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Memory Suppression: The Importance of Baseline Learning for the Think/No-Think Task

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The Importance of Baseline Learning for the Think/No-Think Task

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by

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Memory Suppression: The Importance of Baseline Learning for the Think/No-Think Task

Abstract

Studies using the think/no-think task have never addressed the baselines they use throughout the experiment. This study's primary goal was to investigate the effect differing baselines for word-pair learning (50% vs. 75%) would have on the think/no-think task. A replication of Anderson and Greene's 2001 study using the Think/No-Think task was performed using either a 50% or 75% baseline as a threshold for participants moving to the think/no-think phase of the experiment. Due to the COVID-19 pandemic, this study implemented the think/no-think task online. Recall was evaluated using same and independent-probe memory tests.

Firstly, this study replicated the think/no-think effect in online conditions. This replication of the think/no-think effect followed the inhibition model of memory suppression proposed by Anderson as it was seen in both the same-probe and independent-probe memory test. However, the repetition effect proposed by Anderson was not replicated consistently, bringing into question the application of the think/no-think task to broader theories.

Secondly, this study gave evidence recommending the 50% baseline as a better option for initial word pair learning compared to the 75% baseline to an increased think/no-think effect and lower data exclusion in the 50% baseline. These baselines also showed a potential rehearsal effect of initial learning seen in same-probe memory tests when using higher learning baselines.

Keywords: think/no-think task, suppression-induced forgetting, inhibition, baselines, online, memory suppression

Memory Suppression: A Comparison Between Baseline Learning in the Think/No-Think Task

Introduction

Memories are unconsciously encoded in all individuals. Every new experience is encoded into memory without conscious effort. This is an excellent tool we possess for carrying out our day-to-day activities, however due to the unconscious nature of memory encoding we also encode traumatizing or unwanted events into memory. The ability to, consciously or unconsciously, prevent such traumatic memories from being recalled would be another very useful tool, but currently this possibility is hotly debated. This debate goes back to the time of Freud and his concept of repression, but the discussion has become an important issue again due to the recent emergence of 'memory wars' (Otgaar et al. 2019,2021). The memory wars refer to the battle between clinicians and scientists over whether memories can be repressed for years and recovered for therapeutic purposes, or alternatively that these memories are false memories that appear very real to the recaller. Originally, memory researchers sided with the notion of false memories, but in recent years some memory researchers have raised the real possibility that memories can be suppressed from recall, and the more often they are suppressed, the more difficult they are to recall. This thesis evaluates the main research methodology used to make such claims.

The most popular, and most impactful, laboratory-based methodology developed to study memory suppression is the Think/No-Think (TNT) method (Anderson & Greene, 2001). The TNT method is an adaption of the Go/No-go task developed to investigate inhibition of motor responses (Gordon,1983). In the go/no-go task, a participant is asked to press a button in response to cues. However, for some cues, called no-go cues, the participant must prevent the motor response of a button press. The cues for pressing the button outnumber the cues for

prevention of a button press, thus an inhibition of the motor response must occur for no-go cues to suppress the predominant response of a button press. Anderson adapted the Go/No-go task to investigate the inhibition of memory retrievals. This adaptation uses learned word pairs (cue-target) and requires participants to respond to some cue words by recalling their paired target word (think trials) and not to respond to other cue words by purposefully preventing the paired target word from being recalled (no-think trials).

During the TNT task, participants go through several phases. The first phase is a learning phase in which participants learn word pairs (i.e. INSECT-GRASS), and Anderson used 50-word pairs for this phase. These word pairs are then tested for memorization in a testing phase using cued recall tests. A minimum percentage of word pairs must be learned before the participant can move on to the next phase of the TNT task. This baseline was set at 50% of word pairs learned in Anderson's original experiment, although no clear justification was provided for this baseline. The participant was allowed to repeat this learning-test phase again if they did not reach the required baseline. Participants who failed to meet this baseline within three iterations of the learning-test blocks of trials were excluded from the study. After the learning phase, participants completed the think/no-think phase. In this phase, participants were shown the cue word for each word pair. If it was a think trial, the participant was instructed to respond with its paired target word. If it was a no-think trial, the participant was instructed to prevent the retrieval of the paired target word. In Anderson's original experiment, participants were provided with a list of the no-think cue words to memorize so that they knew which words would require memory suppression during the think/no-think phase. However, Anderson changed this experimental method in later iterations of the think/no-think task and used different font colors for the cue words to distinguish think trials (green) and no-think trials (red) (see Anderson and Greene, 2004). The

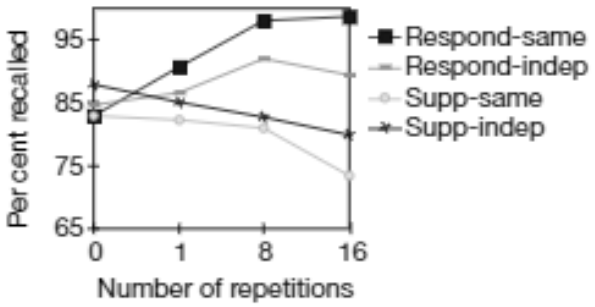
participant would receive different amounts of rehearsal or suppression practice for different word pairs. Word pairs could be shown 0, 1, 8, or 16 times during this phase. Filler word pairs were also used to increase the number of think trials to make the TNT task consistent with the go/no-go task.

After the think/no-think phase, the participant is tested for their recall of the target words using the cue words as prompts (same probe test). An independent probe test of the participant's memory for the target words was the final memory test, and involved using a target word semantic category as the prompt with the first letter of the target word to be recalled (e.g., YARD-G). The same-probe test is used to evaluate the TNT effect when using the same cue-words seen throughout the experiment. Anderson added the independent-probe test to isolate whether the TNT effect of memory suppression was due to inhibition. If the effect is due to inhibition, the memory suppression would be seen even if a unique cue such as the semantic category was used to evaluate recall. The order of the same-probe and independent-probe memory tests was counterbalanced across participants.

