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# The Effect of Cognitive Load on Involuntary Musical Imagery

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**The Effect of Cognitive Load on Involuntary Musical Imagery**

By

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Accepted in Partial Completion
of the Requirements for the Degree
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# Master's Thesis



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A Thesis
Presented to
The Faculty of
Western Washington University

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Abstract

This research was conducted to understand the effect of cognitive load on the occurrence of earworms. A go/no go task, a typical mind wandering method, was used to create different levels of cognitive load based on the difficulty of the task. We also used a control condition which more closely matched previous earworm studies. Both probe-caught and survey reports were used to measure earworms and mind wandering in the study. Earworms were not found to occur more often in the lower experimental levels of cognitive load but controls reported spending more time with earworms. This finding is mostly inconsistent with research on mind wandering which occurs in low cognitive load conditions when more resources are available. I theorize that earworms may occur with minimal resources where more complex thoughts in mind wandering cannot. Earworms may follow a U-shape continuum where earworms may occur in lower levels of cognitive load but must compete with the opportunity of other mind wandering topics. Future research should aim to use more moderate cognitive load tasks to better understand when the occurrence of earworms increases on the lower end of the cognitive load spectrum.

## Acknowledgements

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## Introduction

During our daily lives, we can often find ourselves unintentionally thinking about a song and having it replay in our heads repetitively. People often refer to the experience of having a song stuck in their head as having an earworm (Halpern & Bartlett, 2011; Levitin, 2006), but the experience has also been called various names such as involuntary musical imagery (Liikkanen, 2008) or an involuntary song (Hyman et al., 2013). The earworm experience has been reported to happen regardless of external stimuli, and sometimes without the realization that it had started, which has led multiple researchers to propose that earworms are a form of mind wandering (Floridou & Mullensiefen, 2015; Hyman et al., 2013). Mind wandering has been defined as when cognitive resources are reallocated toward internal streams of thought that are unrelated to the external task or stimuli (Smallwood and Schooler, 2009). Since earworms seem to manifest similarly to mind wandering episodes, the occurrence of earworms may be affected by cognitive load in a similar manner to mind wandering (Floridou & Mullensiefen, 2015; Hyman et al., 2013; Williamson et al., 2011). However, current research on the occurrence of having a stuck song consists mostly of diary and survey studies with only a few experimental studies. In this study, I will experimentally investigate the role of cognitive load on the occurrence of involuntary musical imagery.

Having a song stuck in one's head is a common experience for people, with most reporting that they have the experience a few times a week (Hyman et al., 2013; Liikanen 2008). Earworms are not always purposely recalled, instead they are triggered by something in the environment or by hearing the song earlier (Beaman & Williams, 2010; Halpern & Bartlett, 2011; Hyman et al., 2013). Once started, songs can stick around in our heads from just a few minutes to hours, sometimes reoccurring for several days (Beaman & Williams, 2010; Halpern & Bartlett, 2011; Hyman et al., 2013; Liikanen 2008). To get rid of the earworm, people have reported that they either engaged in another activity or played another song (Halpern & Bartlett, 2011). However, earworms can often return despite moving one's thought to another topic. Hyman and colleagues (2013) found evidence for a Zeigarnik effect with involuntary songs which is the idea that unfinished thoughts are more likely to return to mind after some time.

Earworms can be reduced in frequency by completing tasks that use the same cognitive resources (like listening). Perception and recall of music share neural activation patterns (Farrugia, Jakubowski, Cusack, & Stewart, 2015; Halpern & Zatorre, 1999; Herholz, Halpern, & Zatorre, 2012) and thus compete for resources. Furthermore, interference with the articulatory motor systems reduces the occurrence rate of earworms (Beaman, Powel, & Rapley, 2015; Hyman, Cutshaw, Barker, et al., 2015). Hyman, Cutshaw, Barker, and colleagues (2015) found that involuntary musical imagery occurred less often when the distracting task was verbal such as anagrams compared to non-verbal tasks such as Sudoku. Furthermore, Beaman, Powell, and Rapley (2015) found that chewing gum may interfere with articulatory motor function, which reduced participants' ability to experience an earworm. Thus, earworms occur less frequently when resources are unavailable.

For this reason, it is important to consider how cognitive load may influence the experience of having an earworm. During instances of high cognitive load, one might expect that people would have little excess cognitive capacity remaining for involuntary musical imagery. But in very demanding tasks, people are likely to become overloaded mentally and may not have capacity to notice that they are experiencing an earworm. Hyman and colleagues (2013) found that during higher cognitive load tasks participants were more likely to report having a song stuck. They gave participants tasks that were either the moderate difficulty or a challenging difficulty, while listening to music. Those who completed the challenging task reported having more earworms return later in the experiment than those who had the moderate task.

