Developing an Earworm Suppression Strategy Using the Think/No Think Paradigm

Honors Research Thesis

Presented in partial fulfillment of the requirements for graduation *with honors research distinction* in Neuroscience in the undergraduate offices of The Ohio State University

by
Christine Wu

The Ohio State University
Autumn 2013

Project Advisor: Dr. Per Sederberg, Department of Psychology

Developing an earworm suppression strategy using the think/no think paradigm

You never know when an earworm will strike. Suddenly that song you heard on the radio yesterday won't get out of your head, no matter how hard you try, and it might take hours or even days before the song is no longer stuck in your head. Despite being a common phenomenon, and despite many anecdotal accounts, very little is known about the behavioral mechanisms of earworms, which are also referred to as stuck song syndrome, sticky music, or involuntary musical imagery (INMI).

Previous research has focused on characterizing the nature of earworm episodes through self-report methods, such as surveys, large-scale Internet questionnaires, and diary studies. Research conducted by Liikkanen (2008) and Williamson et al. (2011) provides strong support that earworms are a common experience and occur frequently among the general population. There is a high degree of individual difference in earworm experiences, from the songs that become earworms to the strategies employed to stop earworms (Beaman & Williams, 2010; Halpern & Bartlett, 2011). In addition, Beaman and Williams (2010) found that the occurrence of an earworm was related to familiarity with the tune; that is, participants reported having earworms with familiar songs to which they had received previous exposure. This finding helps explain the individual differences in earworms and relates the likelihood of an earworm occurrence with an individual's previous exposure to the song, rather than the characteristics of the song itself (Beaman & Williams, 2010). Furthermore, earworm experiences can be triggered due to a wide variety of circumstances, affective states, and attention states (Williamson et al., 2011). Some common triggers included having a personal affinity for the song, recent exposure, and semantic associations with the song (Halpern & Bartlett, 2011). Despite the high degree of individual variation, one consistent factor is that familiar lyrical music is most prevalent in earworm episodes, both for musicians and non-musicians (Liikkanen, 2008).

While these studies have generated a rich, descriptive summary of earworm experiences, expanding the small pool of knowledge on earworms, they do not provide any insight into the underlying neural mechanisms. Beaman and Williams (2010) explain, “It’s difficult to apply experimental methods to the appearance of involuntary thoughts,” acknowledging the limitations of studying earworms in an experimental setting. In addition to the difficulty of inducing involuntary thoughts, the range of individual differences adds to the difficulty of inducing earworms in a controlled design. Although we could not definitively recreate earworms in an empirical setting, we applied the understanding that earworms are a form of musical memory and recreated the conditions that might lead to earworms. Thus, our study did not focus on earworms directly but rather on manipulating people’s memory for music through suppression strategies. The purpose of the current study was to identify a neural mechanism for suppression of musical memory, potentially creating a cognitive strategy for terminating earworm episodes.

We proposed Anderson and Green’s think/no think (TNT) paradigm as a viable strategy for suppressing musical memory. Using the TNT paradigm, Anderson and Green demonstrated that learned items can be voluntarily suppressed using executive control mechanisms (2001). In the original study, participants learned pairs of semantically unrelated words such that left-hand member of the pair served as a cue and the right-hand member of the pair was the response. During the TNT phase, participants were given a cue word and instructed to either respond with the corresponding word (think) or suppress the corresponding word (no think). A list of cue words in the no think condition was shown to participants prior to the TNT phase so that they knew which items to suppress responses to. After the TNT task, participants were tested on their recall of all word pairs to determine if suppression occurred. Subjects' memory for items in the no think condition was worse than items in the baseline or think conditions, suggesting that suppression of unwanted memories can occur (Anderson & Green, 2001).

Neuroimaging studies of the TNT task have identified neural correlates of successful voluntary repression. Anderson et al.'s 2004 event-related fMRI study found that suppression involved recruitment of a large number of prefrontal cortex regions, thus highlighting an executive control network used for inhibition (see Fig. 1). Activation of the hippocampus, which is related to memory formation and recollection, was reduced for no think items relative to think items (Anderson et al., 2004). Furthermore, activation in the bilateral dorsolateral prefrontal cortex (DLPFC) predicted activation in the right hippocampus for no think items, suggesting an inhibitory mechanism from the DLPFC (Anderson et al., 2004).