Anderson (2001) hypothesized that suppressing the recall of target words during the think/no-think phase would impact recall from long-term memory due to inhibition. Anderson's findings supported his hypothesis when reduced target word recall was found for the no-think word pairs when compared with the think word pairs in both the same-probe memory test and the independent-probe memory test in a think/no-think effect. (see Figure 1) The reduced target word recall for no-think word pairs in the independent-probe test supported the hypothesis that inhibition was the driving force for memory suppression in the think/no-think task. In addition, a repetition effect was seen for the more rehearsal (1-16 times a think trial presented) the better the

recall, and the more suppression (1-16 times the no-think trial was presented) the poorer the recall.

Figure 1



Note: Original findings from Michael Anderson and Greene in 2001. (Anderson and Greene, 2001)

Further support for Anderson's memory inhibition hypothesis for the suppression findings has come from recent neuroimaging studies (Anderson, 2004; Anderson 2007; Benoit et al. 2015; Butler and James 2010; Depue 2007; Hertel 2009; Levy and Anderson 2012; Wang, Cao, Zhu, Cai, & Wu, 2015) These studies have shown that the no-think effect is not due to less rehearsal on the no-think trials when compared with the think trials, because increased activity was found in the inhibitory control areas, such as the prefrontal cortex and parietal regions, on the no-think trials. (Anderson 2004; Depue 2007). The increase in inhibitory brain activity was also matched with reduced activity in memory processing areas of the brain, such as the hippocampus, and in brain regions involved in processing sensory information, such as the occipital cortex (Butler and James 2010; Levy and Anderson 2012) These findings suggest a neurological inhibitory mechanism for memory suppression.

Unfortunately, the TNT and repetition effects have been difficult to replicate, and for this reason, some researchers have called into doubt the validity of the memory suppression effect (Bulevich et al. 2006; Wessel et al. 2020). One explanation for the inconsistent results using the

TNT methodology could be the variability in the TNT experimental protocol used by different researchers. A slight change in the TNT methodology could reduce, and even possibly eliminate, the memory suppression effect. The first phase of the TNT method is obviously critical for the success of the TNT task, but this is one phase where there has been little consistent baseline protocol used across different studies. Why would different baselines affect the success of the TNT task? Anderson and Greene (2001) relied on a 50% baseline for learning the cue-target words but did not provide any justification for this choice. If this baseline is too low, the suppression effect is unlikely to result because the participant does not need to suppress the memory of a target word that was never learned in the first place. Likewise, the rehearsal improvement will also not be shown for word pairs that cannot be recalled. Anderson and others have successfully shown a memory rehearsal effect using a 50% baseline (Anderson 2004; Anderson 2007; Bulevich et al. 2006; Racsmany et al. 2012), but we do not know about researchers who used this baseline and were not successful at revealing a memory suppression effect. Some researchers have increased the baseline to a higher value and have had mixed success with this change to the TNT method (Benoit et al. 2015; Butler and James 2010; Depue 2006,2007; Wang et al. 2015). Although this reduces the problem of not remembering the word-pairs well enough to successfully complete the TNT task correctly, this method also changes the difficulty in showing clear rehearsal (think) and suppression (no-think) effects. The rehearsal effect may now be reduced because of ceiling effects on recall performance, and the suppression effect may be decreased due to difficulty to suppress. The goal of the current thesis is to examine the effect of changing the baseline used in the cue-target word pairs learning phase.

One change to the TNT methodology was unexpectedly required during this era of the COVID-19 pandemic. The TNT task was always conducted in-person with the experimenter and

the participant sitting together in the same testing room. Unfortunately, in-person research was banned at the College of William & Mary during this first year of the pandemic and so I developed a remote version of the TNT task. I sat in my room and the participant sat in their room and we communicated via Zoom. This change was not planned but provides an interesting adaptation to the TNT methodology that could have important implications. Research on memory suppression has important practical implications in many applied fields of psychology. For example, the inhibition hypothesis provided by Anderson has been provided as support for Betrayal Theory that has been provided by clinical psychology researchers working with victims of childhood assault (DePrince et al. 2011; Freyd et al. 2007; Giesbrecht and Merckelbach 2009; Mary et al. 2020; Otgaar et al. 2019; Sullivan et al. 2019). If the TNT method could be adapted for special populations of participants, such as sexual assault victims, these participants would not need to be tested in the cold unfamiliar context of a laboratory setting, and this would be an important finding in itself.

Method

Participants

One hundred participants took part in this experiment and were undergraduate students at the College of William and Mary. Sixty-five women and thirty-five men participated with a mean age of 19 years (SD=1.34 years). All participants were required to be native English speakers. Participants were given course credits for participating in this research and provided informed consent before participating. The research conducted in this thesis was approved by the college's ethics committee.

Procedure

A Zoom meeting was used in conjunction with PowerPoints with assigned slide transitions. Participants downloaded the supplied PowerPoints and shared their screen using Zoom while completing the experiment and were instructed by the experimenter watching their shared video. The camera videos for the participant and the experiment were turned off and the participant's microphone was kept on throughout the experiment. (Figure 2) Responses provided by the participant were recorded on Excel spreadsheets by the experimenter.

Figure 2

Image 1: Participant Screen

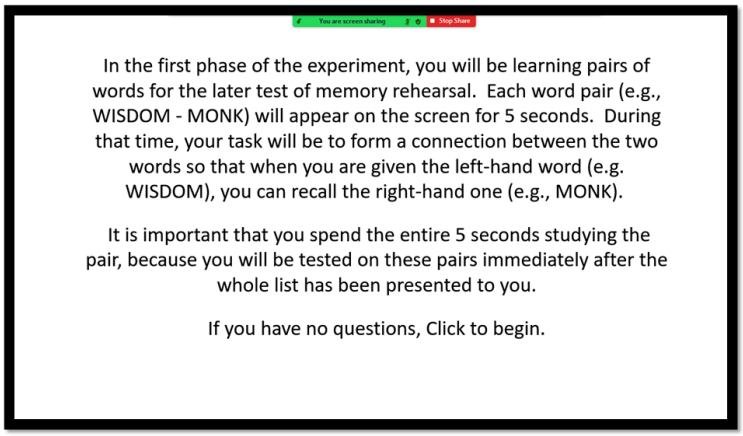
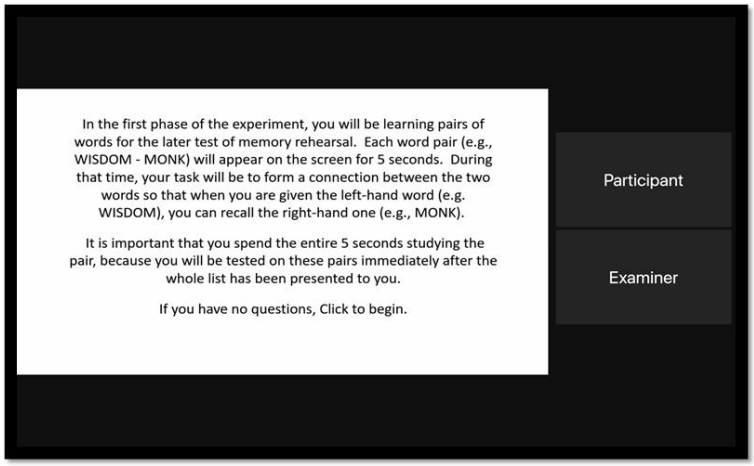


