THESIS

SUPPRESSION OF FREE ASSOCIATIONS IN THE THINK/NO-THINK PARADIGM

Submitted by

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In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Spring 2014

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ABSTRACT

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THINK/NO-THINK PARADIGM

Empirical support for forgetting due to memory suppression, the act of intentionally pushing material out of one's mind, has been found using the think/no-think (TNT) paradigm. However, there is little consistency in results across experiments using this paradigm, with no known systematic difference that can predict whether a given experiment will be successful or not. Prior published findings and pilot data suggest that one mediating factor may be speed of response, with fast responders demonstrating suppression while slow responders do not. In order to directly investigate this hypothesis, the present with-in subjects experiment manipulated time allowed for subjects to respond in a free-association variation of the standard TNT paradigm. Results did not show any differences based on speed of response, or on other qualitative information provided by participants. It remains unclear whether there is a particular factor that can predict the success of the TNT paradigm.

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Review of Literature

Throughout the past decade, conflicting reports have emerged on the issue of whether people can suppress unwanted memories. Whereas some researchers have reported that being instructed not to think of a target word in response to a cue leads to suppressed memory for that target word (e.g., Anderson & Green, 2001; Anderson et al., 2004), other researchers report failures to replicate the basic finding (Bulevich, Roediger, Balota & Butler, 2006). Various potential explanations for these discrepancies have been put forward. One such explanation is the executive deficit hypothesis, according to which people who are lower in executive function ability are less able to suppress unwanted memories (e.g., Levy & Anderson, 2008), which could potentially account for why evidence of suppression is sometimes found and sometimes not. Other evidence points toward response time possibly playing a role; fast responses may be associated with a greater likelihood of successful suppression than slow responses (Noreen & MacLeod, 2013). A major purpose of the present study was to investigate the hypothesis that participant response time is a factor that can determine whether or not suppression will occur and in turn, whether this may be a contributing factor to the sometimes elusive nature of the suppression effect.

The issue of whether people can suppress unwanted memories is related to the concept of memory repression (the ability to push an unpleasant or unwanted memory out of consciousness, without conscious effort). According to Freud's theory, one function of memory repression is to serve as a defense mechanism; through repression people can avoid a psychologically harmful memory by excluding it from consciousness (Jones, 1910). However, this adaptive forgetting is

very controversial, and it is not certain that humans have the capacity to repress information they once knew.

Much of the early work on repression came from case studies and anecdotal evidence of repression. For example, in a highly controversial case, "Jane Doe" was thought to have recovered a vivid memory of childhood sexual abuse by her mother over eleven years later (Loftus & Guyer, 2002). However, it has been suggested that many anecdotal accounts are "empirical observations lacking in scientific underpinnings" (Ganaway, 1992, p. 203), and Loftus and Guyer (2002) warned that although case studies are compelling, they are often misleading. In the case of Jane Doe, evidence later became available that dismissed several of Jane's recovered memories that had been repressed from her childhood, and it seemed highly likely that the "recovered" memory was not accurate. Despite the conflicting evidence, the case study had already become a popular example through the media and through university classrooms that repressed memories truly exist (Loftus & Guyer, 2002). This case demonstrates the need for greater experimental control and empirical methodology to gain a clearer understanding of repressed memories.

One of the main difficulties in studying repression using the scientific method is that repression cannot be ethically induced in a laboratory setting. As a result, a methodological paradigm was developed to study memory suppression, which has been theorized to be a voluntary form of repression according to the repression hypothesis (Anderson & Green, 2001; Lambert, Good, & Kirk, 2010). The methodological paradigm is called the think/no-think (TNT) paradigm (Anderson & Green, 2001). In the TNT paradigm, participants learn a series of unrelated cue-target word pairs, for example *ordeal-roach*. Subjects were then tested on their ability to retrieve the second word in response to the first to a criterion to ensure that the pairs

had accurately been learned. For example, they may have needed to reach a level of 90% cued recall performance in order to proceed to the next phase. In the next phase of the experiment, subjects were presented with only the original cue, and an instruction to either actively think about (think) or avoid thinking about (no-think) the corresponding target. Of the total word pairs learned, one third were presented with a remember instruction, one third with a suppress instruction, and the final third were not presented during this middle phase; this acted as a baseline condition for comparison. In the third and final phase, participants completed a cued recall task for all of the target words learned in the first phase. Importantly, an independent cue was used. For example, if the studied pair had been ordeal-roach, on the final test, the cue might have been insect-r_____. Anderson and Green (2001) showed that participants exhibited better cued recall for "think" words and poorer cued recall for "no-think" words than words in a baseline condition. As described below, the use of an independent cue was important to the claim that suppression was the mechanism underlying the reduced memory found in the no-think condition compared to the baseline condition. Though this overall pattern of results implies that through intentionally suppressing a word the later recall of the word can be reduced, other conflicting reports exist in the literature.

One of the earliest questions to arise based on the evidence of suppression found in the TNT paradigm was what are the underlying mechanisms of suppression? Two competing theories exist for why suppression occurs: 1) retrieval competition and 2) inhibition (Anderson & Green, 2001). According to retrieval competition, during the process of suppression, the subject replaces the target word with a substitute. When this happens, the substitute gains association with the cue word and the target loses the association power it had initially. Thus, in a cued recall test, the target would be weaker as a result of the competition with the substitute,

and the pattern of results would show lowered recall. The competing theory of inhibition contends that retrieval competition is not necessary to lower activation, but that through pure intention of suppression, the subject can weaken the accessibility of the target word through cognitive control, which would result in lowered recall, and an identical pattern of results to the retrieval competition theory.

As a result, two types of cued recall tests were developed for the paradigm, one in which the original cue word was used, and one which employed a cue that is independent of the original word pair, but related to the target word in a different context (for example if the original learned cue-target pair was *ordeal-roach*, the independent cue for the target roach might have been *insect*). The purpose of the independent cue was to differentiate the underlying cause of suppression patterns, the idea being that if global inhibition of the term occurred (not just in the context of the cue-target pair, as would be predicted by the retrieval competition theory), then testing with an independent cue would show the suppression pattern. However, if retrieval competition were the underlying cause, when a new route to the target was provided through the independent cue, it would not have been any less accessible. Research displays conflicting evidence regarding the underlying mechanisms of suppression. Experiments that used an independent cue did show evidence of suppression, which would support inhibition theory. However, effects found using a dependent cue at recall had a larger effect size and were found more frequently than experiments that used an independent cue (Anderson & Huddleston, 2012). As a result, a key component of TNT research is the use of an independent cue in order to further investigate the circumstances under which inhibition vs. competition seems to play a role in suppression.

