response word by actively avoiding the target word from coming to mind at all (no-think condition). Some of the initially learned word pairs will not be tested in a think or no-think condition but are rather used as a baseline measure (*Table 1*). In the last phase of the TNT task, individuals were instructed to recall all response words in two different types of tests Same Probe (SP) and Independent Probe (IP) (Anderson & Green, 2001; Conway, 2001; Raaijmakers & Jakab, 2013). In SP, individuals are presented with the hint word (e.g., Ordeal) and asked to recall the response word (e.g., Roach). In IP, individuals are presented with a novel test cue, a category word and the first letter of the response word (e.g., Insect – R) and asked to recall the response word they learned earlier. IP was implemented into TNT to test the assumption that inhibitory control processes are connected to suppression. Insufficient recall of no-think items in the SP condition can be due to inhibitory and non-inhibitory processes. In IP condition, an insufficient recall of no-think

items would indicate that the cue itself has been inhibited and not the association between the trained cues. Therefore IP eliminates the possibility of unlearning and interference caused by association, otherwise referred to as thought substitution (Anderson & Green, 2001; Anderson & Huddleston, 2012; Anderson & Levy, 2007; Raaijmakers & Jakab, 2013; Wang et al., 2015; Wessel et al., 2020).

Over the past two decades, the suppression effects of Anderson and Green's (2001) TNT task have been the subject of a considerably amount of research in this specific field. Some of these studies could not replicate SIF, while others did. Certain studies that found SIF in TNT did not include IP, did not find an effect in IP or were only able to report effects in certain conditions (Davidson et al., 2020; Hertel & McDaniel, 2010; Raaijmakers & Jakab, 2013; Stramaccia et al., 2021). There have been multiple explanations for these contradictory findings. These primarily focused on non-compliance with the suppression task. The non-compliance explanation for previous findings of SIF in TNT, is that participants used thought substitution strategies instead of the instructed direct suppression. However, this could also be the explanation for previous null findings, when participants treated the different phases of the TNT task as practice to further strengthen their recall (Liu et al., 2021; Raaijmakers & Jakab, 2013). Therefore, Stramaccia et al. (2021) highly encourages implementing cue-independent recall like the IP into the TNT study design to test if the observed SIF stems from direct suppression or from unlearning/thought substitution.

With the current state of research on SIF in the TNT paradigm being characterized by some challenges in its replication and missing consensus on the core processes underlying suppression (Davidson et al., 2020; Stramaccia et al., 2021). The present study aims to investigate SIF in the TNT paradigm in an online administration and the possibility of underlying executive control processes and thought control ability as an explanatory framework for suppression. Therefore, the research question for this study is: "What are the



influences of self-perceived executive control and thought control performance on suppression-induced forgetting in the Think/No-Think task?". In order to investigate this research question, the following hypotheses were proposed:

Hypotheses 1 and 2 were postulated and analysed to address the obtained results of SIF in an online administered TNT study. Stramaccia et al. (2021) meta-analysis found small-to-moderate effect sizes for SIF in TNT and suggested these findings to be generalisable to a broader population. Other studies, including Anderson et al., (2004), Good and Kirk (2010), and Hertel and McDaniel (2010), have reported similar findings, suggesting that the following hypotheses:

*Hypothesis 1: Participants will recall more baseline than suppress items in both SP and IP.*

*Hypothesis 2: SP and IP will be statistically equivalent.*

Furthermore, Hypotheses 3 and 4 were postulated and analysed to address the connection between self-perceived executive control and thought control performance on the obtained SIF results. Previous studies including Anderson and Green (2001), Davidson et al. (2019), and Chen et al. (2022) reported a possible connection between executive control and suppression. Hence, individuals experiencing difficulties in executive control may also show a decline in their ability to suppress memories, suggesting the following hypothesis:

*Hypothesis 3: Participants scoring lower on self-reported executive function will show less SIF.*

Due to a proposed connection between thought control ability and executive control (Williams et al., 2010), Hypothesis 4 was postulated. Although Göbel et al. (2015) meta-analysis only found a non-significant low effect size estimate regarding thought control ability and SIF in TNT, the following hypothesis was postulated due to the theoretical link with executive functioning: *Hypothesis 4: Participants scoring lower on self-reported thought control ability will show less SIF.*

## Method

This study was a registered replication report (the original manuscript has received stage one acceptance, to in-principle accepted manuscript <https://osf.io/jnk78/>).

### Design

This study was an experimental within-subject design with participants being counterbalanced over three groups of word pairs (Distraction Studies A, B and C) and a randomised order of receiving Same or Independent Probe conditions on all three levels. All other measures taken were identical for all participants.

### Participants

The current research used the Bayesian stopping rule, testing whether the evidence speaks for or against effects in the Same Probe and Independent Probe ( $BFs > 5$  or  $BFs < 0.2$ ). The lower limit was said at  $N = 102$  and the upper limit was set at  $N = 198$ , and increments of  $N = 24$  were added until an effect was determined. The upper limit was said to be due to feasibility since every testing took approximately 75 minutes. The final sample contained  $N = 150$  after excluding 15 participants who failed the compliance screening (a sum score above four for the compliance questions) and two participants who did not finish the end of the study questionnaire. The sample consisted of 40.7% males and 59.3% females, with a mean age of 31.14 ( $SD = 7.73$ ) ranging from 18 to 45. A Pearson's correlation coefficient with 150 participants (G\*power; (Faul et al., 2009) was set to be sensitive to effects of  $r_s = .26$  with 80% power ( $\alpha = .0125$ , two-tailed). This means the study was unable to reliably detect correlations smaller than  $r_s = .26$ .