Image 2: Examiner Screen



Participants were asked to find a quiet and isolated room for the experiment. If any interruptions occurred, data was still kept to reflect issues that may arise in real-world circumstances. Each participant was randomly assigned to one of the two baseline conditions (50%, 75%). Participants were allowed to ask any question about the experiment following the end of the testing phase. A full debrief was sent to all participants over email explaining the task used, what they were evaluated on, and what was occurring in each phase. An email was provided for any further questions participants had after the experiment or after reading the full debrief.

Think/No-Think Task

A version of the Think/No-Think (TNT) experiment originally implemented by Michael Anderson and Collin Green (Anderson and Greene, 2001) was used in the current research. The TNT task involves three phases: (1) Learning phase, (2) TNT phase, and (3) Testing phase.

(1) Learning phase.

The participant was instructed to learn 50 novel cue-target word-pairs which include 40 word-pairs used in later phases (Table 1) and 10 filler word pairs not used in the later phases (Table 2). Each word pair was presented for five seconds after a 400ms fixation cross was displayed at the center of the participant's screen. All 50 word-pairs were presented in the same central location of the screen in capital letters and in black Calibri 48-point font (e.g., i.e. BUG - GRASS). Once all 50 word-pairs were viewed by the participant, their memory for the word pairs was tested by providing the cue-word for each word-pair and asking the participant to give the target-word paired with that cue-word. The correct target word was then displayed on the screen next to the cue-word in the same format as the original viewing of the word-pairs for four seconds. The participant's recall of the word-pairs was scored by the experimenter and if their

recall performance did not reach the baseline threshold of recall for their baseline condition (50% or 75%), the participant was tested again using the same procedure for all word-pairs but in a new random order of word-pairs If after three repetitions of this recall testing, the participant failed to reach the baseline threshold of word-pairs required to be learned, they were told that this was the end of the experiment for them.

Table 1: Think and No-Think Word Pairs and Independent Probes

Think word-pairs and Independnet Probes				No-Think word-pairs and Independnet Probes		
Cue Word	Target Word	Independent Probe (IP)		Cue Word	Target Word	Independent Probe (IP)
AVENUE	MILE	DISTANCE--M		GLOW	GHOST	SUPERNATURAL--G
CHOIR	GUITAR	INSTRUMENT--G		JOURNEY	PANTS	CLOTHES--P
STEAM	TRAIN	VEHICLE--T		BROOM	HOUSE	BUILDING--H
BEACH	AFRICA	CONTINENT--A		VITAMIN	LEMON	FRUIT--L
LENS	PHYSICS	SCIENCE--P		LEAP	BALLET	DANCE--B
NAIL	PICTURE	ART--P		CRACK	LOBSTER	SEAFOOD--L
TAPE	RADIO	MEDIA--R		NEEDLE	DOCTOR	PROFESSION--D
PUMP	OIL	FUEL--O		CRADLE	PARENT	RELATIVE--P
JAW	GUM	CANDY--G		STUMBLE	CLOWN	CIRCUS--C
PET	MOUSE	RODENT--M		PICNIC	HILL	LANDFORM--H
SURPRISE	SNAKE	REPTILE--S		BREATH	NOSE	BODYPART--N
LIBERTY	EAGLE	BIRD--E		MIXTURE	JAR	CONTAINER--J
OFFICER	BLUE	COLOR--B		SOIL	TOMATO	VEGETABLES--T
PIPE	WRENCH	TOOL--W		DOUGH	SALT	SPICE--S
LAWN	BEEF	MEAT--B		CANDLE	WINE	ALCOHOL--W
DECAY	CARBON	ELEMENT--C		RUG	WOOL	FABRIC--W
ACCIDENT	SNOW	WEATHER--S		RELAX	BED	FURNITURE--B
HUG	ROSE	FLOWER--R		DIET	CREAM	DAIRY--C
POLISH	DIAMOND	GEM--D		CRUMB	TOASTER	APPLIANCE--T
REMOVE	CANCER	DISEASE--C		ANTLER	KNIFE	WEAPON--K

Table 2: Filler Word Pairs and Independent Probes

Filler word-pairs and Independnet Probes		
Cue Word	Target Word	Independent Probe (IP)
COMB	MIRROR	BATHROOM--M
ALERT	ROBBERY	CRIME--R
JOGGER	COLLIE	DOGS--C
LINE	TROUT	FISH--T
FIREPLACE	SLIPPERS	FOOTGEAR--S
HELMET	OPERA	MUSIC--O
HIVE	HEXAGON	SHAPE--H
HAIR	DOLL	TOYS--D
WAFFLE	MAPLE	TREE--M
SCRATCH	MOSQUITO	BUG--M

(2) TNT phase.