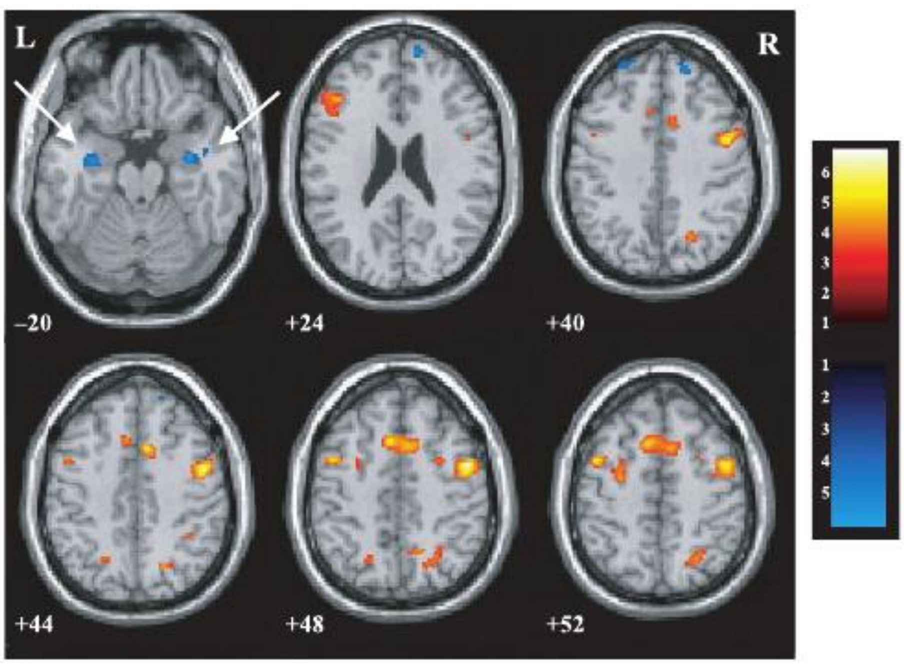

Figure 1. Representative fMRI images showing different activation patterns for think versus no think trials. Areas in yellow were more active during no think trials, while areas in blue were less active during no think trials. (Anderson et al., 2004)

Differential patterns of neural activation for think versus no think items have also been observed in EEG studies. The left parietal episodic memory effect, also known as the left parietal old/new effect, is a positive evoked-response potential (ERP) that occurs at the left parietal regions approximately 400 to 800 ms following stimulus presentation. This effect is a correlate of conscious recollection. Bergström, Velmans, de Fockert, and Richardson-Klavehn investigated this correlate using a modified version of TNT (2007). An initial cued recall test was added between the pair-learning phase and TNT phase to identify items that participants had successfully learned and not successfully learned, creating four conditions for items the TNT phase: Learned Think, Learned No Think, Not Learned Think, and Not Learned No Think. The left parietal positive ERP was greater for Learned Think items compared to the three other conditions, suggesting that participants can voluntarily avoid conscious recall of learned items (Bergström et al., 2007). In addition, the ERP for Learned No Think items was not significantly different than ERPs of Not Learned Think and Not Learned No Think items, providing further support for successfully voluntary avoidance during the TNT phase (Bergström et al., 2007). Like others who had tried to replicate Anderson’s study, the authors of the ERP study were not able to reproduce a subsequent forgetting effect for no think items; however, their findings were valuable because they demonstrated that voluntary repression of unwanted items can occur during TNT even though this repression did not produce a later involuntary memory impairment (Bergström et al., 2007).

The incorporation of the TNT paradigm in our study was crucial because it provided a complex strategy beyond simply avoiding or repressing a memory. The original TNT paradigm demonstrated that repression occurred by first activating a memory to a certain threshold and then inhibiting it; this effect is supported by the retrieval-induced forgetting (RIF) model

(Anderson & Green, 2001; Norman, Newman, & Detre, 2007). The RIF model states that for the memory of any given item, there is a threshold, such that re-activation of the memory below this threshold will lead to weakened or reduced memory for the item, while re-activation above the threshold will lead to enhanced or strengthened memory for the item (Norman et al., 2007). A recent fMRI study from the Norman lab provides neural evidence for this theory. Detre et al. (2013) found a nonmonotonic relationship between level of activation of a memory and subsequent strengthening or weakening of that memory; in other words, a moderate degree of memory activation below a certain threshold lead to reduced memory for an item, while a higher degree of activation was related to strengthened memory for an item. This "nonmonotonic plasticity hypothesis" (Detre et al., 2013) may also explain why Bergstrom et al. (2007) and other studies have failed to reproduce the subsequent forgetting effect with the TNT paradigm.