Participants were recruited through the online portal *prolific.co*. Inclusion criteria were fluency in English, western/non-western (based on nationality and native language being English), physical and psychological health, normal vision and age 18 – 45. Participants partook in a zoom session and were compensated financially with approximately €12 (partial

payments were possible if a participant failed the Test Feedback Phase or the session needed to be ended sooner).

## **Materials**

### ***Demographics***

To assess the demographic of our sample, participants were asked to indicate their gender [Male; Female; Non-binary/Third Gender] and age [open text entry], both with the option of “Prefer not to say”.

### ***Experimenter Control Questionnaire***

At the beginning of every testing, the participants partook in an 11-item questionnaire to ensure that their equipment was ready and the session environment was adequate enough to commence the session. Eight items were directed towards the accuracy of the set-up (should all be answered with “Yes”). Three items were distraction checks (should all be answered with “No”). Testing was immediately stopped if these questions were not answered as desired (see in full <https://osf.io/e75a6/>).

### ***Think/No-Think Task***

The Think/No-Think (TNT) task was coded on a psychological experimentation application called Inquisit (Version 5 and 6). It can run a multitude of psychological measures like attitude measures, surveys, learning and memory task with a given script.

Overall the TNT task consisted of 54 cue-target pairs (stimuli set by Benoit and Anderson, 2012), which were divided into three groups of 12-word pairs (counterbalanced over conditions A, B and C) and one group of 18 filler pairs. In order to keep participants counterbalanced between A, B and C, a tally was kept so that experimenters knew what test should be administered next to keep the conditions equal.

First, Participants underwent a *Learning Phase* in which they were presented with all 54-word pairs (e.g., Ordeal – Roach). After the presentation of all word pairs, participants

were tested on their recall in the *Test Feedback Phase*, during which they were given the hint word (e.g., Ordeal) and were asked to recall the response word (e.g., Roach). When participants succeeded at recalling all of the word pairs within 20-25 minutes, they moved on to the *Practice TNT Phase*. In this phase, participants were given all the essential instructions for the main TNT Task but got the possibility of practice. Participants were instructed to either recall (words appeared in green on the screen), as they were instructed in the Test Feedback Phase or suppress (words appeared in red on the screen) specific response words. Participants were instructed, for the suppress words, to pay full attention to the red hint word and try to stop the response word from coming to mind at all while also not thinking of anything else. After the *TNT phase*, participants were tested on retrieving the target word (e.g., Roach) when given the hint word (e.g., Ordeal) (*Same Probe, SP*) and on retrieving the target word (e.g., Roach) when given a novel test cue (e.g., Insect – R) (*Independent Probe, IP*). Both IP and SP were randomized in their order by Inquisit for every participant (Baddeley et al., 2015; Stramaccia et al., 2021) (see in full <https://osf.io/e75a6/>).

### ***Diagnostic Questionnaire***

During the Practice Phase, the experimenter and participants went over a seven-item questionnaire (as used by Anderson et al., 2004) to determine if they understood and properly followed the instructions for the TNT task. The Diagnostic Questionnaire was scored on a 4-point Likert scale (1 = Never – 4 = Always) (see in full <https://osf.io/e75a6/>).

### ***Compliance Questionnaire***

To assess participants' compliance with the think/no-think conditions, a three-item compliance screening (as used by Anderson et al., 2004) was administered using a 4-point Likert scale (0 = Never to 4 = Very frequent). The questions asked were “I read the red HINT word, made sure I still knew the associated word first and then tried to not think of this associated word”, “I read the red HINT word, tried to not think of the associated RESPONSE,

but then after the trial was over, I made sure that I still remembered the response word” and “I read the red HINT word and kept myself from saying the RESPONSE word aloud, but kept repeating the response word to myself to improve my memory for it”. A sum score above four indicates non-compliance and therefore was treated as an exclusion criterion.

### ***Web-based Executive Function Questionnaire***

The Web-based executive function questionnaire (Webexec) was used as a self-assessed questionnaire designed to test for overall executive problems, intending to be as brief as possible to lower the executive load on participants (Buchanan et al., 2010). The Webexec consisted of the following six items: “Do you find it difficult to keep your attention on a particular task?” (i.e., attention), “Do you find yourself having problems concentrating on a task?” (i.e., concentration), “Do you have difficulty carrying out more than one task at a time?” (i.e., multitasking), “Do you tend to “lose” your train of thoughts?” (i.e., distractibility), “Do you have difficulty seeing through something that you have started?” (e.g., perseverance) and “Do you find yourself acting on “impulse”?” (i.e., impulsivity). Each of these items was coded on a 4-point Likert scale (1 = no problems experienced; 2 = a few problems experienced; 3 = more than a few problems experienced; 4 = a great many problems experienced). The Total Score was calculated by adding up the responses of all six items leading to a total score range of 6 – 24, with a higher score indicating problems in executive functioning (Buchanan et al., 2010). The internal consistency of the Webexec in our sample size of N = 150 is Cronbach’s  $\alpha = .842$ .