Once the threshold for learning the word-pairs was achieved by the participant, the participant moved to the TNT phase. Prior to the full TNT phase, a practice phase was conducted to ensure full understanding of the task by participants. In the practice and full TNT phase, the cue-word was shown in green (Think trials) or red (No-Think trials). If the cue-word was presented in green, the participant was instructed to provide the target-word for that cue-word (if remembered). In the case of the cue-word being red, the participant was instructed to not give or even think about the target-word in any way. An error beep was played by the experimenter if the target word was voiced on a no-think trial to inform the participant that this was a no-think trial. Participants were given several practice-word pairs to learn and use in this practice phase. The participant was first instructed to respond with the paired target-word for cue-words displayed in green within a four second display time, if the cue-word was remembered. They were then given an example trial using one of the practice word pairs and allowed to ask questions. This process was repeated with a practice trial of a red cue-word after participant instruction to not respond or think of the target-word in any way when the cue-word was displayed in red. A third practice phase was given with several mixed practice trials of red or green cue-words. After this final practice session, the participant was asked again if they had any questions about this phase of the task. Participants were also asked what strategy they applied to ensure they did not recall the target-word on No-Think trials. The importance of the TNT phase was emphasized to each participant prior to beginning the main part of the TNT phase.

The TNT phase consisted of 360 trials with each trial beginning with a cue-word displayed for four seconds in either red or green and followed by a four-hundred millisecond

fixation cross. Thirty second rest breaks were provided to the participant after every ninety trials to prevent the participant from fatiguing during this phase.

During the TNT phase, the cue-words from the word pairs being tested were shown for either 0, 1, 8, or 16 times with 10-word pairs assigned to each of frequency conditions. The repetitions were spread randomly through the block of 360 trials. The word pairs shown zero times were used as a control comparison (words neither rehearsed or suppressed) and the three other frequency conditions were used to evaluate the effectiveness of the TNT procedure. Filler words were shown eleven times each and functioned as think trials during the TNT phase to increase the total number of trials to 360. This resulted in approximately 65% of the 360 trials being think trials. All responses provided by the participant for think trails were recorded, as well as any responses incorrectly given for no-think trial.

(3) Testing phase.

Participants were given two memory tests (a)same-probe memory test (SP) and (b) independent-probe test (IP). The order of the memory tests was counterbalanced across all participants.

(a) **Same-probe test (SP).**

The same probe test involved displaying the target word for each word pair for five seconds followed by a 400ms fixation cross. During the five seconds, the participant must respond with the remembered target-word regardless of it having been part of a think or no-think trial during the TNT phase.

(b) **Independent-probe test (IP).**

During the independent probe test, a semantic category for the cue word and the first letter of the target word for each word-pair was presented For example, PLANT - G_____ was

displayed for the word-pair BUG - GRASS. Each category and first letter pair was shown for five seconds and preceded by a 400ms fixation cross.

Results

Excluded Data

Three of the sixty-six participants in the 50% baseline group and six of the twenty-nine participants in the 75% baseline group did not reach the baseline threshold condition and were not included in the data analysis for this thesis. Five participants had technical issues that caused the exclusion of their data from the data analysis.

Same-probe memory test

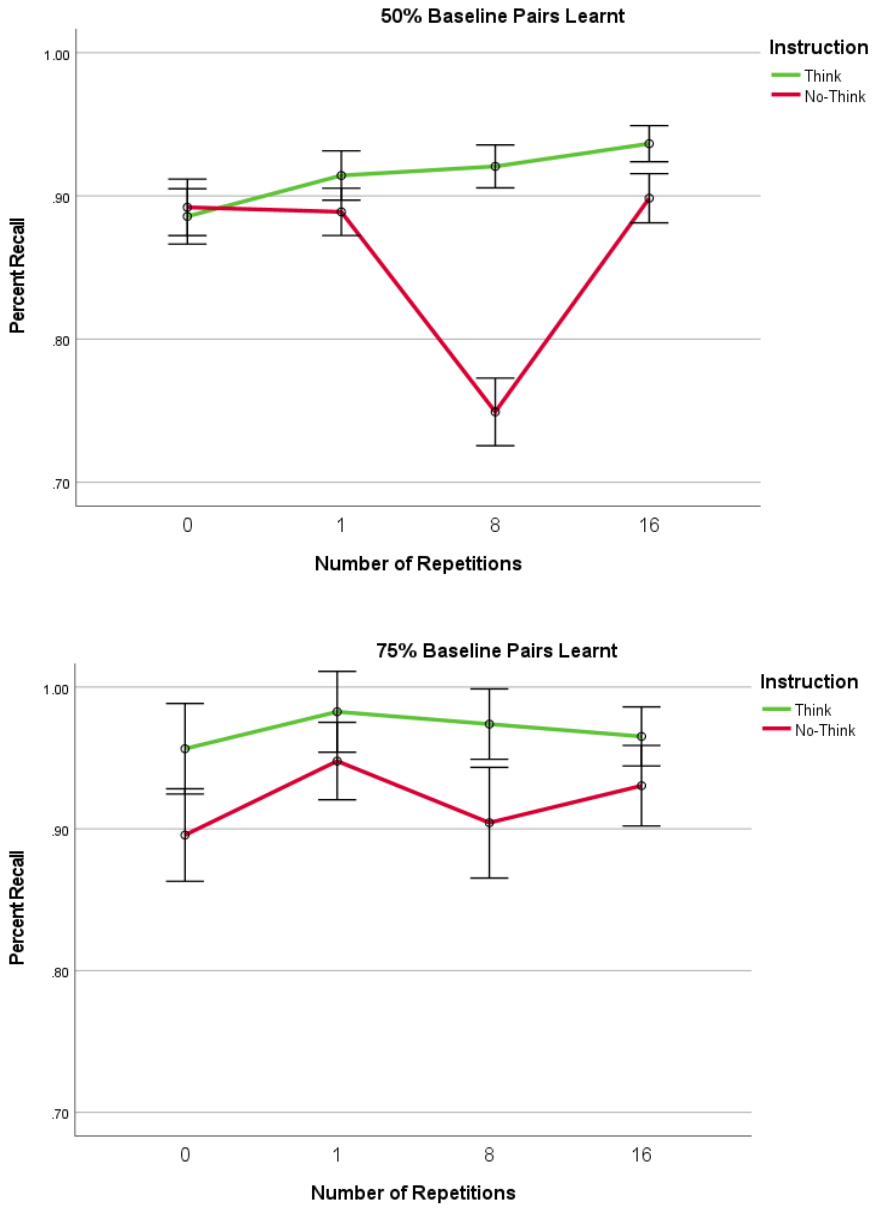
A three-way ANOVA was conducted with the within-subject factors of instruction (think vs no-think trial) and number of repetitions (0,1,8,or 16 repetitions) and the between-subjects factor of baseline condition (50%,75%), and there was significant main effects for instruction, $F(1,84)=38.29$, $p<.001$, $\eta^2_p= 0.31$, and number of repetitions, $F(3,252)=4.17$, $p=.007$,$\eta^2_p=.047$. (Table 3) Of the three two-way interactions, only the instruction and number of repetitions interactions was significant. The three-way interaction was very close to significance, $F(3,252)=2.56$, $p=.06$, $\eta^2_p=.03$, and for this reason is the only interaction discussed in more detail, and depicted in Figure 3. The rehearsal effect for Think trials is shown in this interaction but a ceiling effect is evident for the 75% baseline condition. The repression effect for No-think trials is strongest for 8 repetitions but disappears for 16 repetitions. This effect is again strongest for the 50% baseline condition.