The use of the TNT paradigm in our study represents a novel strategy for suppressing musical memory, and the potential findings of our research have exciting implications for many disciplines. Earworms provide a model for studying memory suppression of music, which has received little attention from the academic community. Cognitive psychology research on memory suppression has frequently utilized words and images for stimuli. Because of the multi-modal qualities of music, its use in memory research can more closely mimic stimuli and situations encountered in real life, thus making the results more applicable and relatable to real-life situations. For example, the strategies for suppressing musical memory could be applied to other types of involuntary thoughts, such as the obsessive thoughts seen in obsessive-compulsive disorder (OCD). Pervasive, recurring memories are also characteristics of post-traumatic stress disorder (PTSD) and other anxiety disorders. Because music is a complex stimulus that more closely models these recurring memories, strategies for earworm suppression may represent a novel thought suppression strategy for patients with these conditions. Greater insight on earworm suppression could also lead to greater understanding of the musical hallucinations and obsessions observed in biological psychiatry (Liikkanen, 2008).

Hypothesis

Based on the TNT and RIF models, we hypothesized that familiar songs would be more likely to be forgotten when participants were actively instructed to not think of them while simultaneously re-activating the memory for the song. We expected that weaker memory re-activation would occur for items in the no think condition compared to the think condition, and that participants would have reduced recognition memory for no think items compared to think and baseline items. We also expected distractor tasks to increase the cognitive load in a way that should weaken the level of activation overall for all items, but especially for the no think items because participants were instructed to not think of those items. In addition, we hypothesized that we could measure neural activation in the frontal cognitive control regions during no think periods to predict the drop in memory for those songs. We expected to see a pattern of stronger left parietal ERPs for items in the think condition compared to the no think condition, demonstrating voluntary repression.

Methods

Experiment 1

Subjects. 49 volunteers were recruited from a pool of undergraduate students at The Ohio State University. All students were enrolled in the Research Experience Program (REP) for Introductory Psychology 1100 students and were compensated for their time with partial course credit. All participants were at least 18 years of age and provided consent as required by the Institutional Review Board (IRB).

Exclusions. 13 participants were excluded from analyses due to technical errors that led to incompletion of the experiment.

Materials. The experiment was presented on individual computer screens using PsychoPy v1.77, a free, cross-platform software for collecting data in psychology and neuroscience experiments (Pierce, 2007; Pierce, 2009). Stimuli consisted of 271 music video clips of songs from the Billboard Hot 100 lists in years 2010, 2011, and 2012. The clips were generated by screening each song for the 10 s segment that was most likely to produce later recall (usually the chorus or lyrics containing the name of the song). The first frame of each clip was extracted and saved as an image, creating a pool of 271 screenshots.

Design and procedure. The experiment consisted of four phases: a pretest, an exposure block, think/no think blocks, and a recognition memory test (see Fig. 2).