### ***Thought Control Ability Questionnaire***

The Thought Control Ability Questionnaire (TCAQ) was used as a questionnaire to test an individual's self-perceived ability to control intrusive and unwanted thoughts (Williams et al., 2010). The TCAQ consisted of 25 items coded on a 5-point-Likert scale (1 = strongly disagree – 5 = strongly agree). The Total Score was calculated by adding up the

responses of all 25 items leading to a total score range of 25 – 125, with a higher score indicating better control over unwanted thoughts (Feliu-Soler et al., 2019; Göbel et al., 2022; Williams et al., 2010) (see in full <https://osf.io/e75a6/>). The TCAQ with 25 items has a Cronbach's  $\alpha = .920$  in our sample size of  $N = 150$ .

### ***Other Measurements***

Due to the word limit and particular questionnaires of this already-established research project not being crucial for the current paper, some questionnaires, like the Session Evaluation Questionnaire and Exploratory Measures, will not be discussed. Explanations and questionnaires of further measures taken can be found at <https://osf.io/jnk78/> and <https://osf.io/e75a6/>.

### **Procedure**

Participants were recruited through the online platform Prolific.co. After booking a timeframe for the online testing, participants were sent a reminder and Zoom link approximately 30 – 15 minutes before the beginning of the session. Upon entering the Zoom session, participants first partook in the *Experimenter Control Questionnaire* to assess if their environment is adequate to commence the session (i.e., no distractions, stable internet connection, etc.). If participants failed this questionnaire, the session was immediately stopped, and they were not compensated. When participants passed the questionnaire, the session continued with the *Learning Phase* of the TNT Task. The experimenter turned their camera off and shared the screen with the on Inquisit coded task. During the *Learning Phase*, participants were presented with 54-word pairs (e.g., Roach – Ordeal), which they were asked to remember. Thereafter in the *Test Feedback Phase*, participants were presented with the left-hand member (hint word) of the word pairs (e.g., Roach) and were asked to recall the right-hand member (response word) (e.g., Ordeal) out loud. The experimenter coded the correct answers. If participants failed to recall all word pairs within 20 – 25 minutes, they

were excluded and only partially compensated. After successfully completing the *Test Feedback Phase*, participants continued with a *Practice TNT Phase* in which they were introduced to the procedure. Then participants filled out the first *Diagnostic Questionnaire*, which assessed if they understood the assignment. Next, they underwent the 20-minute main *TNT Task*, which also entailed two one-minute breaks and another assessment of the *Diagnostic Questionnaire*. Afterwards, participants participated in the SP and IP procedures (randomly ordered). After that, participants were done with the Inquisit TNT files, and the experimenter stopped sharing their screen. Participants were sent the Qualtrics link to the *End of Study Questionnaire*, which they were asked to fill out and share when the End of study screen appeared so that the experimenter knew that the participant has completed the session and can be compensated (all material used can be found <https://osf.io/e75a6/>).

### **Planned Analysis**

Preliminary to the hypotheses testing SIF score were computed by subtracting the suppression item from the baseline item in both SP and IP condition.

*Hypothesis 1* “Participants will recall more baseline than suppress items in both SP and IP.” was tested using paired sample t-test, comparing the percentage of correct responses (DV) and scores of suppress and baseline (IV) in both SP and IP conditions.

*Hypothesis 2* “SP and IP will be statistically equivalent.” was tested using equivalence testing looking at the effect size (DV) and Score of SIF in SP and IP (IV). As taken by the rule of Simonsohn (2015) to calculate the SESOI with an error rate of 33% and the sample size of a previous study ( $N = 32$ ) in this field by Anderson and Green (2001), we ran a G\*Power analysis. A sensitivity analysis indicates an effect size with 32 participants would be sensitive to effects of  $d = .27$  with 33% power ( $\alpha = .05$ , two-tailed). Therefore, the equivalence bounds were chosen to be ranging from  $-.27$  to  $.27$ . Calculations were made with the Excel spreadsheet available at <https://osf.io/qamc6/> (Isager et al., 2022).

*Hypothesis 3 “Participants scoring lower on self-reported executive function will show less SIF.”* was tested via computing a Pearson correlation between the previously computed SIF Scores SP/IP and Webexec total score and its individual items (i.e., attention, concentration, multitasking, distractibility, perseverance and impulsivity). The reasoning for including the individual items of the Webexec in the analysis is that all six items question different aspects of executive control with the possibility of holding different importance for suppression (i.e., attention, concentration, distractibility).

*Hypothesis 4 “Participants scoring lower on self-reported thought control ability will show less SIF.”* was tested via computing a Pearson correlation between the previously computed SIF Scores of SP/IP and TCAQ.



## Results

Table 2 gives an overview of the descriptive statistics of the items needed for the hypotheses testing.