In extremely low cognitive load situations, people are likely to have extra resources available, which may allow a song to start replaying in their head. In diary studies, people reported having a song stuck in their head when they were performing daily activities such as traveling, grooming, walking, exercising, and other times of low cognitive load (Floridou & Mullensiefen, 2015; Hyman et al., 2013). Earworms still occurred in low to moderate cognitive load situations such as working or interacting with others but mind wandering in general did not occur as often (Floridou & Mullensiefen, 2015). The discrepancy in earworm and mind wandering occurrence rates in low cognitive load situations led Floridou and Mullenseifen to suggest that more experimental studies on earworms are needed to fully understand the effect of low to moderate cognitive load on earworms. Theories about mind wandering may guide our understanding of earworms since earworms potentially follow many of the same patterns.

Mind wandering is an internal thought process that uses working memory resources by reducing executive function for attention regulation (Kam & Handy, 2013; Kam, Dao, Stanciulescu, Tidesley, & Handy, 2013; Smallwood, Beach, et al., 2008; Smallwood et al., 2007; Smallwood & Schooler, 2006). Our thoughts in mind wandering are often unrelated to external stimuli and events, and tend to focus on internal streams of thought about the past, the future, worries, concerns (Baird, Smallwood, & Schooler, 2011), and sometimes earworms (Floridou & Mullensiefen, 2015; Hyman et al., 2013).

The frequency of mind wandering appears to be dependent on cognitive load (McVay & Kane, 2010; Smallwood & Schooler, 2006). Mind wandering is more common at both low and high levels of cognitive load when cognitive resources for attention are available. For example, mind wandering can happen when external stimuli do not use all available resources (low cognitive load), or when people are overloaded and concede resources to easier internal thoughts (high cognitive load). But when cognitive load requires available attention resources to focus on external stimuli, mind wandering may cease or occur less frequently.

Two competing theories address why people mind wander. The first theory is that mind wandering happens because of mental control failure (McVay & Kane, 2009). According to this theory, mind wandering happens almost constantly and people may not notice that they are mind wandering until their attentional resources have failed on focusing on outside stimuli. McVay and Kane (2009) proposed people fail to keep their attention on an easy task because it is unengaging, which causes them to default to the thoughts in the background of our mind, or mind wander. In tasks that are more difficult, attention control failures are less common because the task is more engaging.

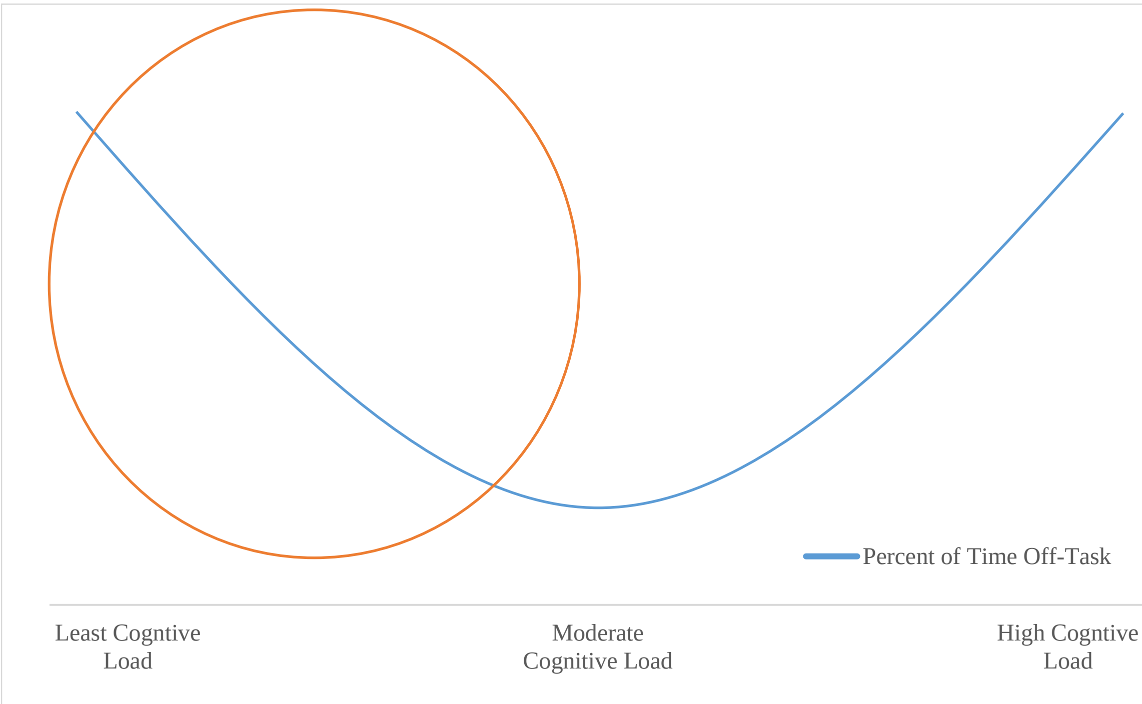
The other theory of mind wandering proposes that people can only focus on either internal or external thoughts because both use the same mental resources such that, as one increases in attentional focus, the other decreases (Schooler et al., 2011; Smallwood, Beach, et al., 2008; Smallwood, Mcspadden, et al., 2007; Smallwood & Schooler, 2006; Teasdale et al., 1993; Teasdale et al., 1995). In support of this theory, Teasdale and colleagues (1993) found that tasks requiring fewer mental resources (low cognitive load) allowed for more mind wandering than moderate tasks that required more resources. Since moderate tasks caused a decrease in mind wandering, they theorized that both share the same mental resources (see also Teasdale et al., 1995; Mason et al., 2007).