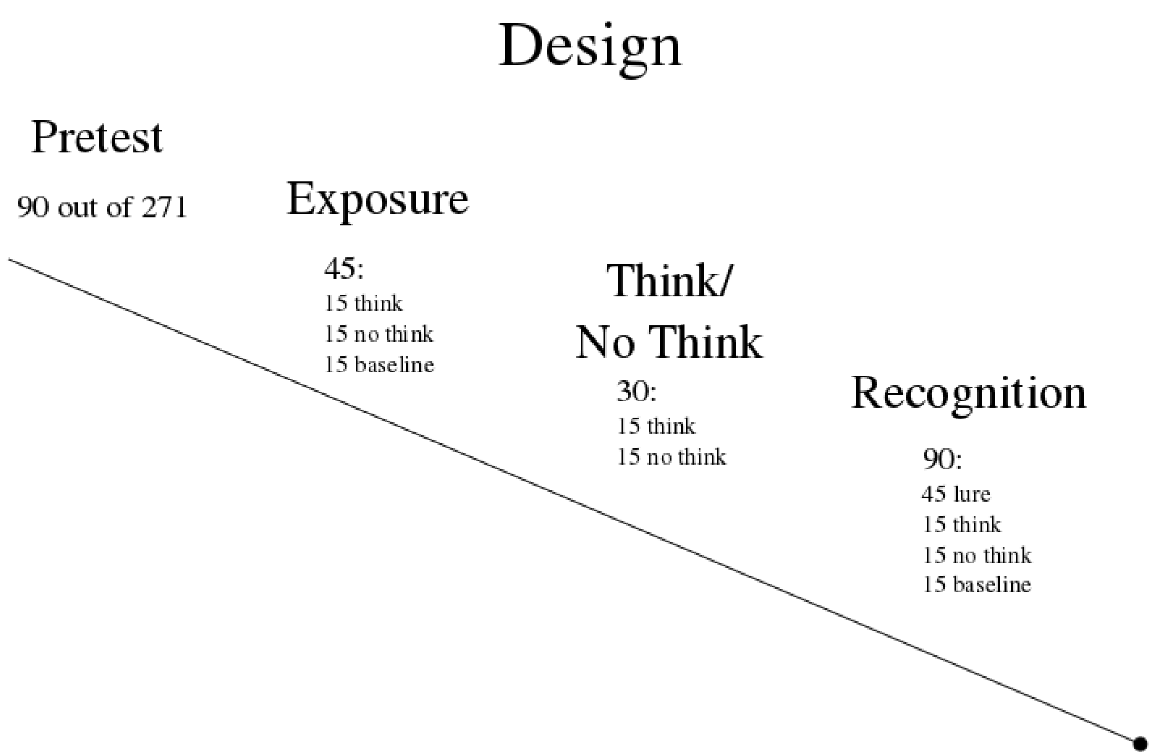

Figure 2. Order of phases in experiment design.

Pretest phase. To control for the effects of previous exposure to songs and varying tastes of music, a unique set of stimuli was generated for each participant such that each set consisted of songs that participants were familiar with. Participants viewed slides containing a song title, artist name, and screenshot from the corresponding video. Rather than playing music clips to assess familiarity, the stimuli were presented in this manner because the experimental design required that participants activate the memory of a song when presented with a song title, artist name, and screenshot from a music video. For each song, they rated their level of familiarity using a continuous sliding scale from 1-7 with precision to the hundredths decimal (see Fig. 3). On the scale, 1 represented “Not at all,” meaning the participant had never heard of the song or was only vaguely aware of it, and 7 represented “Very much,” meaning the participant knew the song well and was capable of singing or humming part of the song. Any rating equal to or higher than 4 was counted as a “familiar” rating. Participants had unlimited time to make their responses and were instructed to be as accurate as possible while not spending too much time on each item. Response times were recorded by the software. The rating process continued until one of these conditions was met: 90 songs had received familiar ratings, or every stimulus in the pool had been rated.

Figure 3. Example of pretest trial with song and artist information, music video screenshot, and continuous rating scale.

Assignment of stimulus conditions. For each participant, the 90 highest-rated songs for familiarity were used as stimuli for the experiment and divided into four conditions: lure, think, no think, and baseline (see Fig. 2). Of the 90, 45 randomly chosen items were labeled as lures and did not appear until the recognition memory test at the end. The remaining 45 were shown in the exposure phase and were randomly and equally assigned to one of three conditions: think, no think, or baseline. Think and no think items appeared in the think/no think phase as two different strategies of recollection (i.e. recollection and avoidance). Baseline items were omitted from the think/no think phase.

Exposure phase. Participants were instructed to watch and listen to 45 music video clips of songs shown in random order. For each trial, a fixation cross appeared for 1500 ms. Then, a song title and artist name were displayed for 500 ms preceding a 10 s video clip, during which time the song and artist information remained on the screen. Trials were separated by a 500 ms intertrial interval. This is considered an exposure or incidental encoding phase rather than a study phase because participants were only instructed to watch and listen, and did not receive any instructions to remember the videos.

Figure 4. Example of exposure trial. Song and artist information and video appear in the same position in this phase as song and artist information and screenshot in the pretest phase.

***Think/no think phase*.** A modified version of the Think/No Think (TNT) task (see Anderson & Green, 2001 for original task) was used. This phase consisted of 5 blocks of 30 trials each, with a self-paced rest period between blocks. All of the think and no think items were presented in each block in random order, such that items appeared in different order each block. For each trial, participants viewed a fixation cross for 1000 ms followed by the presentation of song information and an image for 4000 ms. The bottom of each slide featured either the word “THINK” printed in green text or the words “DON’T THINK” printed in red text (see Fig. 5).