**Table 2**

*Descriptive Statistics of all variables used for analysis.*

	<i>M</i>	<i>SD</i>	<i>Mdn</i>	<i>IQR</i>
<b>Webexec</b>				
Total Score	9.32	3.32	8	7-10
Attention	1.43	.67	1	1-2
Concentration	1.46	.74	1	1-2
Multitasking	1.48	.69	1	1-2
Distractibility	1.73	.77	2	2-2
Perseverance	1.47	.76	1	1-2
Impulsivity	1.75	.79	2	1-2
TCAQ				
Total Score	83.10	16.86	84	71.5 – 93
<b>SP</b>				
SIF	.01	.19	.00	-0.08 - 0.08
Suppression	.78	.19	.83	0.66 – 0.92
Recall	.98	.05	1	1-1
Baseline	.79	.16	.83	0.66 – 0.92
<b>IP</b>				
SIF	.01	.02	.00	-0.08 - 0.08
Suppression	.73	.16	.75	0.58 – 0.83
Recall	.79	.83	.157	0.66 – 0.92
Baseline	.74	.17	.75	0.83 – 0.92

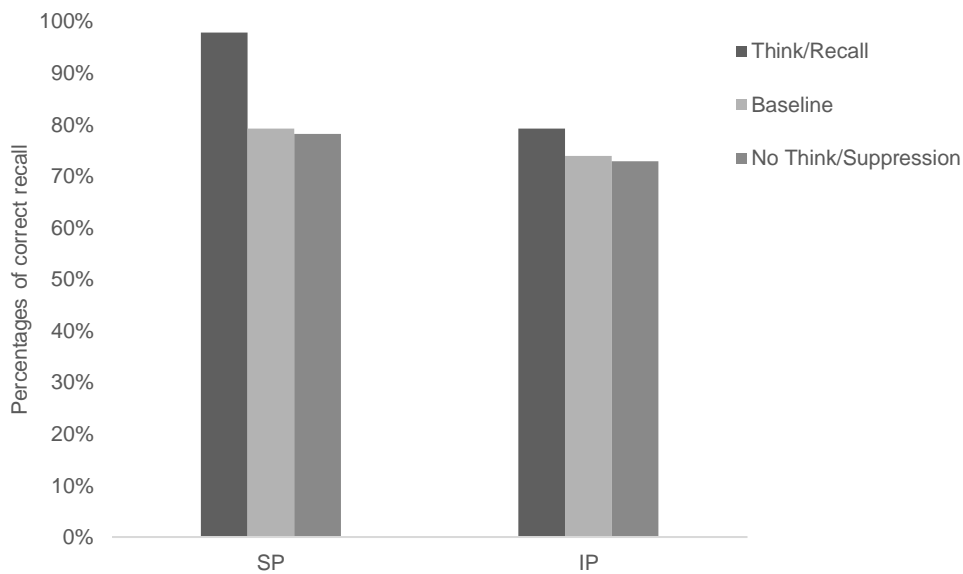
*Note.* The Web-based Executive Functioning Questionnaire (Webexec) includes items of Attention, Concentration, Multitasking, Distractibility, Perseverance, Impulsivity and an overall Total Score. For the Thought Control Ability Questionnaire (TCAQ) only a total score is included into this table. The Same Probe (SP) and Independent Probe (IP) conditions of the Think/No-Think (TNT) task consisted of measures reporting the suppression and recall of items, as well as baseline items. Further a score of Suppression-Induced Forgetting (SIF) is reported in both conditions, which is computed by subtracting suppression from baseline items.

A paired sample t-test was conducted to test if participants would recall more baseline than suppress items in both SP and IP conditions (*Hypothesis 1*). There was no statistically significant difference in SP for participants recalling more baseline than suppressed items  $t(149) = 0.69, p = .488, d = 0.06$ . In IP as well, there was no statistically significant difference

for participants recalling more baseline than suppressed items  $t(149) = 0.70, p = .483, d = 0.06$ . Due to no statistically significant differences in the recollection of baseline and suppress items in both SP and IP conditions, we failed to reject the null hypothesis and *Hypothesis 1* is not supported by the current data. *Figure 1* shows the observed percentages of correct recall for the different items of suppression, recall and baseline in both SP and IP conditions.

**Figure 1**

*Percentages of correct recall for the different items in SP and IP Conditions*



*Note.* This figure visualizes the percentages of correct recall of baseline items and the items that were instructed to either recall/ think about or suppress/ not think about in both the Same Probe (SP) and Independent Probe (IP) conditions. The percentage of correct recall was best for the items practiced as recall in both SP (98%) and IP (79%). The percentages of correct recall for baseline (SP=79%, IP=74%) and suppression item (SP=78%, IP=73%) did not differ much in both conditions.

The TOST procedure determines the statistical equivalence between SP and IP conditions (*Hypothesis 2*), indicating that the observed effect size ( $d_z = 0$ ) was statistically significantly within the equivalent bounds of  $d_z = -0.27$  and  $d_z = 0.27$ , (or in raw scores:  $-0.07$  and  $0.07$ ),  $t(149) = 3.31, p = .001$ . These results indicated that the null hypothesis that SP and IP differ in their SIF scores is rejected. Therefore, *Hypothesis 2* is supported by the current

data, with SP and IP being statistically significantly equal, meaning that individuals did not differ in their SIF.

A Pearson correlation between the Webexec and SIF in the SP and IP conditions was conducted to determine whether individuals scoring lower on self-perceived executive functioning would also show less SIF (*Hypothesis 3*). Initially, the analysis was conducted to solely compare SIF and the total score of the Webexec. Due to the individual item testing for different aspects of executive functioning, an additional analysis was conducted to see if effects would differ depending on subcategories. As illustrated in *Table 3*, there were no statistically significant correlations, so *Hypothesis 3* was not supported by the current data. Although it is important to mention that the correlation between the items of the Webexec and SP were positive, while the correlations of the Webexec and IP were negative, except for “Perseverance”.