Table 3: Same Probe Descriptive Statistics

	Baseline Pairs Learnt	Mean	Std. Deviation	N
Think 0 Repetitions	50%	0.8857	0.1712	63
	75%	0.9565	0.08435	23
Think 1 Repetitions	50%	0.9143	0.15539	63
	75%	0.9826	0.05762	23
Think 8 Repetitions	50%	0.9206	0.13218	63
	75%	0.9739	0.06887	23
Think 16 Repetitions	50%	0.9365	0.10049	63
	75%	0.9652	0.09821	23
No-Think 0 Repetitions	50%	0.8921	0.15586	63
	75%	0.8957	0.15805	23
No-Think 1 Repetitions	50%	0.8889	0.14268	63
	75%	0.9478	0.0898	23
No-Think 8 Repetitions	50%	0.7492	0.20936	63
	75%	0.9043	0.10215	23
No-Think 16 Repetitions	50%	0.8984	0.14311	63
	75%	0.9304	0.11455	23

Figure 3

Instruction X Repetition X Baseline Interaction for Same-probe Memory Scores Split into 2-way Instruction X Repetition Interactions for Each Baseline Group.



Note: Standard error bars (+/- 1 SE).

Independent-probe memory test

A three-way ANOVA was conducted with within-subject factors of instruction (think or no-think) and number of repetitions (0, 1, 8, 16 repetitions) and between-subject factor of baseline group on independent-probe memory scores. There was significant main effects for instruction, $F(1,84)=19.44$, $p<.001$, $\eta^2_p= 0.188$, and number of repetitions, $F(3,252)=14.893$, $p<.001$, $\eta^2_p=.151$. The main effect of baseline was not significant, $F(1,84)=.194$, $p=.661$, $\eta^2_p=.002$. Of the three two-way interactions, only the instruction and number of repetitions interactions was significant, $F(3,252)=12.376$, $p<.001$, $\eta^2_p= 0.128$. (Table 4) The results of this interaction are displayed in Figure 4. The three-way interaction of both within-subject factors and the between-subject factor was not significant. Memory recall was significantly better for the Think trials in both the 50% baseline (M = .8928; SD = .0875) and 75% baseline (M = .8913; SD = .0733) than the No-think trials for 50% baseline (M = .8294; SD =.1410) and 75% baseline (M = .8457; SD = .0737).

Re-analysis of Repetition effect

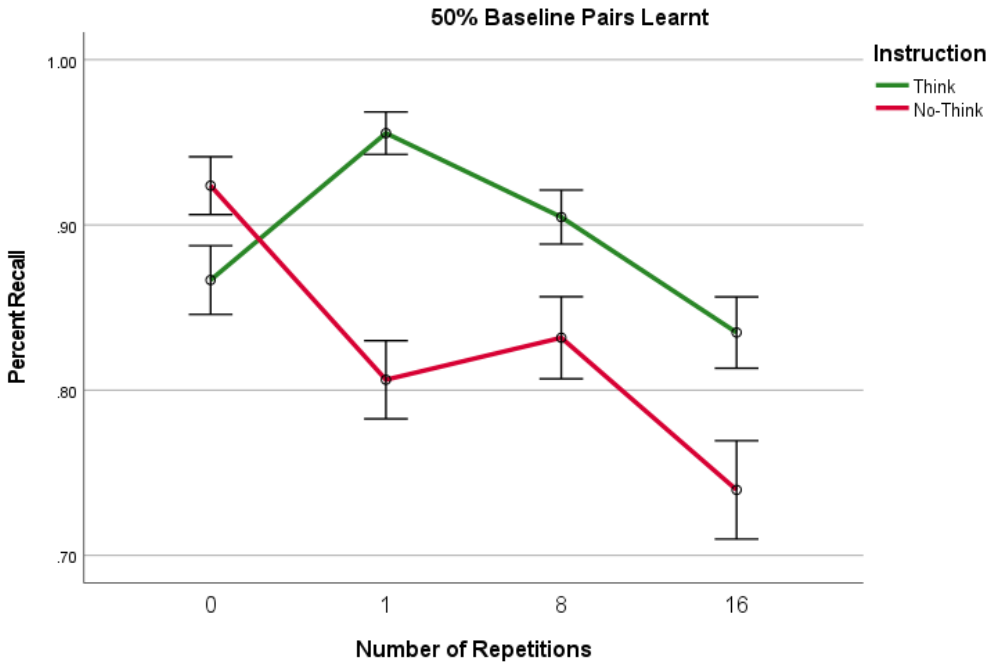
Due to trends seen when the results were graphed (see Figure 3 and Figure 4), the effects were re-evaluated via simple effect analysis to parse out repetition effects more effectively. The simple effect analysis was done on the two-way instruction by repetition interaction via a one-way ANOVA to isolate the repetition effect. Simple effect analysis showed no repetition effect for think trials and a repetition effect only for the 8 repetitions condition in no-think trials for same-probe memory tests. The independent-probe memory test had repetition effects in think trials from 0 to 1 repetition but not for the 8 or 16 repetition conditions. For no-think trials, recall progressively worsened from 0 to 1 repetition and 8 to 16 repetitions but a decrease was not seen between 1 and 8 repetitions.