One of the avenues for further research using TNT was suppression for emotional material. Research supports that memory is enhanced for emotional material compared to emotionally neutral stimuli (Depue, Banich, & Curran, 2006). Thus, the question of whether more salient memories can still be intentionally suppressed was investigated. Lambert et al. (2010) applied the TNT paradigm to study emotional stimuli, comparing suppression for emotionally positive or negative to neutral stimuli. They found that typical TNT suppression effects were evident for negative emotional material, but not for positive emotional material. These findings are interesting because they imply that it is not necessarily just that the stimuli are emotional, but that the actual valence (positive or negative), is a factor that determines whether suppression is possible. They argue these results to be in support of the repression hypothesis, as repression occurred only for troubling, emotionally negative material, and not positive emotional material.

Besides considering the valence of the stimuli, other theories regarding emotion and memory have been tested using the TNT paradigm. Depue et al. (2006) applied the TNT paradigm to determine the processes underlying the enhancement of memory for emotional material by studying the interaction of emotional stimuli and suppression. They proposed that one of two possible outcomes would occur: 1) if the strengthening due to emotional content was attributed to heightened cognitive control, then memory for emotional "think" words would be better than neutral "think" words, and memory for emotional "no-think" words would be worse than neutral "no-think" words, *or* 2) if the enhanced memory of emotional material was due to better encoding, then "think" emotional words would be better remembered than "think" neutral words, and memory for "no-think" emotional words would be better than memory for "no-think" neutral words. Their results supported the theory that enhanced memory of emotional material is

due to increased cognitive control. That is, when emotional material was present the person was better able to remember it when intending to remember, and also able to better suppress the material when intending to suppress it. Although this study shows support for suppression of emotional material, no independent cue was used in this experiment, so it was unclear whether interference or inhibition is responsible for the pattern of results, or whether suppression will persist if an independent cue is used with the more salient material.

Although these studies on emotion and suppression show support for the repression hypothesis, a study of suppression effects over a delayed time period finds evidence that challenges this theory. While finding that memory for neutral words was indeed reduced in the suppression condition when tested immediately, Nørby, Lange, and Larsen (2010) observed that subjects who were tested one week after the initial learning and suppression phases had better memory for items in the suppression condition than for items at baseline. Nørby and colleagues (2010) concluded that the inhibition produced through suppression initially succeeded in blocking the target word from production but was released over time, making it so that the target word was no longer blocked. As a result, suppression led to short-term blocking rather than long-term forgetting.

In social psychology research on suppression, Wegner, Schneider, Carter, and White (1978) found that when subjects were instructed to not think of a white bear, not only were they unable to suppress thoughts of white bears, but they had more intruding thoughts of white bears than subjects that were instructed to think of white bears. In both the study by Wegner et al. (1978) and TNT studies (Anderson & Green, 2001; Anderson & Levy, 2009; Depue et al., 2006; Lambert et al., 2010; Nørby et al., 2010), subjects were told to push specific thoughts out of

mind. However, in the TNT paradigm subjects were successful, and in the other case, subjects not only failed, but became preoccupied with the thought they intended to suppress.

Additional problems with the TNT paradigm have also emerged. Although Anderson and Green (2001) were able to find suppression effects using the TNT paradigm, other researchers have failed to replicate this effect, even when using an identical method to the original study (Bulevich, Roediger, Balota, & Butler, 2006). Particularly when using an independent cue at test, which Anderson and Spellman (1995) argue is necessary for study of suppression, suppression effects are small and are not always replicable. Furthermore, Bulevich and colleagues (2006) could not determine a plausible explanation based on individual differences between samples that would lead to the inability to replicate the results of the original study.

One individual differences hypothesis accounts for discrepancies in TNT research through differences in executive function (Anderson & Levy, 2008). According to the executive deficit hypothesis, suppression results from using executive control mechanisms; therefore, individual differences in executive control function could account for variation in suppression effects across subjects. This study found that subjects with low working memory capacity did not show suppression, and even sometimes showed facilitation for to-be-suppressed information, while high capacity working memory predicted successful suppression. In this experiment, strategy of suppression was not shown to affect the outcome of suppression efforts, but speed of response was not considered. Furthermore, while this hypothesis seems very likely, it still does not account for the findings of Bulevich et al. (2006), which found no differences between their sample and the sample used by Anderson and Green, (2001). Although TNT seems like a

promising means to study mechanisms of repression, these inconsistencies across laboratories show that the TNT paradigm is not a reliable technique for demonstrating memory suppression.

Another major issue with the TNT paradigm is that studies have participants learn word-word pairs or word-face pairs. These pairs are arbitrarily formed and often pairs are not associated in any way (semantically, phonologically, etc.). Although the methodology of the paradigm ensures that subjects are tested to a criterion prior to the think/no-think phase to confirm that subjects have indeed learned the word pairs accurately, it is not highly likely that the word pairs become very meaningful to the subject. Particularly when considering the possible application of TNT research to PTSD treatment, research should focus on making the material being suppressed very accessible and personally relevant to the participant.

The question of whether it is possible to suppress personally relevant memories has been addressed in the form of the autobiographical TNT paradigm (Noreen & Macleod, 2012). In this paradigm, subjects generated autobiographical memories when presented with a cue (as opposed to learning existing pairs). Subjects were tested to ensure that they remembered the pairs they had created, and went through a think/no-think phase, just as in the original paradigm. At test, subjects were presented again with the original cues, and recall for the gist of the event and for details of the event was measured. This study found suppression of no-think items for autobiographical memories, but only for details of the memories rather than the entire event.

Although Noreen and Macleod (2012) detected suppression effects, they did not employ an independent cue in the testing phase. Anderson and Green (2001) have argued that in using an independent cue at test, inhibition, rather than interference, is the underlying mechanism of suppression. Because the independent cue provides a different route to access the memory, suppression effects should only occur if the memory had been globally inhibited, and therefore is

less accessible overall, not only when the original cue is used. Because Noreen and Macleod used the same cues at test as they had used through the whole experiment, it is possible that the decrease in recall for no-think memories is due to interference rather than inhibition. From their study, it is impossible to determine whether suppression of autobiographical compared with non-personal information involve the same underlying mechanisms for suppression.

Although their experiment does not provide information about the underlying mechanisms of suppression, Noreen and MacLeod (2012) identify another factor that may explain suppression: response time. They investigated individual differences in response latency across participants, and determined that no-think memories that were unsuccessfully suppressed (i.e. remembered) were recalled more slowly than memories in the baseline condition. Based on this information it may be possible that with sufficient time to actively search for a target, suppression effects would not be obtained. Consequently inhibition may lead to forgetting, but more specifically may make a memory *less* accessible, rather than inaccessible. The theory that suppression effects may be dependent on response time has yet to be investigated in TNT literature. It is possible that because response time has yet to be investigated, this variable could be responsible for failures to replicate TNT that many researchers experience. Noreen & Macleod (2012) begin to investigate the role of response time; however, they did not directly manipulate response time but rather looked at self-paced responses of the subjects.