**Table 3**

*Overview of a Pearson’s’ correlation analysis of Webexec items and SIF in SP and IP*

	<i>SIF in SP</i>		<i>SIF in IP</i>	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Webexec				
Attention	.01	.981	-.07	.374
Concentration	.03	.757	-.02	.813
Multitasking	.11	.171	-.04	.665
Distractibility	.02	.768	-.07	.391
Perseverance	.04	.637	.03	.738
Impulsivity	.01	.865	-.06	.476
Total Score	.05	.553	-.05	.540

*Note.* The *p*-value represents the statistical significance of the correlation, with values less than 0.05 indicating a significant correlation. The Web-based Executive Functioning Questionnaire (Webexec) measure for self-perceived executive function consists of six items measuring attention, concentration, multitasking, perseverance, and impulsivity. The Suppression-induced forgetting (SIF) scores for the Same Probe (SP) and Independent Probe (IP) were calculated by subtracting the correct responses of suppression items from the correct responses for the baseline items. Overall, no statistically significant correlations were observed between the Webexec measure for self-perceived executive function and SIF, indicating a very weak relationship between the two variables.

A second Pearson correlation between the TCAQ and SIF was conducted to assess whether individuals scoring lower on self-perceived thought control ability would also show less SIF effects (*Hypothesis 4*). A positive correlation between the total score of the TCAQ and SIF in the SP condition was found to be statistically non-significant  $r(148) = -.03, p = .742$ . Despite achieving a statistically significant negative correlation between the TCAQ and SIF in IP  $r(148) = .177, p = .031$ , the correlation is characterized by a small effect size, suggesting a weak inverted relationship between the TCAQ and SIF in IP. *Figure 2* and *3* give a visualization of the patterns and associations between the TCAQ and SIF in SP and IP (found in *Appendix A*). This analysis suggests that self-perceived thought control ability may have a limited impact on SIF. Therefore, *Hypotheses 4* could not be supported by the data in the SP condition and could only be weakly supported by the data in the IP condition.

### **Exploratory Analysis**

Exploratory analyses consisted of square rooting the Webexec, testing for a positive control effect and a correlation between the total scores of the TCAQ and Webexec questionnaire.

The Webexec was square-rooted to correct for the extreme skewness (see *Appendix B* for frequency distributions). A correlation between the total score square rooted Webexec and SIF showed a statistically non-significant positive correlation of  $r(148) = .05, p = .514$  in the SP condition and a statistically non-significant negative correlation of  $r(148) = -.06, p = .475$  in the IP condition. Hence, in both the correlations between SIF and Webexec, and between SIF and the square-rooted Webexec no statistically significant correlations were observed.

Examining a positive control effect, a paired sample t-test was conducted to determine whether participants would retrieve a higher level of recall items than baseline items in both SP and IP conditions. The data for both conditions indicates a statistically significant

difference for individuals recollecting more recall than baseline items in both SP  $t(149) = -14.98$   $p < .001$ ,  $d = 0.15$  and IP conditions  $t(149) = -3.50$ ,  $p < .001$ ,  $d = 0.19$ .

A Pearson correlation was conducted to see if there is a relationship between the measures of self-perceived thought control ability and executive function. The analysis showed a statistically significant negative correlation at a two-tailed level of  $r(148) = -.42$ ,  $p < .001$ .

## Discussion

The current study aimed to investigate SIF in an online administered version of Anderson and Greens' (2001) TNT study, and explore executive and thought control processes as an explanatory framework for SIF.

Contrary to previous findings, including Stramaccia et al. (2021), Anderson et al. (2004), Good and Kirk (2010), and Hertel and McDaniel (2010), the current study could not replicate any statistically significant effects of SIF in TNT in either SP or IP conditions. The analysis showed that participants did not statistically significantly recall more baseline than suppressed items which would have been an indication of SIF (*Hypothesis 1*). Further, an equivalence analysis of SP and IP conditions showed that the results of SIF were statistically equivalent (*Hypothesis 2*). This may be understood by both conditions not providing a statistically significant difference between the recall of baseline and suppression items.

Unlike previous studies, including Anderson and Green (2001), Davidson et al. (2019), and Chen et al. (2022), the results concerning the research question on the influence of executive control and thought control ability on SIF, indicated no statistically significant relationships. A correlation between the total score of the Webexec and SIF scores in SP and IP conditions showed no statistically significant relationship. Further, the individual items of Webexec, like Attention, Concertation, Multitasking, Distractibility, Perseverance, and Impulsivity, also showed no statistically significant relationship. Although all relationships were statistically insignificant and very weak, it is essential to mention that all correlations between the Webexec items and the SP condition were positive. In contrast, all correlations with the items (except Perseverance) and the IP condition were negative, suggesting that cue-independent suppression is negatively related to executive control (*Hypothesis 3*). A correlation between the total score of the TCAQ and SIF scores in SP conditions showed a negative, weak, statistically insignificant relationship. A correlation between the TCAQ and

SIF in IP, on the other hand, showed a positive, weak, statistically significant relationship. These results suggest that a higher self-perceived thought control ability might be connected to higher SIF in cue-independent suppression (*Hypothesis 4*). Interestingly an exploratory correlational analysis of the TCAQ and Webexec showed a moderate negative relationship, indicating an inverse association between both measures.