For "Think" instructions, participants were instructed to recall and think about the song that they heard earlier in the exposure phase for the entirety of the trial (4000 ms). For "Don't Think" instructions, participants were instructed to prevent the song from entering consciousness at all for the entirety of the trial.

Figure 5. Example of think trial within Experiment 1 think/no think phase. No think instructions appeared as "DON'T THINK" in red text.

Recognition memory phase. In this phase, we measured recognition memory for songs, which was our dependent variable. This phase consisted of all 45 songs from the exposure phase and 45 lures that did not appear in the exposure or think/no think phases. The 90 items appeared in random order. Participants viewed slides containing a song title, artist name, and a screenshot from that music video and were instructed to think back to the exposure phase when they were listening to and watching clips of music videos. For each song, participants rated whether or not they had previously listened to and watched the music video clip during the exposure phase using a continuous sliding scale from 1-7, with 1 being "No" and 7 being "Yes." "Yes" meant that the participant was fully confident that they had heard the song earlier in the experiment. "No" meant that the participant was fully confident that they did not hear the song earlier in the experiment. Participants had unlimited time to make their responses and were instructed to be accurate as possible while not spending too much time on each item. The ratings were recorded to a precision of the hundredths place, and response times for each rating were also recorded in milliseconds.

Results. The recognition phase measured participants' ratings of recognition memory for think, no think, baseline, and lure items. The recognition ratings for each condition were averaged for each subject. We conducted within-subject paired t-tests comparing think vs. no think, baseline vs. no think, and baseline vs. lure. We observed significant differences in average recognition memory between think and no think items ($t(70)=4.00$; $p<.001$) and between baseline and lure items ($t(70)=17.42$; $p<.001$). Differences in average recognition memory between baseline and no think items were not significant ($t(70)=-1.82$; $p<.1$).

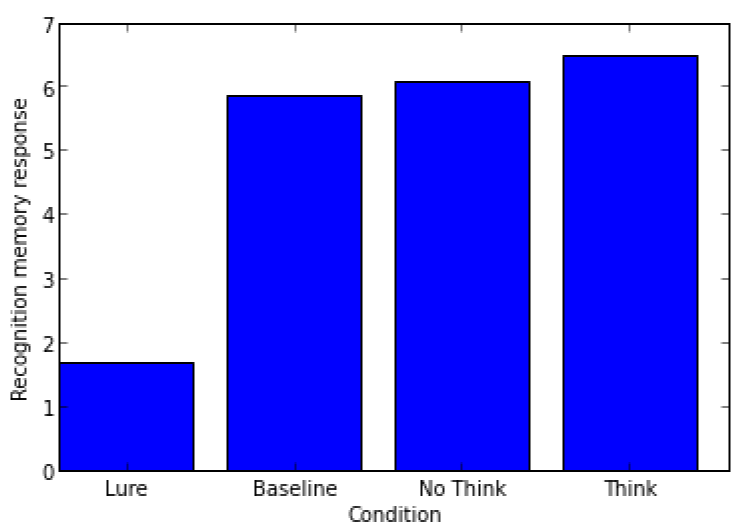

Figure 6. Overall levels of recognition memory responses for lure, baseline, no think, and think conditions.

Discussion. Although we saw a significant difference in recognition memory response between the think and no think conditions, we did not see a significant decrease in memory for think items compared to baseline items. This result can be explained by the RIF model, which relates the strength of memory re-activation with a subsequent increase or decrease in memory for an item (Norman et al., 2007). We believe that the level of re-activation for no think items was either too strong or not strong enough during the TNT phase to lead to a subsequent memory decrease compared to baseline. However, the significant memory difference between think and no think items suggested that our work was moving in the right direction. In response, we adapted our design for the TNT phase in the subsequent experiment to decrease re-activation levels. We removed the song and artist information text from each TNT trial so that only the screenshot image was presented. To further reduce memory re-activation, we added a random dot kinematogram (RDK) task to each trial so that the increased cognitive load would interfere with the re-activation of no think items.

Experiment 2

Subjects. 3 volunteers were recruited from the university community at The Ohio State University. All participants were at least 18 years of age and right-handed. Participants provided consent as required by the Institutional Review Board (IRB) and were given financial compensation for their time.

Design and procedure. A modified version of Experiment 1 was used for this experiment. Relative to Experiment 1, the following changes and additions were made. In addition, two synchronization pulses were sent during every trial in the exposure, TNT, and recognition phases for EEG data alignment purposes.