Although no experiments using the TNT paradigm have directly manipulated the time allowed to respond, this manipulation has been explored in a related paradigm used to study inhibition versus interference, the retrieval-induced forgetting (RIF) paradigm (Verde & Perfect, 2011). Typical results of this paradigm support that when competition between exemplars is induced, then the activation of one exemplar through practice would result in the inhibition of the

other unpracticed exemplars in order to facilitate recall. This pattern was present both when the original category was used in a cued recall test, and when an independent cue (for example, the category RED instead of FRUIT) was used. Verde and Perfect (2011) directly manipulated the time subjects had to respond during the cued recall test, and found that when a speeded test was used, then the pattern of lowered recall for inhibited items was not present as it was during a self-paced test. Considering that the RIF and TNT paradigms were both designed to explore inhibition versus interference, it seems as though response speed may be a regulating factor in TNT research as well. Perhaps the speed of response may even help to explain why suppression is evident in some experiments but not in others, considering that no TNT experiments directly measure or control time spent on the recall test. This was a major purpose of the present study.

Purpose

The current study utilized the original TNT paradigm with two major changes in methodology. First, rather than learning a set of unrelated word pairs, participants created their own word pairs. Similarly to word association games, participants were given a cue word and were instructed to name the first word that comes to mind. Once the list of word pairs was created, participants were tested on remembering what word association they chose. Following this, the typical TNT procedure continued; cue words were presented and participants were told to suppress or think of the word association they had previously generated. The test phase of this experiment used an independent cue word to prompt recall of the originally freely-associated word, as an independent cue had been determined by Anderson and Spellman (1995) to be the most effective way to determine the accessibility of the target word following suppression. The major contribution of this manipulation was to provide a method to study how suppression affects strongly associated material, but that still allowed for the use of an independent cue. The

second change in methodology occurred during the testing phase following suggestion from Noreen and Macleod (2012) and pilot data preliminarily collected (see Experiments 1-3): the amount of time allowed to respond to the independent cue was manipulated to determine whether response time contributed to the occurrence of suppression effects.

It may seem unlikely to expect that a subject wouldn't be able to recall a word they had thought of themselves; the idea that someone could suppress a thought that had so recently come easily in to mind is very counterintuitive. However, a study by Benjamin, Bjork, & Schwartz (1998) found evidence to support making this counterintuitive hypothesis. In this study, participants were initially tested on general knowledge questions. It was found that those answers that initially came easily to mind were in fact more difficult to recall on a later episodic free recall test than answers that were initially more difficult to retrieve. This finding suggests that words retrieved easily from semantic memory are not necessarily later easily recalled on an episodic memory test for words generated during the encoding phase (Benjamin et al., 1998). This task is very similar to the altered TNT procedure proposed in this study, with the addition of an instruction to either focus attention to the target or suppress the target between the semantic free association and the episodic recall.

Pilot Experiments

Given the elusive nature of the suppression effects found in the TNT paradigm and the novel components of the present experiment, pilot research was conducted with the purpose of determining that a scrambled version of a word would be reasonable to use as an independent cue (Experiment 1a), that free associations can be successfully used in the TNT paradigm (Experiment 1b), and that response speed would affect outcome of a pure replication of a previous TNT experiment (Experiment 2).

Experiment 1a

One of the key elements of a TNT study was the independent cue at test. In many cases, a semantically related independent cue was employed (for example ordeal-roach would have the independent cue insect-r____). This type of cue was impossible to use for this study as word pairs were created by the subject. It was proposed that a sufficient independent cue would be a scrambled version of the user entered word. The familiarity of the letters, although out of sequence, would facilitate the retrieval of a specific target word, without the presentation of the original cue, thus making it independent of the original word pair. In this experiment, scrambled words were tested to determine if they were an effective independent cue for originally associated words.

Method

Participants

Participants were recruited from the Psychology Department Research Pool at Colorado State. Participants were students enrolled in an introductory psychology course, and received partial credit for participation. A total of 12 subjects were tested.

Materials

The computer program E-Prime Version 1.2 was used to present the cue words, record subject responses, and subsequently scramble the subjects' input for later presentation. The cue words were selected based on their accessibility according to the General Accessibility Index developed by the University of South Florida (Nelson, McEvoy, & Schreiber, 1998). A total of 48 words were selected (See Appendix), meaning that they are words that are typically highly associated with other words. By using words that have many possible association pairs (as opposed to words with few likely pairs), it increased the likelihood that subjects would create unique responses. Cue words were presented in random order to each subject.

Procedure

Participants were tested individually. To begin this study, participants completed a free association task in which they were presented with a word and were instructed to type in the first word that comes to mind after viewing the original cue. Subjects were given examples of how to form associations. A series of 48 free associations were subsequently completed. Following the creation of the free associations, subjects were once again presented with the original cues and were tested on memory of the associations they created to ensure they were able to accurately remember the associations. This step in the original think-no/think paradigms involves testing the subject's learning of the word-pairs for accuracy using a forced-choice recognition task; however for the purpose of this study, a free recall task was used to test accuracy. Subjects were required to remember their free associations to a 90% accuracy criterion; if this criterion was not met, the subject was excluded from data analysis.

After all cue words were presented, participants began the test phase of the experiment. In this phase, participants were presented with an independent cue, which in this case was the

original free-associated word presented with its letters scrambled. Subjects were asked to name, if possible, the word they had earlier free-associated and responses were recorded.

Results and Discussion

Across the 12 participants, the average for proportion correct identification of the scrambled word was .636 (*SD*=.151). No subject was able to correctly identify every scrambled independent cue, and the lowest performance rate was .417. These results indicate that a scrambled version of the free associations successfully serve as an independent cue at test.

Experiment 1b

In Experiment 1b, preliminary data were gathered to determine whether a free association manipulation to the standard TNT procedure was reasonable. Because subjects created their own word pairs, it was impossible to repeat the learning phase to force the subject to learn to criterion, as there was no objective measure, except to compare the subjects' responses a second time through to their initial responses. The purpose of this experiment was to ensure that subjects could accurately remember the free associations they used so that during the suppression phase of the experiment, the subject was thinking or not thinking of the appropriate word. Furthermore, this experiment served as an initial investigation as to whether suppression can occur for word pairs that high very strong association in the mind of each subject.

Method

Participants

Participants were recruited in the same way as described in Experiment 1a. A total of 94 subjects were tested.

Materials

The same materials were used from Experiment 1a.

Procedure

Participants were tested individually. To begin this study, participants completed a free association task in which they were presented with a word and instructed to type in the first word that came to mind after viewing the original cue. Subjects were given examples of how to form associations. A series of 48 free associations were subsequently completed. Following the creation of the free associations, subjects were once again presented with the original cues and were tested on memory of the associations they created to ensure they were able to accurately remember the associations. This step in the original think-no/think paradigms involved testing the subject's learning of the word-pairs for accuracy using a forced-choice recognition task; however, for the purpose of this study, a free recall task was used to test accuracy. Subjects were required to remember their free associations to a 90% accuracy criterion; if this criterion was not met, the subject was excluded from data analysis.