Overall, the current results cannot provide any clear evidence of SIF or whether self-perceived executive control or thought control ability are related to SIF in either IP or SP conditions of the TNT. Further research would be necessary to investigate these relationships in more detail. There are theoretical and methodological limitations that could provide an explanatory framework for these current predominately null findings.

Theoretical implications mainly concern the robustness of a SIF in the TNT Paradigm and the perseverance of the inhibitory control theory (Davidson et al., 2020; Hertel & McDaniel, 2010; Raaijmakers & Jakab, 2013). Anderson and Green (2001) originally constructed the TNT study after the assumption that direct suppression results from the exertion of inhibitory processes stopping memory recollection due to observations of similarities between memory and motor stopping. The current results lead to two speculations regarding the TNT Paradigm.

First, the question arises of whether TNT can indeed induce SIF by recruiting direct suppression, as indicated by Stramaccia et al. (2021), SIF has yet to be universally replicated. Raaijmakers and Jakab (2012) proposed the idea that previous effects of SIF in TNT can be attributed to thought substitution strategies rather than direct suppression, which can be traced back to previous studies not providing specific instructions on the task of suppression.

This leads to the second speculation regarding inhibitory control and the rather infrequently included and replicated IP condition. Anderson and Green (2001) incorporated the IP condition to check if participants used direct suppression (inhibitory processes) by

questioning the recall for novel test cues to eliminate the possibility of unlearning or interference. Still, this assumption does not withstand if participants used a substitution thought of the same category (e.g., the substitution of the word "Roach" with "Bug" in the word pair "Ordeal – Roach", IP condition "Insect – R ") (Anderson & Huddleston, 2012; Raaijmakers & Jakab, 2013). Further, this raises the question of whether direct suppression can actually be attributed to an inhibition control process.

In addition to those theoretical implications, several methodological limitations are worth mentioning. First of all, the current study was administered online, which might have impacted the obtained results due to the influence of technology issues and potential distractors that would have been controlled better in a lab setting.

Second, there is a possibility of participants answering regarding social desirability and a decrease in vigilance. Although the current study implemented a compliance screening, Liu et al. (2021) stated that people tend to suspect a later memory test and therefore take advantage of other strategies or use the time to practice.

Third, language barriers in the non-western participants might have been present. It seems as if some participants lacked the vocabulary necessary, making it harder for them to make an association between the word. Further issues were observed in regards to the accents, as the experimenter sometimes experienced issues with understanding the pronunciation and, therefore, possibly miscoded without being aware of it. As such, it is possible that these linguistic factors may have influenced the results of the study and warrant consideration in future research.

Future research should consist of replication attempts for SIF in Anderson and Greens' (2001) TNT paradigm considering different setting and including additional measurements to evaluate these aspects' possible influence on SIF in TNT. Additional measurements should include a more detailed and specific examination of executive function during TNT and other



aspects concerning the executive functioning capacity, like time of day and length of the study (Liu et al., 2021; Raaijmakers & Jakab, 2012). Due to the possibility of thought substitution being the main reason for the previous effect in TNT, further investigation of the IP conditions would be essential. Concluding it is safe to say that further research on SIF and its connection to executive functioning would be essential for legal and clinical practices.

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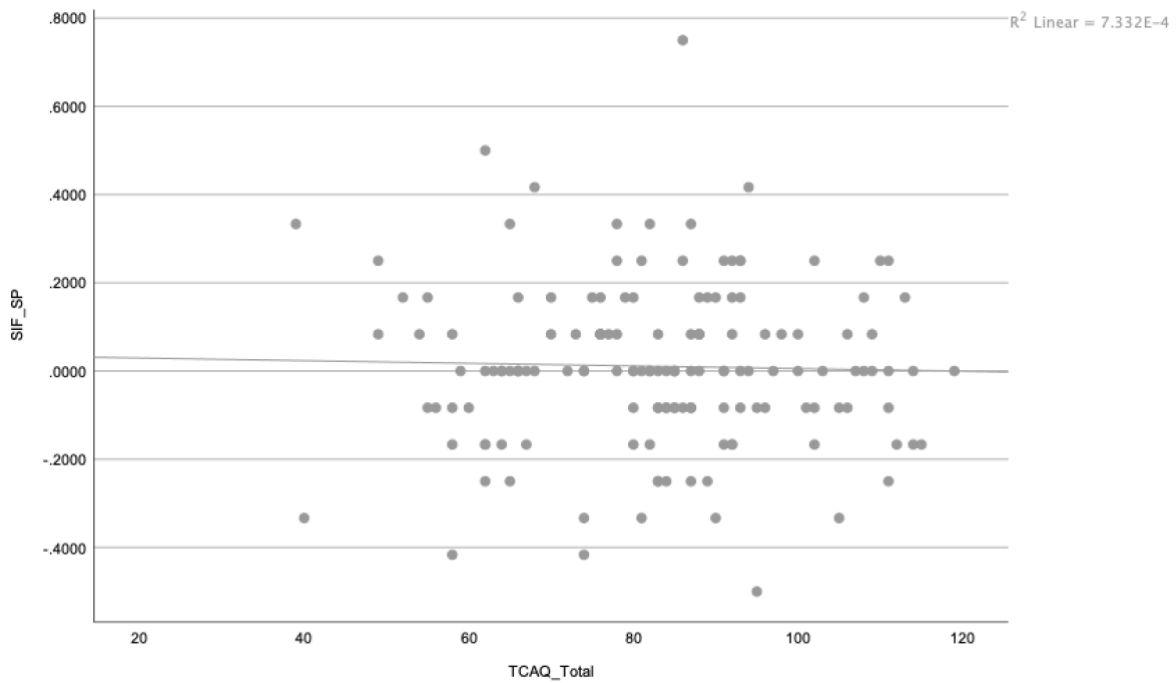
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## Appendix A