Exposure phase. Each trial was preceded by a fixation cross that was jittered between 0 - 1500 ms. A 500 ms intertrial interval followed each trial.

Think/no think phase. This phase consisted of 8 blocks of 30 trials in random order. All items were repeated in each block. A random dot kinematogram (RDK) was added to each TNT trial in order to further weaken memory re-activation particularly for no think items. Each trial consisted of a fixation cross jittered between 0 - 300 ms, followed by the presentation of a screenshot image and an RDK on the screen, with the RDK overlaid on top of the image (see Fig. 5). Participants performed the think/no think task described in Experiment 1 while simultaneously viewing the RDK. Participants judged whether the overall motion of dots was to the left or to the right via key-press response. A response of “J” indicated “left” while a response of “K” indicated right. Each trial ended when the participant had made a judgment about the dot direction via key-press response. A feedback message appeared for 500 ms after each trial.

In this phase, the opacity of each image was set to .5 to reduce memory activation. In addition, to further weaken activation of songs, the song and artist information were not displayed in this phase. However, the think/no think text appeared at this time and was displayed above the image. The direction of the dots was randomly set to left or right for each trial. The properties of the RDK were in pixels and were configured as in Scase, Braddick, and Raymond (1996). The coherence was set to .2 with a dot lifetime of 10 and dot size of 4. The field was a 600 x 600 square. There were 1000 white dots in any given frame, and the dots moved at a speed of 3 pixels per frame.

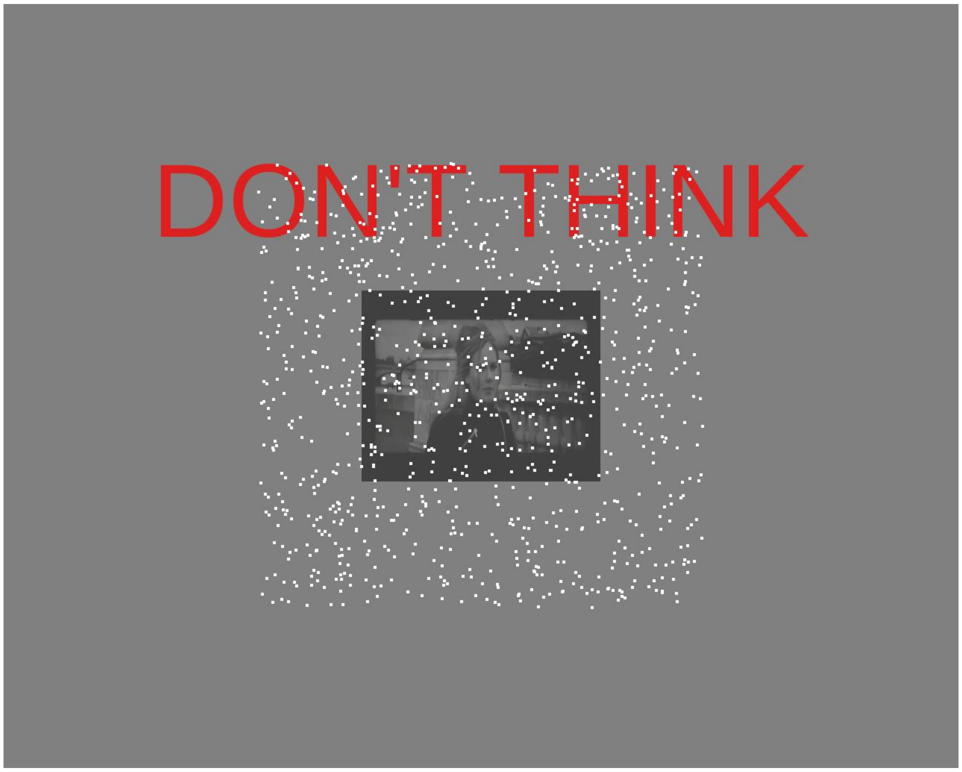

Figure 7. Example of no think trial within modified Experiment 2 think/no think phase. The screenshot was presented at lowered opacity underneath the RDK. No think instructions appeared above the image.