The theory that mind wandering and controlled processing compete for mental resources was also supported for high cognitive load tasks. Levinson, Smallwood, and Davidson (2012) found that mind-wandering still increased as working memory resources increased but proposed that mind wandering uses working memory resources differently depending on the difficulty of the task. When people are tasked with something too difficult, they may lose engagement with that task and allow cognitive resources to be freed, which then may be used to mind wander (see also Feng, D'Mello, & Graesser, 2013; Mills, D'Mello, Kehman, Bosch, Strain, & Graesser, 2013). Once off-task, people use working memory resources to continue to mind wander rather than using those resources to return focus to the task (Levinson, et al., 2012), which may explain why it is often hard to stop mind wandering once it has started.

More recently, Thompson, Besner, and Smilek (2015) combined the theories of attentional resource and thought control failure to explain the susceptibility to mind wander in high cognitive load situations. They proposed that mind wandering is a result of executive control failure that leads to inappropriate reallocation of attention resources that deteriorates with time. As a task continues and executive control wanes, resources that were once devoted to a task move to mind wandering instead. People then use more effort to reallocate resources to the task rather than mind wandering (Thompson, Seli, Besner, & Smilek, 2014). Since challenging tasks require more executive control, attention resources are consumed faster, thus leading to sharper increases in the rate of mind wandering in higher cognitive load situations. People are also less likely to notice that they have made an error when mind wandering because of the shared mental resource, which can make it difficult to know when to reallocate resources back to the task (Kam, Dao, Blinn, Krigolson, Boyd, & Handy, 2012).

Based on the theories of mind wandering, I propose that the relationship between cognitive load and earworms may follow the same U-shape continuum reflecting a "Goldilocks Effect." The name of the curve refers to children's story of the little girl who finds everything in the three bears' house is either too big, too small, or just right for her. If cognitive load is just right, the chance for getting an earworm is low (see Figure 1). In diary studies, researchers have found that people use strategies that filled mental capacity to remove the earworm such as listening to other music or starting another task (Beaman & Williams, 2010; Halpern & Bartlett, 2011). Filling mental capacity suggests that earworms follow the Goldilocks effect and that an earworm may not actually be leaving consciousness but rather plays until the mental capacity diminishes, and the song disappears from awareness. As cognitive load moves towards the high or low end of the spectrum, the likelihood for a song to become stuck in awareness increases. Hyman and colleagues (2013) found that those given a more challenging task were more likely to have a song stuck in their head than those given an easy task. They theorized that the easy task was the just right area in cognitive load so that people did not have as many mental resources for an earworm to occur. For the challenging task, people become mentally overloaded which reduces their change of noticing an earworm has invaded their mental resources.

Figure 1. *Proposed model of frequency of earworms based on cognitive load level*




Once an earworm is noticed, it may continue but people have become meta-aware of the song in their head. Meta-awareness is the awareness of the process of mind wandering as it occurs. People only notice the content of their thoughts intermittently but can purposefully draw their attention to their thoughts when asked (Schooler et al., 2011). Additionally, people may not notice their mind wandering because mind wandering and meta-awareness share cognitive resources (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009). When resources are available, such as when a task is easy, people are more likely to report having meta-awareness while mind wandering (Smallwood, McSpadden, et al., 2007). Smallwood, McSpadden, and colleagues (2007) argued that meta-awareness might serve to help process information in mind wandering. It may also function as way to control or give the illusion of control during mind wandering (Schooler et al., 2011).