**Figure 2**

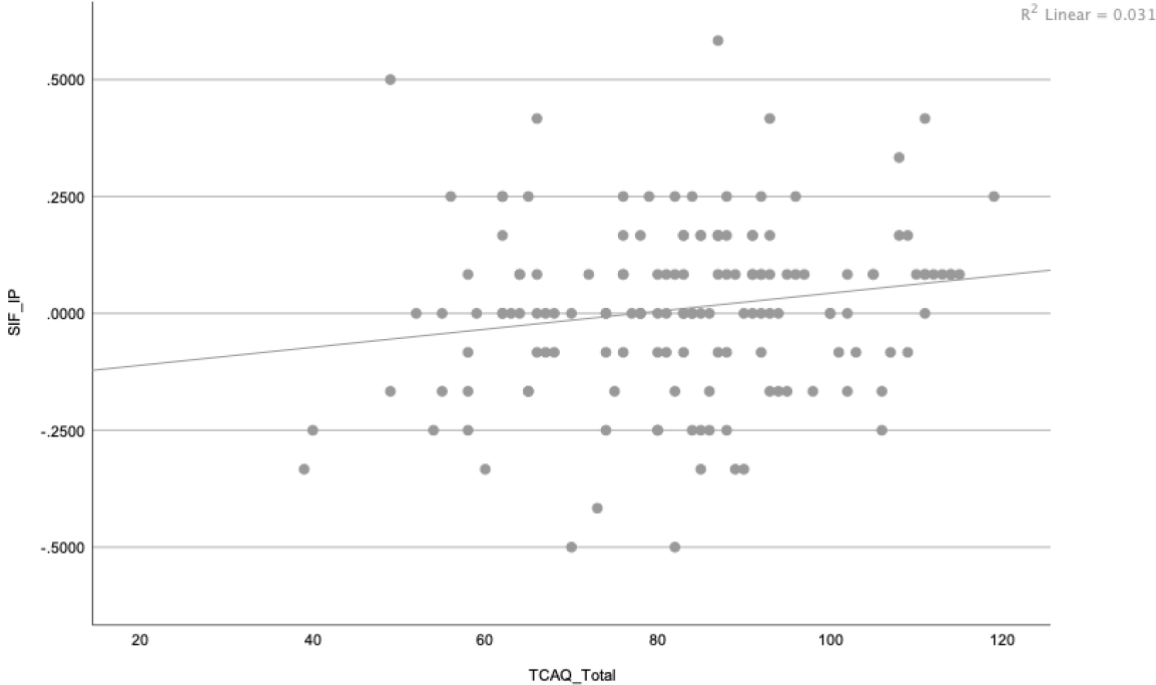
*Scatterplot of the TCAQ Scores and SIF scores in the SP condition*



*Note.* The scatterplot shows the relationship between the Thought Control Ability Questionnaire (TCAQ) scores and the Suppression-induced forgetting (SIF) scores in the Same Probe (SP) condition in the Think/No-Think task. Each data point represents an individual's scores on both measures, with the TCAQ scores plotted on the x-axis and the SIF scores plotted on the y-axis.