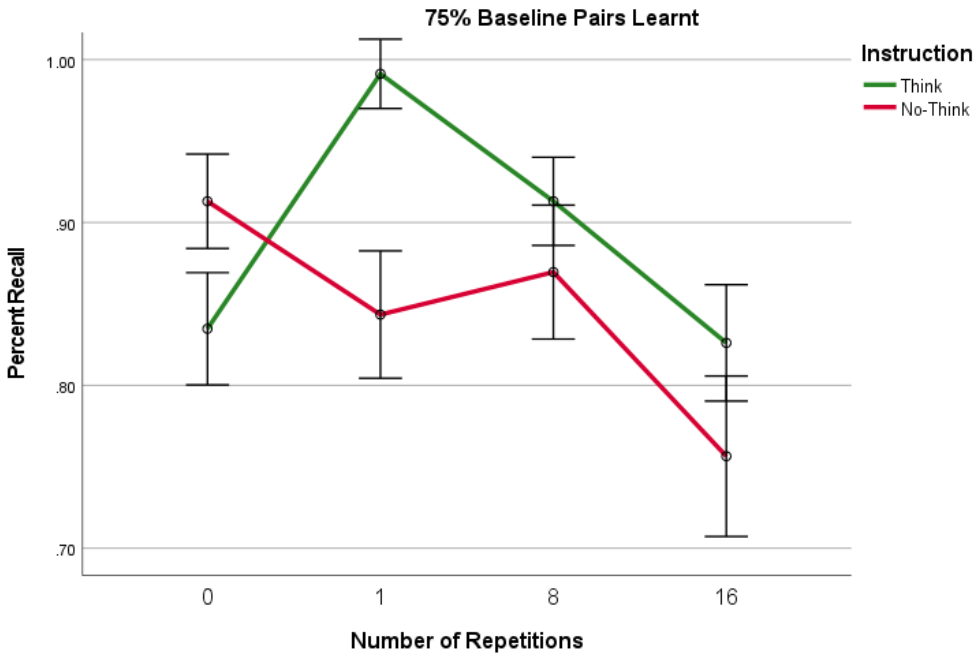
Table 4: Independent-probe Descriptive Statistics

	Baseline Pairs Learnt	Mean	Std. Deviation	N
Think 0 Repetitions	50%	0.8667	0.1606	63
	75%	0.8348	0.1774	23
	Total		0.1648	86
Think 1 Repetitions	50%	0.9556	0.1161	63
	75%	0.9913	0.0417	23
Think 8 Repetitions	50%	0.9048	0.1385	63
	75%	0.9130	0.1014	23
Think 16 Repetitions	50%	0.8349	0.1779	63
	75%	0.8261	0.1514	23
No-Think 0 Repetitions	50%	0.9238	0.1365	63
	75%	0.9130	0.1456	23
No-Think 1 Repetitions	50%	0.8063	0.1900	63
	75%	0.8435	0.1805	23
No-Think 8 Repetitions	50%	0.8317	0.2131	63
	75%	0.8696	0.1428	23
No-Think 16 Repetitions	50%	0.7397	0.2479	63
	75%	0.7565	0.1996	23

Figure 4

Instruction X Repetition X Baseline Interaction for Independent-probe Memory Scores Split into 2-way Instruction X Repetition Interactions for Each Baseline Group.





Note: Standard error bars (+/- 1 SE).

Cue-recall Cycles Across Baselines

The 50% baseline had an average number of learning cycles of 1.40 learning cycles to reach baseline of word-pairs learned with a sample size of 63. The 75% baseline had an average number of learning cycles of 1.96 learning cycles to reach baseline of word-pairs learned with a sample size of 23. The higher baseline of 75% required on average 0.56 more learning cycles to obtain the necessary baseline of word-pairs learned.

Discussion

The Think/No-Think task developed by Anderson and Greene in 2001 has two major aspects to evaluate: (1) the think/no-think effect and (2) the repetition effect. The think/no-think effect is seen in the higher recall of think instruction word-pairs and the lower recall of no-think instruction word-pairs. The repetition effect is seen by the polarization of the think/no-think effect across different amounts of word-pair repetition during the TNT phase of the Think/No-think Task. This polarization follows the trend of more repetitions equates to a higher polarization of recall for think word-pairs and recall suppression in no-think word-pairs. These

effects are evaluated via the same-probe and independent-probe memory tests. The same-probe memory test is less conclusive for recall reduction being caused by inhibition, as interference effects have been seen to influence its results (Anderson and Huddleston, 2011; Anderson and Levy 2009; Noreen and de Fockert, 2017; Wang et al., 2015). The independent-probe test, if the think/no-think effect is seen in it, shows inhibition as the cause of recall reduction moving to novel cues used in the independent-probe memory test. In original findings from Anderson and Greene in 2001, the think/no-think effect and repetition effect were seen in both memory tests showing that with repetition a polarized, inhibitory think/no-think effect can be caused using the Think/No-Think task.

The current study supported the original think/no-think (TNT) effect results of Anderson and Greene in 2001, but in a remote setting where the experimenter and participants were not in the same room and communicated via Zoom. Better recall was achieved on the think trials and poorer recall on the no-think trials in both same-probe and independent-probe memory tests. The think/no-think effect, denoted as instruction in the current studies results, was found to be significant for both memory tests. This shows that the think/no-think effect can be reliably replicated in online conditions for both memory tests. These results indicate the inhibitory mechanism proposed by Anderson is seen in remote applications of the Think/No-Think task.

When the think/no-think effect was evaluated between baselines, there was a reduction in the think/no-think effect for higher baseline condition (75%) compared to the lower baseline condition (50%), but only in the same-probe memory test. (see Figure 3) There was no significant effect on independent-probe memory tests between baselines. The explanation for baseline only affecting the same-probe memory test can be attributed to a greater amount of rehearsal during initial learning for higher baselines. The 75% baseline had a higher average

number of learning phase cycles compared to the 50% baseline. The higher average number of learning phase cycles may have allowed for stronger associative connections in word-pairs. The stronger connections of words in word-pairs would act as interference on the no-think instruction word-pairs and ,due to being an interference effect, would not pass over to the novel cues of the independent-probe memory test. This potential of a higher rehearsal can be further investigated by looking at the inhibitory actions in the prefrontal cortex and hippocampus across baselines. Additionally, the 50% baseline condition had a much lower rate of data exclusion due to the participant not reaching the minimum baseline needed in the learning phase. The 50% condition had a 4.55% data exclusion rate compared to the 20.69% data exclusion rate of the 75% baseline pairs learnt condition. Due to this, the efficiency of data collection using the 50% baseline pairs learnt condition is much higher. This aspect of the baselines impacts both same and independent-probe tests as loss of data is not test exclusive. The two results of less interference in same-probe memory tests and lower data exclusion for the 50% baseline word-pairs show it as being a more efficient baseline for data collection and evaluator for the think/no-think effect when compared to the 75% baseline; however, more baselines and the learning rehearsal effect of higher baselines should be evaluated in future studies.