***Recognition phase*.** Each trial was preceded by a fixation cross jittered between 0 - 300 ms.

EEG recording and data processing. Scalp EEG data was recorded during the exposure, think/no think, and recognition phases. Each participant was fitted with an elastic cap containing 96 active electrodes. Two additional electrodes measured the electro-oculogram (EOG). Electrode impedances were reduced to less than 25 K in accordance with operating instructions for the actiCAP system (BrainProducts GmbH, Munich, Germany). EEG data were sampled and recorded at 1000 Hz using a DC-powered BrainAmp amplifier/analog-to-digital converter connected to a desktop PC equipped with BrainVision Recorder software (BrainProducts GmbH, Munich, Germany).

EEG data was preprocessed using the Python Time Series Analysis (PTSA) library (http://ptsa.sourceforge.net). The data was re-referenced to linked mastoids, high-pass filtered at .25 Hz to reduce low frequency drift from skin potentials, and downsampled to 250 Hz. Artifacts from eye blinks and other sources of minor motion were corrected using the wavelet-enhanced independent components analysis algorithm (Castellanos & Makarov, 2006).

Results. We conducted our analysis of the behavioral data from Experiment 2 in the same manner as Experiment 1. The recognition ratings for each condition were averaged for each subject. We conducted within-subject paired t-tests comparing think vs. no think, baseline vs. no think, and baseline vs. lure. We did not observe significant differences between any of the categories; however, we believe that this was due to the small number of participants (n=3). The average recognition memory ratings for each condition are summarized in the table below.

	subject	lure	baseline	no_think	think
0	01	1.134000	6.198667	6.992667	6.600000
1	02	2.571778	5.883333	5.605333	6.403333
2	03	1.329333	5.266000	5.002000	5.400000

Figure 8. Average recognition memory ratings by condition for participants in Experiment 2.

Analyses of EEG data from this experiment are ongoing. For our analyses, we plan to map the neural activity for no think items during the TNT phase to the subsequent recognition memory ratings of these items. We expect to see patterns of neural activity that correlate to successful (lower recognition memory) or unsuccessful (high recognition memory) inhibition of no think items. We also plan to investigate correlates of conscious recollection during the TNT phase and expect to see a greater left positive parietal ERP for think items compared to no think items, as previously observed in other EEG studies of the TNT paradigm (Bergstrom et al., 2007). In addition, we plan to analyze neural activation during the exposure phase to investigate the relationship between neural activation during encoding and later recognition memory. Lastly, we plan to analyze neural activity during the recognition memory phase to look for differences in neural activity between item conditions.

Discussion. Due to our ongoing EEG analysis, we are not able to draw any conclusions from Experiment 2 yet. However, we would like to highlight a trend from our behavioral analysis. Figure 8 shows that for participants 2 and 3, the average recognition memory was lower for no think items compared to both think and baseline items. While neither of these differences were significant in our t-tests, these trends are noteworthy, especially the lowered recognition memory for no think items compared to baseline items. This was a new trend that was not observed in our analysis of Experiment 1, and it suggests that the addition of the RDK task might have reduced activation of no-think items. This suggests that our work continues to move in the right direction toward creating the conditions that lead to moderate activation according to Detre et al.'s nonmonotonic plasticity hypothesis (2013).

General Discussion

This study was a preliminary investigation of suppression of musical memory using the think/no think paradigm. While our initial results were not significant from either experiment, we observed a subsequent trend in reduced no think memory compared to baseline in Experiment 2, possibly as a result of our changes in the TNT task from Experiment 1 to Experiment 2. Furthermore, the RIF model and the nonmonotonic plasticity hypothesis provide a possible explanation for the observed lack of significant memory reduction for no think items (Detre et al., 2013; Norman et al., 2007). Both of these models emphasize that moderate activation of memory below a certain threshold is necessary for subsequent memory weakening. It is difficult to identify and create the conditions that lead to this moderate amount of activation - just enough to activate the memory, but still below a certain threshold. Therefore, it is highly possible that we have not identified the right set of conditions yet, as we only tested two possible sets of activation conditions in this study. However, we will need to continue adapting and refining conditions in order to identify the specific experimental manipulations that lead to moderate activation. Furthermore, Detre et al. (2013) point out that “there are fundamental limits on our ability (as experimenters) to control activation dynamics”; that is, we have no way of regulating participants’ level of activation during an experiment aside from participant instructions.