**Figure 3**

*Scatter plot of the TCAQ Scores and SIF scores in the IP condition*



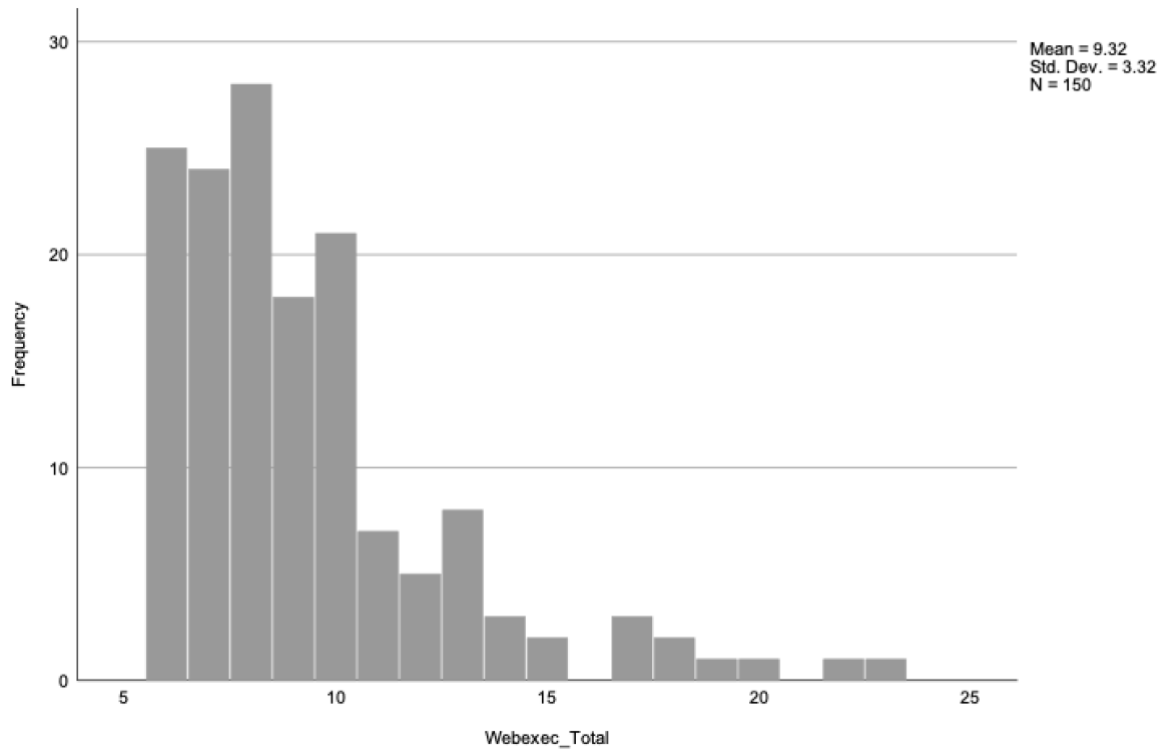
*Note.* The scatterplot shows the relationship between the Thought Control Ability Questionnaire (TCAQ) scores and the Suppression-induced forgetting (SIF) scores in the Same Probe (IP) condition in the Think/No-Think task. Each data point represents an individual's scores on both measures, with the TCAQ scores plotted on the x-axis and the SIF scores plotted on the y-axis.



## Appendix B

**Figure 3**

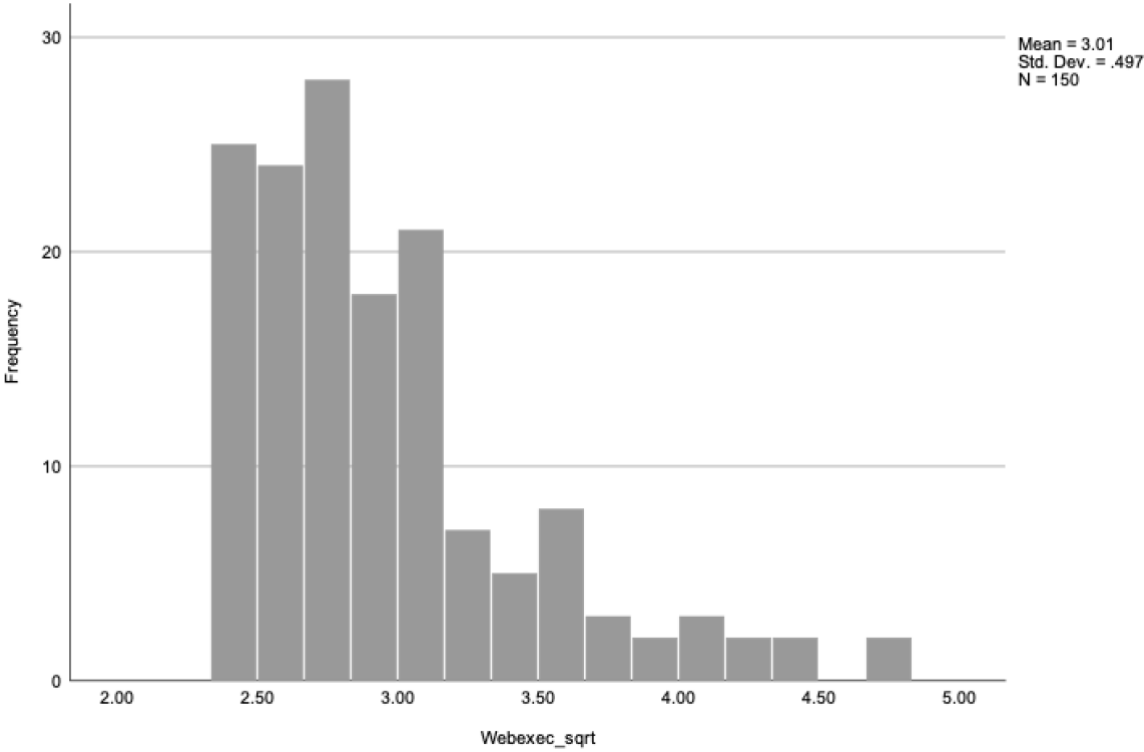
*Frequency Distribution of the Webexec Total Score*



*Note.* The figure shows a histogram of the Webexec total score (Web-based executive control questionnaire), with the frequency of each score represented by the height of each bar. The x-axis represents the range of square-rooted total scores, and the y-axis represents the frequency of each score.

**Figure 4**

*Frequency Distribution of the Square-rooted Webexec Total Score*



*Note.* The figure shows a histogram of the square-rooted Webexec total score (Web-based executive control questionnaire), with the frequency of each score represented by the height of each bar. The x-axis represents the range of square-rooted total scores, and the y-axis represents the frequency of each score.