Next, participants began the second phase of the study, in which they were again individually presented with the original cue words and instructed to either actively think of the free-associated pair word, or to suppress thoughts of the free-associated pair word, following the procedure of Depue, Banich, and Curran (2006). Preceding the presentation of each cue word, a red (suppress) or green (think) fixation cross appeared on the screen for 1,500 ms to indicate which action the subject should take for each individual word. The cue word was then displayed for 4,000 ms, during which the subject activated or suppressed the free associated pair in his or her mind. A blank screen appeared for 500 ms after each word was presented (Depue et al., 2006). Each original cue word was presented ten times in this fashion in a randomized order.

After all cue words were presented, participants began the third and final phase of the experiment. In this phase, participants were presented with an independent cue, which in this

case was the original free-associated word presented with its letters scrambled. Subjects were asked to name, if possible, the word they had earlier free-associated. All response words and response times were recorded by the E-Prime program for each cue presented.

Following completion of the experiment, participants were asked to answer a few short questions asking for qualitative explanations of strategies used to either remember or suppress each free associated pair word. Participants were thanked for participation and debriefed regarding the purpose of the experiment.

Results and Discussion

A one-way analysis of variance (ANOVA) was used to the compare proportion of correct responses for the think (M = .692, SD = .168, SE = .017), baseline (M = .699, SD = .155, SE = .016), and no-think (M = .679, SD = .154, SE = .016), conditions. No significant effect was detected at an alpha-level of .05, $F(2,90) = .694$, $p = .502$. To further investigate the role of response speed on suppression effects, subjects in Experiment 2 were divided based on response speed (Noreen & Macleod, 2012) into quartiles. The middle 50% were dropped from analysis, and fast and slow responders were compared. A one-way ANOVA was conducted with just the middle 50% of participants comparing responses for the think (M = .701, SD = .171, SE = .025), baseline (M = .709, SD = .167, SE = .024), and no-think (M = .672, SD = .155, SE = .022), conditions to determine that there was still no significant effect for instruction across this sample. It was confirmed no suppression effect was detected $F(2,94) = 1.353$, $MSE = .013$, $p = .263$. A 2(speed) x 2(instruction) factorial ANOVA was run at an alpha-level of .05. Comparisons were made between the fast baseline condition (M = .745, SD = .156, SE = .033), fast suppression condition (M = .657, SD = .163, SE = .035), slow baseline condition (M=.701, SD = .159, SE = .034), and slow suppression condition (M = .693, SD = .134, SE = .029). A trend towards an

interaction was detected between speed and instruction $F(1,42) = 3.257$, $MSE = .011$, $p = .078$. These results suggested that response speed may determine whether suppression effects occur in the TNT paradigm, with fast responders showing suppression, while slow responders show no effect.

Experiment 2

Results from Experiment 1b indicated that how quickly a person responds to independent cues at test may influence whether or not suppression effects occur. Experiment 2 sought to further examine the role of speed of response. In this experiment, the TNT method used by Depue, Banich, and Curran (2006) was used but with the addition of the use of independent cues. The purpose of this was to extend the finding beyond free associations and to a more established TNT method, but with independent cues. Subjects learned word-face pairs, completed the think/no-think phase, and were tested using independent cues. Each subject underwent this procedure twice, once with a forced-fast response (maximum 4 sec) at test, and once with a forced-slow response (minimum 15 sec) at test. It was hypothesized that subjects would show suppression effects (recall no-think<baseline) when responding quickly, but effects will disappear (recall no-think=baseline) when forced to respond slowly at test.

Method

Participants

Participants were recruited during the summer on the campus of Colorado State University. Participants were volunteers recruited via flyers posted around campus. Subjects were paid at a rate of $10/hour of the experiment. A total of 60 subjects were tested.

Materials

The computer program E-Prime Version 1.2 was used to present all stimuli and record all participant responses. A total of 48 word-face pairs were used in this study. Faces were obtained from the International Affective Picture System (IAPS) and words from the Affective norms for English words (ANEW) stimulus sets. These 48 pairs were broken into 2 blocks of 24 word-face pairs. Face-word pair blocks were counterbalanced across conditions (think, no-think, and baseline) and across fast/slow tests.

Procedure

Participants were tested individually. To begin this study, participants completed a learning task in which a face and emotional word were presented together. Subjects were instructed to remember the word that went with each face. After viewing all 24 word-face pairs, subjects were tested on accuracy of learning using a forced choice recognition task. Subjects viewed a face, and had to choose the correct word from two options. Subjects were required to learn face-word pairs to a criterion of 90% accuracy. If this criterion was not met, subjects repeated the learning/test portion of the experiment until the criterion was met (up to five times).

Next, participants began the second phase of the experiment, in which they were again individually presented with a face from the learning phase, and were instructed to either actively think of the pair word, or to suppress thoughts of the pair word, following the procedure of Depue, Banich, and Curran (2006). Preceding the presentation of each cue word, a red (suppress) or green (think) fixation cross appeared on the screen for 1,500 ms to indicate which action the subject should take for each individual word. The cue word was then displayed for 4,000 ms, during which the subject activated or suppressed the associated pair in his or her mind.

A blank screen appeared for 500 ms after each word was presented (Depue, Banich, & Curran, 2006). Each face was presented ten times in this fashion in a randomized order.

After phase two was complete, participants began the third and final phase of the experiment. In this phase, participants were presented with an independent cue, which in this case was a non-word that was graphemically similar to the originally learned words (Ryals & Cleary, 2012). Subjects were asked to name, if possible, the word from the learning phase that was similar to the independent cue. At test, subjects had to respond quickly; they viewed the independent cue for 4000ms, and had an additional 4000ms to type in their response. The entire experiment (all three phases) were then repeated with the other half of face-word pairs (24-pair block) and at test, subjects viewed the independent cue for 15000ms, and then had an infinite amount of time to type in their response. It was counterbalanced across subjects whether the subject completed the fast or slow test condition first.

Following completion of the experiment, participants were asked to answer a few short questions that asked for qualitative explanations of tactics used to either remember or suppress each free associated pair word. Participants were thanked for participation and debriefed regarding the purpose of the experiment.