The current study did not support the original repetition effect from Anderson and Greene in 2001. In initial ANOVA testing, repetition of word-pairs came back as significant for both the same-probe and independent-probe memory tests. Simple effect analysis showed no repetition effect for think trials and a repetition effect only for the 8 repetitions condition in no-think trials for same-probe memory tests. The independent-probe memory test had repetition effects in think trials from 0 to 1 repetition but not for the 8 or 16 repetition conditions. For no-think trials, recall progressively worsened from 0 to 1 repetition and 8 to 16 repetitions but a decrease was not seen

between 1 and 8 repetitions. This re-analysis of the repetition effect shows inconsistent trends in the repetition effect with some of the repetition conditions showing a significant effect but others showing no significant effect at all. A consistent trend of the repetition effect is essential to its significance in the think/no-think effect and, if it doesn't follow the trend proposed by Anderson in 2001 (see Figure 1), creates problems in the think/no-think application.

In the same-probe test, a ceiling effect for think instruction word-pairs was seen and may have prevented the hypothesized upward trend of recall across repetitions seen in Anderson and Greene's 2001 study, but no-think instruction words showed no trend. (see Figure 3) In the independent-probe test, both think instruction and no-think instruction word-pairs showed a decrease in recall across repetitions. (see Figure 4)

The lack of a consistent repetition effect in either the 50% or 75% baseline prevented an evaluation of baselines effect on repetition. However, an absence of the repetition effect originally found in Anderson nad Greene's 2001 study and found again in his later studies can be evaluated. As discussed above, a consistent repetition effect like Anderson's original findings is essential. If the repetition effect is not universally seen in all Think/No-Think tasks, it can't be reliably used as a measure of the task and its overall effect. The repetition effect is a large part of how the Think/No-Think task supports other theories such as the Betrayal Trauma theory. Anderson has applied the Think/No-Think task to explain how, in the Betrayal Trauma theory trauma in youth causes greater suppression and executive memory control. The repetitive nature of the trauma and thus the repetitive nature of suppression of the trauma is proposed to be replicated and explained by the reduction in recall for no-think instruction word-pairs seen in the Think/No-Think task's repetition effect. If the repetition effect is not a reliable measure for the Think/No-Think task this support or explanation for the Betrayal Trauma theory wavers.

This lack of the repetition effect may be due to it not being a true effect or , more likely, there being a fault in the think/no-think methodology. The ceiling effect seen could play an impact in reducing the upward trend normally seen for think instruction word-pairs from the repetition effect. One way to circumvent the ceiling effect seen in the current study is adding a retention period between the TNT phase and the administration of the memory tests in the testing phase. Additionally, the effect evaluation is based off only five word-pairs for each category. (i.e. five word-pairs for think instruction with zero repetitions, five word-pairs for think instruction with one repetition, etc.) This can cause outlying data to polarize and drastically alter individual conditions. Thus, increasing the number of word-pairs per condition could re-introduce the upward trend of think instruction word-pairs in the repetition effect.

Another area that could be altered from Anderson and Greene's original study is randomization of word-pairs across categories between participants. The original methodology had word-pairs placed into a category across all participants. In this methodology, if the valence of some word-pairs was higher for the population being evaluated, polarization of the category the word-pair was in could occur. The randomization of word-pairs in categories between participants would reduce the impact by spreading it across all categories. This change in methodology has been seen in several think/no-think studies already (Butler and James, 2010; Hulbert and Anderson, 2018).

Limitations

One major drawback of this study was the sample sizes for the two baseline groups. The 50% condition had significantly more data points (n=63) compared to the 75% condition (n=23), and this may have caused the 75% baseline condition to show a weaker Think/No-think effect compared to the 50% condition for the same-probe test. However, this drawback could have been

easily checked by adding more data for participants in the 75% condition if time had allowed this.

The other drawback of this study was in it being done online. While statistically significant results were still found, five of the hundred participants were excluded from the study due to technical difficulties: an exclusion rate of 5%. These technical difficulties included internet connection failure, microphone issues causing a failure in response collection, and slide timing corruptions. Access to the technology and an appropriate participant room could also be an issue if a remote version for the TNT was implemented to test special populations (e.g., patients).

Conclusion

In conclusion, the current study was able to replicate the think/no-think effect in uncontrolled, online conditions. This replication was in both the same-probe and independent-probe tests following the inhibition model of memory suppression displayed in Anderson's original study. However, difficulty in replicating the repetition effect raises concerns for the application of the Think/No-Think task to other memory inhibition theories. The repetition effect allows a wider application of this task as it allows for the conclusion that the inhibitory mechanism seen in the think/no-think effect can have a degree of effect based upon the number of experiences with a memory and how that memory was handled by the individual. Without the repetition effect, many of the potential clinical or research applications for the Think/No-Think task are lost. The current study gave evidence recommending 50% baseline pairs learnt as a better option as a baseline for initial word pair learning compared to 75% baseline pairs learnt. More so, the increase to a 75% baseline potential introduces a rehearsal effect from initial learning in same-probe memory tests. While the current study supports the use of 50% as a learning baseline to show the think/no-think effect, further investigation into higher baseline interference is an intriguing route of study. Additionally, the replication of the think/no-think effect online may allow for easier use of the Think/No-Think task with trauma victims if the methodology of the Think/No-Think task can be further optimized to re-introduce the repetition effect consistently.

References

Anderson, M. C., & Green, C. (2001). Suppressing unwanted memories by executive control. *Nature, 410*, 366-369.