We acknowledge several limitations in our design, particularly those related to the stimulus pool. Although our music videos were songs from the Billboard Hot 100 list, personal taste in music varies widely among the general population, and it is possible that some participants were familiar with very few songs in our stimulus pool because they preferred different genres of music. A stimulus pool generated from a wider database of songs may be more conducive in generating musical memory for a wider range of participants. As the stimuli were the most popular songs in the past few years, it is possible that participants may have had prior recent exposure to some of the songs before the experiment, such as listening to a song on their iPod or hearing it on the radio. While this may have affected participants’ later recognition memory for items, we were not able to control for recent exposure.

Furthermore, our current EEG data comes from a small number of participants, which may cause our subsequent analyses to be disproportionately affected or skewed by outliers. Future directions include continuing to collect EEG data and completing our EEG analysis for this experiment. We plan to use trial-level activation during the TNT phase to predict memory weakening or strengthening as in Detre et al. (2013). We will also continue narrowing down the threshold between moderate and high levels of activation by modifying the conditions in the

TNT task to further reduce activation. In one potential design, music videos in the no think condition will slowly be revealed from noise while participants complete another task, and participants will press a key to stop the song as soon as it reaches the threshold of recognition. We are also exploring other designs and will begin running behavioral experiments to test these designs as soon as the REP participant pool opens in January.

Overall, this experiment was ambitious in that it applied the think/no think paradigm to musical memory, a rarely used stimulus in studies of memory suppression. In addition, several aspects of the design led to unforeseen challenges in the development of the experiment. In particular, the presentation of music videos as experimental stimuli and the creation of unique stimulus pools for each subject presented computational challenges that delayed the data collection process. However, based on our preliminary findings, we believe that our study has potential to identify both a neural mechanism and cognitive strategy for suppressing musical memories, especially those that are unwanted.

References

Anderson, M.C. and Green, C. (2001), Suppressing unwanted memories by executive control. *Nature*, *410*(6826), 366-369. doi: 10.1038/35066572

Anderson, M.C., Ochsner, K.N., Kuhl, B., Cooper, J., Robertson, E., Gabrieli, S.W.,...Gabrieli, J.D.E. (2004). Neural systems underlying the suppression of unwanted memories. *Science, 303*(5655), 232-235.

Beaman, C.P. and Williams, T.I. (2010), Earworms (stuck song syndrome): Towards a natural history of intrusive thoughts. *British Journal of Psychology, 101*: 637–653. doi: 10.1348/000712609X479636

Bergström, Z.M., Velmans, M., de Fockert, J., Richardson-Klavehn, A. (2007). ERP evidence for successful voluntary avoidance of conscious recollection. *Brain Research*, *1151*: 119-133. http://dx.doi.org/10.1016/j.brainres.2007.03.014

Castellanos, N. P., & Makarov, V. A.(2006). Recovering EEG brain signals: Artifact suppression with wavelet enhanced independent component analysis. *Journal of Neuroscience Methods*, *158,* 300-312.

Detre, G. J., et al. Moderate levels of activation lead to forgetting in the think/no-think paradigm. *Neuropsychologia* (2013), http://dx.doi.org/10.1016/j.neuropsychologia.2013.02.017i

Halpern, A.R. and Bartlett, J.C. (2011), The Persistence of Musical Memories: A Descriptive Study of Earworms. *Music Perception: An Interdisciplinary Journal, 28*(4), 425-432.

Liikkanen, L.A. (2008). Music in everymind: Commonality of involuntary musical imagery. In K. Miyazaki, Y. Hiraga, M. Adachi, Y. Nakajima, & M. Tsuzaki (Eds.), *Proceedings of the 10th International Conference on Music Perception and Cognition (ICMPC10)* (pp. 408–412). Sapporo: Japan.

Norman, K.A., Newman, E.L. & Detre, G.J. (2007). A neural network model of retrieval-induced forgetting. *Psychological Review, 114*(4), 887-953.

Peirce, J.W. (2007). PsychoPy - Psychophysics software in Python. Journal of Neuroscience Methods, 162(1-2), 8-13.

Peirce, J.W. (2009). Generating stimuli for neuroscience using PsychoPy. Frontiers in Neuroinformatics, 2:10. doi: 10.3389/neuro.11.010.2008

Scase M.O., Braddick O.J., Raymond J.E. (1996). What is noise for the motion system? *Vision Research*, *36*, 2579 - 2586.

Williamson, V.J., Jilka, S.R., Fry, J., Finkel, S., Müllensiefen, D., and Stewart, L. (2011). How do “earworms” start? Classifying the everyday circumstances of involuntary musical imagery. *Psychology of Music*. doi:10.1177/0305735611418553