Results and Discussion

Subject responses (n = 60) were scored to determine the proportion of correct responses for the fast baseline words (M=.821, SD=.192, SE = .025), fast no-think words (M=.762, SD=.227, SE = .029), slow baseline words (M=.906, SD=.139, SE = .018), and slow no-think words (M=.906, SD=.147, SE = .019). Since we were only interested in suppression effects, a 2(condition) x 2(response speed) within subjects factorial ANOVA was conducted at an alpha-level of .05. Results indicate there was a main effect for speed of response $F(1,59)=14.75$, MSE

= .053, $p<.001$, a trend toward a main effect for suppression effects $F(1,59)=3.45$, MSE = .014, $p=.07$, and a significant interaction between speed and suppression condition $F(1,59)=4.30$, MSE = .012, $p=.04$. Post hoc analyses indicate in the fast condition recall in the suppression condition was significantly lower than baseline $t(59)=2.69$, $p=.009$, but there was no difference between the suppression condition and baseline for slow responses $t(59)=-.04$, $p=.96$.

These results indicate that suppression effects were dependent on the response time at test; only fast responders showed suppression effects.

Rationale for the Study

By taking the existing TNT paradigm and applying it to pre-existing memories, specifically ones that easily come to mind, we could more accurately make conclusions regarding suppression. Noreen and Macleod (2012) have also identified the need to study personally relevant material in suppression research; however, their autobiographical think/no-think (ATNT) paradigm lacked an independent cue. Anderson and Green (2001) determined an independent cue to be an essential component of the paradigm in order to make conclusions regarding inhibitory processes. The current study shared the underlying goal of studying suppression of personally relevant information with Noreen and Macleod (2012), but employed a method that allowed for an independent cue.

Additionally response time was manipulated in this experiment; time was limited to view the independent cue in the fast-response condition, and extended in the slow-response condition. Using this manipulation, I sought to demonstrate that inaccessibility due to inhibition could be overcome when sufficient time was allotted to search for the target, implying that inhibition is weak and may be overcome with intention to retrieve the target.

Think/no-thinkTNT has become a controversial paradigm because of many researchers were unable to replicate the suppression effects. Since relevant literature on TNT has not investigated the role of response latency, it is possible that failures to replicate this experiment could be due to individual differences in response time. It was hypothesized that if, by chance, subjects in a particular experiment had a higher proportion of slow responders, then suppression effects would not be detected. Through manipulating response time directly, it was sought to demonstrate this relationship, which might have resolved controversy over the paradigm.

Research Question/Hypothesis

RQ1: Will a think/no-think procedure in which subjects create word pairs based on what is easily accessible to each individual still produce suppression effects found using the original TNT paradigm?

H1: I hypothesized that suppression effects would be evident using the adapted think/no-think procedure, showing that free association targets in the think condition would show a higher correct recall proportion than words at baseline, and free association targets in the no-think condition would show a lower correct recall proportion than words at baseline.

RQ2: Will there be an interaction between response time and suppression effects?

H2: I hypothesized that suppression effects would only be detected in the condition in which subjects must respond quickly to the independent probe; if more time is allowed, suppression effects would not be present.

Method

Participants

Participants were recruited from the Psychology Department Research Pool at Colorado State University. Participants were students enrolled in an introductory psychology course, and received credit for participation. A total of 46 subjects were tested.

Materials

The computer program E-Prime Version 1.2 was used to present the cue words, record subject responses, and subsequently scramble the subject's input for later presentation. The cue words were selected based on their accessibility according to the General Accessibility Index developed by the University of South Florida (Nelson, McEvoy, & Schreiber, 1998). A total of 96 words were selected (see Appendix); they are words that are typically highly associated with other words. By using words that have many possible association pairs (as opposed to words with few likely pairs), it increased the likelihood that subjects created unique responses. Cue words were presented in random order to each subject.

Procedure and Design

Participants were tested individually. To begin this study, participants completed a free association task in which they were presented with a word and were instructed to type in the first word that came to mind after viewing the original cue. Subjects were given examples of how to form associations. A series of 48 free associations were subsequently completed. Following the creation of the free associations, subjects once again were presented with the original cues and are tested on memory of the associations they created to ensure they were able to accurately remember the associations. This step in the original think-no/think paradigms involved testing the subject's learning of the word-pairs for accuracy using a forced-choice recognition task;

however for the purpose of this study, a free recall task was used to test accuracy. Subjects' responses were compared to determine their accuracy in remembering the free associations.

Next, participants began the second phase of the study, in which they again were individually presented with the original cue words and instructed to either actively think of the free-associated pair word, or to suppress thoughts of the free-associated pair word, following the procedure of Depue et al. (2006). Preceding the presentation of each cue word, a red (suppress) or green (think) fixation cross appeared on the screen for 1,500 ms to indicate which action the subject should take for each individual word. The cue word was then displayed for 4,000 ms, during which the subject activated or suppressed the free associated pair in his or her mind. A blank screen appeared for 500 ms after each word was presented (Depue et al., 2006). One-third of the 48 words were in the activate category, one-third were in the suppress condition, and the final third were not be presented during the think/no-think phase. Each original cue word was presented ten times in this fashion in a randomized order.

After all cue words were presented, participants began the third and final phase of the experiment. In this phase, participants were presented with an independent cue, which in this case was the original free-associated word presented with its letters scrambled. The method used to scramble the targets was completely random and computer-generated, but obeyed the rule that the scrambled letters should not match the original organization of the letters of the word. This measure was taken to prevent the possibility that letters should randomly be reassembled into the original order. Subjects were asked to name, if possible, a word they had earlier free-associated. Subjects in the fast-response condition were allotted 4000 ms to view the scrambled letters, and an additional 5000 ms to type in their response, during which they were unable to view the independent probe. Subjects in the slow-response condition viewed the scrambled letters for a

minimum 15000 ms and were allotted an infinite amount of time to continue viewing the independent probe and/or to type in their response.

This experiment was a within subjects design, therefore subjects completed the entire procedure for the fast condition, and the entire procedure (using a second block of stimuli) for the slow condition The order in which they completed the two blocks and the block of stimuli used for each condition was randomized and counterbalanced between subjects.

Following completion of the experiment, participants were asked to answer a few short questions regarding the strategies used to either remember or suppress each free associated pair word, the difficulty of the task, and how successful they felt they were at suppressing the items. Participants were thanked for participation and debriefed regarding the purpose of the experiment.

Results and Discussion

A within subjects 2(speed) x 3(instruction) factorial analysis of variance (ANOVA) was conducted at an alpha-level of .05 to compare the proportion of correct responses for words in the think, suppress, and baseline conditions. Data were analyzed using IBM SPSS Statistics software Version 17.0.

Analyses were performed to compare responses for the Fast-Think (M = .689, SD = .162, SE = .024), Fast-Control (M = .704, SD = .175, SE = .026), Fast-No-Think (M = .692, SD = .201, SE = .030), Slow-Think (M = .773, SD = .159, SE = .023), Slow-Control (M = .759, SD = .171, SE = .025), and Slow-No-Think (M = .759, SD = .169, SE = .025) conditions. Similarly to the total subject pool, there was no main effect for suppression condition $F(2,44) = .102$, MSE = .011, p = .903 (see Figure 1), but there was a main effect for speed $F(1,45) = 15.038$, MSE = .022, $p < .001$. There was no interaction between response speed and suppression condition $F(2,44)$ = 676, MSE = .009, p = .514 (see Figure 2).