Anderson, M. C., & Huddleston, E. (2017). Towards a cognitive and neurobiological model of motivated forgetting. *In R. F. Belli (Ed.), Nebraska symposium on motivation Vol. 58*, 53-120.

Anderson, M. C., & Levy, B. J. (2007). Theoretical issues in inhibition: Insights from research on human memory. *In D.S. Gorfein & C.M. MacLeod (Eds.), Inhibition in cognition*, 81-102.

Anderson, M. C., & Levy, B. J. (2012). Purging of Memories from Conscious Awareness Tracked in the Human Brain. *Journal of Neuroscience*, 32 (47) 16785-16794.

Anderson, M. C., Ochsner, K. N., Kuhl, B., Cooper, J., Robertson, E., Gabrieli, S. W., . . . Gabrieli, J. D. (2004). Neural Systems Underlying the Suppression of Unwanted Memories. *Science, 303*, 232-235.

Benoit, R. G., & Anderson, M. C. (2012). Opposing Mechanisms Support the Voluntary Forgetting of Unwanted Memories. *Neuron*, 76(2), 450-460.

Benoit, R. G., Hulbert, J. C., Huddleston, E., & Anderson, M. C. (2015). Adaptive Top–Down Suppression of Hippocampal Activity and the Purging of Intrusive Memories from Consciousness. *Journal of Cognitive Neuroscience*, 27 (1): 96–111.

Bulevich, J. B., Roediger III, H. L., Balota, D. A., & Butler, A. C. (2006). Failures to find suppression of episodic memories in the think/no-think paradigm. *Memory Cognition*, 34(8), 1569-77.

Butler, A. J., & James, H. K. (2010). The neural correlates of attempting to suppress negative versus neutral memories. *Cognitive, Affective, & Behavioral Neuroscience 10*, 182-194.

DePrince, A. P., Brown, L. S., Cheit, R. E., Freyd, J. J., Gold, S. N., Pezdek, K., & Quina, K. (2011). Motivated Forgetting and Misremembering: Perspectives from Betrayal Trauma Theory. *True and False Recovered Memories*, 193-242.

Depue, B. E., & Banich, M. T. (2011). Increased inhibition and enhancement of memory retrieval are associated with reduced hippocampal volume. *Hippocampus 22*, 651-655.

Depue, B. E., Banich, M. T., & Curran, T. (2006). Suppression of Emotional and Nonemotional Content in Memory. *Psychological Science 17(5)*, 441-447.

Depue, B. E., Curran, T., & Banich, M. T. (2007). Prefrontal regions orchestrate suppression of emotional memories via a two-phase process. *Science*, 13;317(5835):215-9.

Freyd, J., Deprince, A., & Gleaves, D. H. (2007). The state of betrayal trauma theory: Reply to McNally - Conceptual issues, and future directions. *Memory 15(3)*, 295-311.

Giesbrecht, T., & Merckelbach, H. (2009). Betrayal trauma theory of dissociative experiences: Stroop and directed forgetting findings. *The American Journal of Psychology 122(3)*, 337-348.

Gordon, B. (1983). Lexical access and lexical decision: mechanisms of frequency sensitivity. *Journal of Verbal Learning and Verbal Behavior*, 24-44.

Han, W., Gao, L., Wu, J., Pelowski, M., & Liu, T. (2019). Assessing the brain on ‘the line’: An ecologically-valid assessment of the impact of repetitive assembly line work on hemodynamic response and fine motor control using fNIRS. *Brain and Cognition 136*.

Liu, M., Zhou, L., Zhang, H., Wang, X., Ye, B., & Liu, Q. (2020). Suppressing negative materials for remitted depressed individuals: Substitution forgetting and incidental forgetting strategies. *Current Psychology*.

Mary, A., Dayan, J., Leone, G., Postel, C., Fraisse, F., Malle, C., . . . Gagnepain, P. (2020). Resilience after trauma: The role of memory suppression. *Science 367(6479)*, 734.

McHail, D., Pettijohn, K., Blacker, K., & Sherwood, S. (2021). Impacts of Cognitive Fatigue on Attention and Neural Activity. *Defense Visual Information Distribution Service*.

Noreen, S., & de Fockert, J. W. (2017). The role of cognitive load in intentional forgetting using the think/no-think task. *Experimental Psychology, 64*, 14-26.

Otgaar, H., Howe, M. L., Dodier, O., Lilienfeld, S. O., Loftus, E. F., Lynn, S. J., . . . Patihis, L. (2021). Belief in Unconscious Repressed Memory Persists. *Perspectives on Psychological Science 16(2)*, 454-460.

Otgaar, H., Howe, M. L., Patihis, L., Merckelbach, H., Lynn, S. J., Lilienfeld, S. O., & Loftus, E. F. (2019). The Return of the Repressed: The Persistent and Problematic Claims of Long-Forgotten Trauma. *Perspectives of Psychological Science 14(6)*, 1072-1095.

Racsmány, M., Conway, M. A., Keresztes, A., & Krajcsi, A. (2012). Inhibition and interference in the think/no-think task. *Memory & Cognition*, 40, 168-176.

Sullivan, D. R., Marx, B., Chen, M. S., Depue, B. E., Hayes, S. M., & Hayes, J. P. (2019). Behavioral and neural correlates of memory suppression in PTSD. *Journal of Psychiatric Research 112*, 30-37.

Thompson, C., Fransen, J., Beavan, A., Skorski, S., Coutts, A. J., & Meyer, T. (2020). Understanding the influence of a cognitively demanding task on motor response times and subjective mental fatigue/boredom. *Brazilian Journal of Motor Behavior 14(01)*, 33-45.

Wang, Y., Cao, Z., Zhu, Z., Cai, H., & Wu, Y. (2015). Cue-independent forgetting by intentional suppression: Evidence for inhibition as the mechanism of intentional forgetting. *Cognition*, 143; 31-35.

Wessel, I., Albers, C. J., Zandstra, A. R., & Heininga, V. E. (2020). A multiverse analysis of early attempts to replicate memory suppression with the Think/No-think Task. *Memory 28(7)*, 870-887.

Zhu, Z., & Wang, Y. (2020). Forgetting Unrelated Episodic Memories Through Suppression-Induced Amnesia. *Journal of Experimental Psychology: General*, 150(3), 401–413.