Additional analyses were performed regarding the criterion to which subjects could accurately re-recall free associations. Only subjects that performed with about 90% accuracy in both the fast and slow conditions were included; a total of 21 of the 46 subjects met this criterion. Responses were compared for the Fast-Think (M = .696, SD = .168, SE = .037), Fast-Control (M = .720, SD = .161, SE = .035), Fast-No-Think (M = .687, SD = .223, SE = .049), Slow-Think (M = .777, SD = .158, SE = .035), Slow-Control (M = .753, SD = .177, SE = .039), and Slow-No-Think (M = .788, SD = .175, SE = .038) conditions. Similarly to the total subject pool, there was no main effect for suppression condition $F(2,19) = .001$, MSE = .013, p = .999 (see Figure 3), but there was a main effect for speed $F(1,20) = 9.82$, MSE = .016, p = .005.

There was no interaction between response speed and suppression condition $F(2,19) = 2.094$, $MSE = .011$, $p = .151$ (see Figure 4).

Analyses were also performed to determine if any additional between subjects factors may have influenced the results. The first factor was the strategy used by the participants, based on qualitative information provided by subjects following the full experiment. Subjects were categorized into two groups based on whether they employed substitution or another method of suppression in accordance with the idea that perhaps suppression is dependent on substitution (Raaijmakers & Jakob, 2013). A mixed 2(strategy) x 3(condition) x 2(speed) ANVOA was run. Results did not show a significant interaction between suppression strategy and suppression condition $F(2,43) = .389$, $MSE = .012$, $p = .912$, or between suppression strategy, response speed, and suppression condition $F(2,43) = .092$, $MSE = .009$, $p = .912$.

Another possibility we explored was perhaps subjects were in tune with their own success at suppression. In the qualitative report, subjects were asked to rate the difficulty of the task of pushing the suppress items out of their mind. Responses were coded based on scores 1-5 or scores 6-10 to differentiate high from low difficulty. A mixed 2(difficulty) x 3(condition) x 2(speed) ANOVA showed no significant interaction between difficulty and condition $F(2,43) = 1.203$, $MSE = .011$, $p = .310$, and no significant interaction between difficulty, condition, and speed $F(2,43) = .337$, $MSE = .009$, $p = .715$.

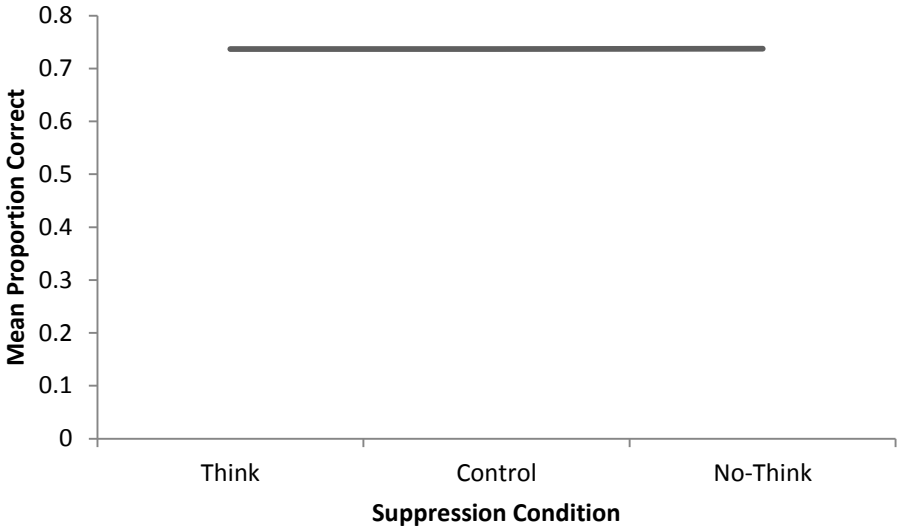

Figure 1. No main effect for suppression condition.

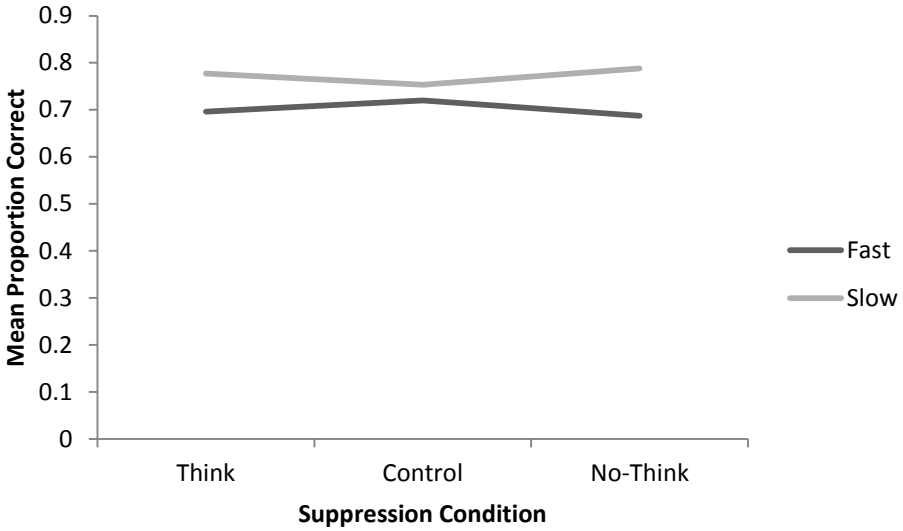

Figure 2. No interaction between suppression condition and response speed.

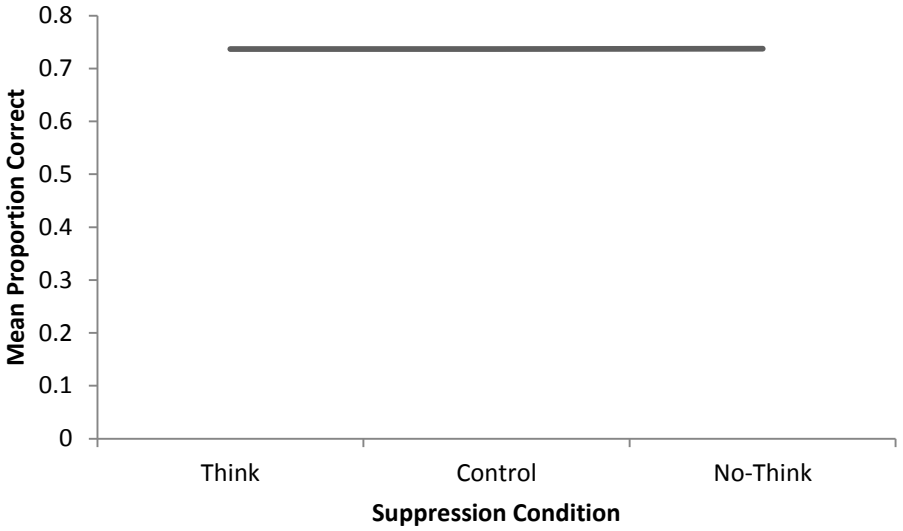

Figure 3. No main effect for suppression condition for only subjects above a 90% learning criterion.

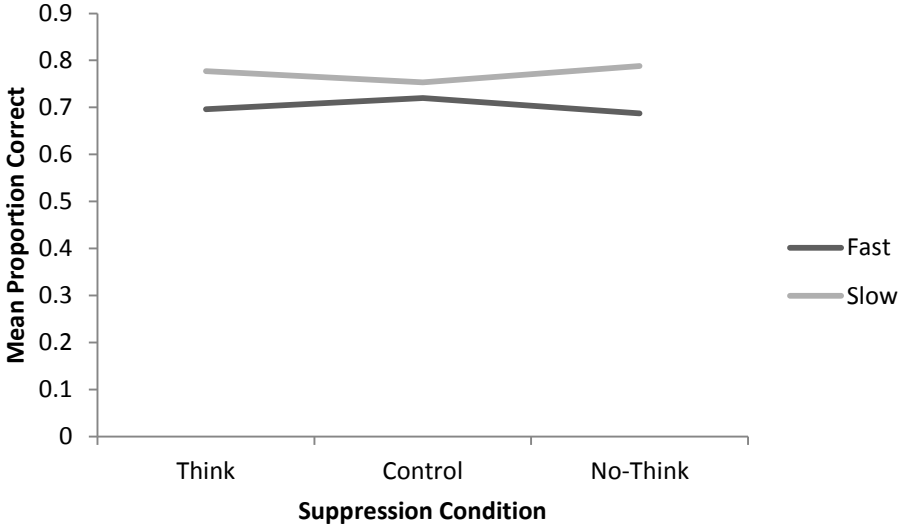

Figure 4. No interaction between suppression condition and response speed for only subjects above a 90% learning criterion.

General Discussion

In this study, comparisons were made between the proportion of words correctly identified in a cued recall task between baseline, active remembering, and suppression conditions for fast and slow responses. My hypothesis that an interaction would be present between response speed and condition was not supported, and furthermore no suppression effects were detected in this experiment. The only significant difference found was that when responding slowly, higher recall was achieved, most likely due to the fact that more time allowed for more accurate responses when unscrambling the independent cues, and was unrelated to the suppression condition. Together, the results reported here suggest that response time was not a likely factor that contributed to the elusive nature of memory suppression effects.

To further explore other potential factors that may affect the likelihood of finding suppression effects, I examined whether participant strategy was a factor. Strategy during the no-think phase has been theorized to play a key role in successful suppression (Raaijmakers & Jakob, 2013). However, the results of this experiment showed no difference between subjects that reported using substitution vs. other methods of suppression. Additionally, exploratory analyses were performed regarding the perceived difficulty of the task, to determine if subjects that felt competent at suppressing the material would perform differently than those who thought the suppression task was very difficult. Results also did not support that there were any differences in suppression patterns depending on perceived difficulty. It seems as though no matter the qualitative experience of the person performing the memory suppression, there are no identifiable patterns based on different experiences.

Although previous published research and pilot experiments suggested that speed might play an integral role in memory suppression, there is no evidence from this experiment for such an argument. The central difference between the present experiment and past studies is that subjects created their own word pairs while response speed was directly manipulated. We investigated potential methodological problems to determine whether certain factors affected the experiment. Even after several exploratory analyses to determine if other factors influenced the outcome of the experiment, no patterns of suppression were detected in the data. There are several possibilities for why no suppression effects occurred, even though pilot research suggested the manipulation in this experiment was likely to lead to a difference in suppression effects across fast and slow groups.

The first difference to be discussed is the nature of the independent cue used in the experiment: the scrambled version of the associated pair that originated from the subject during the trials. Prior research has not provided conclusive information regarding independent cues and their implications in the argument of inhibitory versus retrieval competition theories of forgetting. The purpose of the independent cue – a word that is related to the target word, but not in the same context in which the target was learned (for example, *ordeal-roach* may use the independent cue *insect* for the target roach) – is to disentangle the underlying process of forgetting by providing a new route to access a target word that wasn't a part of the preceding experiment (Anderson & Green, 2001). However, previous research demonstrated inconsistent findings of suppression effects in experiments which used independent cues; suppression was more consistently detected when using the original cue at the recall test (Anderson & Huddleston, 2011). The mere use of an independent cue may help to explain why suppression

effects were not detected, even in the fast response condition where evidence of suppression was expected.

Additional issues related to the independent cue may have also influenced the outcome of this experiment. Although the pilot experiment 1A demonstrated that subjects were successfully able to identify the scrambled word approximately 63.6% of the time, this type of independent cue had never before been used in research on inhibition. Raaijmakers and Jakob (2013) discussed the efficacy of semantically related independent probes, and suggested that these probes may not be truly independent. They describe the possibility that especially if the subject used a substitution method (replacing the target word with another word) during the no-think phase, the substitute word may have been closely related to the target, and consequently the independent cue may have become related to the target. For example, if the subject substituted *bug* for *roach* in the suppression phase for the pair *ordeal-roach*, the independent cue *insect* could have been activated both by the target *roach* and by the substitute *bug*, making the retrieval competition theory a viable explanation for suppression, even though an independent probe was used (Raaijmakers & Jakob, 2013). In the present experiment, the independent probe was purely unique to the target word. Therefore, if retrieval competition does indeed account for suppression and global inhibition of the target does not occur, there should have been no evidence of suppression with the use of an independent cue unique to the target. A possible route for further research would include using a scrambled independent cue in the original paradigm established by Anderson and Green (2001), which could provide insight on whether the nature of the independent cue matters, and if it is possible that semantic independent cues do not serve their intended purpose of disentangling inhibition from retrieval competition.

Another potential explanation for the lack of evidence of suppression in the present experiment was that the memory strength of the free associations was higher than the forces (inhibition or competition) that result in forgetting from attempting to suppress information. Depue, Banich, and Curran (2006) investigated the theory that memory strength may influence the ability to suppress by examining emotional material. Their findings supported the theory that in the case of emotional memory, greater cognitive control for emotional material rather than greater memory strength seems to account for changing patterns of suppression. However, because the present experiment did not employ emotional material, but rather pairs that are easily accessible to the subject, memory strength could be a contributing factor to the results.

A final potential explanation for the lack of evidence of suppression found in this experiment was that perhaps the TNT paradigm is just not a highly replicable paradigm. The issue of replicability is strongly debated in the current literature, with some authors strongly advising the need for psychological science to place more value on replication of previous findings. Pashler and Harris (2012) contended that conceptual, rather than direct replication is the best route to address the validity of prior findings. Within the TNT paradigm, there have been failures to replicate the experiment directly (Bulevich et al., 2006) and several experiments in which conceptual replications did not pan out (Raaijmakers & Jakob, 2013). After an extensive review of the TNT paradigm and the role of inhibition, authors describe TNT as "an elusive phenomenon at best", and assert that "at present, there seems to be no simple rule that explains why the effect is sometimes absent or very small" (Raaijmakers & Jakob, 2013, p. 114). Although the intention of this experiment was to investigate the possibility that response speed might be a simple rule that predicts the likelihood of successful replication, there was no evidence to support such a claim.

On suppression, inhibition, and forgetting

Given the outcome of the current experiment and the unreliability of the TNT paradigm in general, I would advise that caution be used before making any conclusions about suppression or inhibition from this research. Arguments can be made that the TNT paradigm is very successful in finding suppression, but that a very specific protocol must be used, and deviations from that method are to blame for failures to replicate findings. Though this may be accurate, I ask what is the practicality of such a paradigm? How could one expect to maintain that degree of control when trying to apply this research? Is it even likely that we could rely on a practical application of this research to demonstrate the predicted, given the knowledge that frequently the paradigm fails to replicate even in a controlled laboratory setting?

Furthermore, what is a realistic practical application of suppression research? When the paradigm was initially created, it was argued that suppression was a voluntary form of repression that could be ethically studied in the laboratory. Applications regarding potential treatment for PTSD symptoms were proposed, based on the idea that people could be taught to selectively forget. I would like to challenge the practicality of intentional forgetting. First of all, I would like to remind readers that even in the best cases, intentional suppression results in a relatively small decrease in the percentage of material remembered. There has been no evidence that suppression can result in true forgetting of selected material. Therefore, even if it were applied in clinical settings to help people forget painful material; would it even provide a worthwhile reduction of those memories? It is my opinion that TNT, especially when considering the feasibility of its proposed applications, is quickly demonstrating that the benefit may not outweigh the cost.

One could argue that regardless of viability of application of suppression research, that the theoretical value of understanding the underlying mechanisms of intentional forgetting alone is a worthwhile pursuit. Although TNT was designed to distinguish between interference or inhibition as the underlying mechanism of intentional forgetting, Raaijmakers and Jakob (2013) make the point that semantic independent cues may not in fact be independent and may be susceptible to interference. In the current experiment, no evidence of negative control effects was found when a truly independent cue was used. Unfortunately, no conclusions can be drawn on whether the case is that inhibition is not a factor in memory, or whether this study was yet another failure to replicate the TNT paradigm. Furthermore, although I argue that conclusions regarding the existence of inhibition should not be drawn from the TNT research, I do not completely rule it out as a potential factor in forgetting, based on the possibility of studying it using other more reliable paradigms. However, I would caution making conclusions based on independent cues, and I think great benefits could arise from research specifically on independent cues and whether they are actually as independent as we believed them to be.

I would further like to call into question the investigation of intentional forgetting as a whole. Though the concept of intentional forgetting is an interesting one, what is the true practicality of such research? Research has demonstrated that people are excellent at forgetting information, and that forgetting occurs without any specific intentions to do so. It could be that there are mechanisms such as interference or inhibition that aide forgetting, but perhaps it is that forgetting is more a lack of remembering. We know that when neural pathways are used they are strengthened, which results in better remembering. Would research be better directed at finding ways to continue increasing strength of desired memories? What is the true benefit of researching forgetting? One could argue that intentional forgetting has little to no practical

benefit, seeing as without any effort much of what we need to forget we are very capable of forgetting entirely on our own.

In conclusion, this experiment failed to show that response speed affects memory suppression in the TNT paradigm. In so doing, this study helps to rule out at least one potential explanation for the elusive nature of the memory suppression effect. There are several potential avenues for further research which include investigation of the independence of independent cues and investigation of the executive deficit hypothesis as a potential explanation of failures to replicate. However, as enticing as this area of research is, I hope researchers in the future take into consideration whether the cost put into investigation of TNT is worth the benefits that the paradigm has to offer in practical application of findings or theoretical implications regarding forgetting.

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Appendix

	Word	# Normed Associates	Frequency Values
1.	Money	265	302
2.	Water	442	276
3.	Paper	157	163
4.	Animal	68	156
5.	People	847	154
6.	Happy	98	145
7.	Music	216	132
8.	Party	216	84
9.	Dirty	36	83
10.	Body	276	83
11.	Science	131	81
12.	Together	267	80
13.	Boring	5	78
14.	Stupid	24	73
15.	Ocean	34	72
16.	Ugly	21	70
17.	Television	50	70
18.	Building	160	67
19.	Number	472	66
20.	Country	324	65
21.	Teacher	80	64
22.	Danger	70	61
23.	Beautiful	127	61
24.	Doctor	100	61
25.	Football	36	60
26.	Army	132	59
27.	Mountain	33	58
28.	Quiet	76	58
29.	Chicken	37	57
30.	Religion	119	57
31.	Family	331	56
32.	Picture	162	54
33.	Scary	2	50
34.	Question	257	54
35.	Power	342	53
36.	Evil	72	52
37.	Flower	23	52
38.	Dinner	91	51
39.	Knowledge	145	51
40.	Yellow	55	51

41. Easy	125	50
42. Criminal	24	47
43. Little	831	46
44. Medicine	30	46
45. Chocolate	9	46
46. Table	198	45
47. Metal	61	45
48. Government	417	45
49. autumn	22	4
50. blue	143	61
51. dance	90	62
52. fear	127	57
53. give	291	67
54. gross	30	80
55. meat	45	68
56. noise	37	65
57. open	319	70
58. problem	313	71
59. show	287	72
60. sleep	65	75
61. study	246	60
62. think	433	70
63. walk	100	59
64. wrong	129	87
65. alcohol	13	44
66. apple	9	47
67. art	208	52
68. baseball	57	50
69. beach	61	60
70. change	240	52
71. dress	67	55
72. drug	24	46
73. hole	58	53
74. horse	117	79
75. letter	145	47
76. mother	216	48
77. rude	6	46
78. spider	2	7
79. sport	17	50
80. star	25	51
81. black	203	129
82. child	213	101
83. church	348	85
84. class	207	95
85. clothes	89	147
86. death	277	133

87.	drink	82	101
88.	fire	187	91
89.	fun	44	151
90.	girl	220	127
91.	light	333	95
92.	movie	29	103
93.	round	81	45
94.	small	542	117
95.	white	365	131
96.	work	760	196