In some circumstances, a person may mind wander while in control of their attention (Seli, Cerriere, & Smilek, 2015). However, to control mind wandering, a person must be aware that they are, or have been, mind wandering for some amount of time. Smallwood and colleagues (2007) found that people were more likely to be aware of their mind wandering during times of low cognitive load, which may suggest that awareness of mind wandering may be more common with an abundance of mental resources. However, even if a person is initially unaware they were mind wandering, they can usually recall the content of their mind wandering (Smallwood & Schooler, 2006). Earworms seem to follow the same pattern of mind wandering. People do become aware of the songs in their head but are unsure how their earworm started (Hyman et al., 2013), which could be due to an initial lack of awareness.

Based on surveys and diary studies, earworms should occur less frequently when the task has an appropriate level of cognitive load. In contrast, earworms should occur more frequently when the task is very easy, leaving extra mental resources. In this study, I experimentally investigated the effect of low and moderate cognitive load on earworms. Since earworms seem to occur at similar rates to mind wandering, I predicted that earworms would be less likely to occur when a task is appropriate in difficulty for the individual but not too difficult or too easy. I then compared these task groups to a control group that was given a very simplified version of the task where the target only appeared once at the beginning. However, I predicted that people in the control groups would report the most time spent with an earworm since the task they completed needed the least cognitive resources.

For this experiment, I used a typical mind wandering go/no go task where participants are asked to respond to a series of targets and non-targets which appear at different rates and speeds between participants (McVay & Kane, 2009; Smallwood, Beach, et al., 2008; Smallwood, McSpadden et al., 2007; Smallwood et al., 2009). I varied difficulty of the go/no go task through stimuli speed (slow or moderate) and the probability of the target stimuli (high or low). I predicted that if the task were too slow to require much attention, then the person would begin to mind wander since cognitive resources could be available. I also predicted that if the target appeared too uncommonly to require much attention, then the person would begin to mind-wander since resources are available. People reported the content of their mind wandering either through probes presented throughout the study or just once towards the end of the experiment. I predicted that people who were given probes would report that they spent more time with an involuntary song at the end of the experiment. In addition to the task, music was played before the task to give subjects a consistent mind wandering topic that could be measured throughout the study (Hyman et al., 2013; Hyman, Cutshaw, Barker, et al. 2015).

# Method

## Participants

I recruited 197 Western Washington University students for this experiment. I removed 5 participants from analysis who did not follow instructions for the task by completing the task oppositely from what was instructed compromising the task difficulty. The data from 192 participants remained for analysis. Participants consisted of 49 men, 142 women, and one who said they preferred not to respond. Participants ranged in age from 18-58, with an average of 20.75 years of age (*SD* = 4.88). Of the participants, 72.8% identified as White, 9.2% as Asian, 6.2% as Hispanic, 4.1% as Other or Mixed, 3.6% as African American, 2.1% as Hawaiian or Pacific Islander, and 0.5% as Native American. All participants were compensated with credit for class requirements.

## Materials and Procedure

I used Inquisit software to present the go/no-go task created for the purposes of this experiment. I first gave participants a consent form to read and fill out. Then I gave them instructions on the go/no go task before they listened to two songs.

Prior to beginning the go/no-go task, participants listened to two popular pop songs that played for five minutes. I rotated the order of the two songs used which were *Call Me Maybe* by Carly Rae Jepsen, and *Somebody That I Used to Know* by Gotye featuring Kimbra that both reached number one on the Billboard chart for 2012. These songs should easily become stuck in participants' heads as they are both well-known and used previously for this purpose in Hyman, Cutshaw, Barker, and colleagues' (2015) study.

Participants completed a go/no-go task for 20 minutes. I based the go/no-go task on several go/no-go task studies (Christoff et al., 2009; McVay & Kane, 2009; Smallwood et al., 2007; Smallwood et al., 2009). In a go/no-go task, participants respond to some stimuli and withhold responses for other stimuli. In this go/no-go task, I asked participants to press a button (spacebar) for go stimuli (all numbers 0-9, except 3) and withhold a response for no-go stimuli (number 3). When participants responded correctly, they received a green + at the bottom of their screen. When participants answered incorrectly, they received a red – at the bottom of their screen. No music played during this time.

No-go stimuli appeared either 5% (low probability) or 20% (high probability) of the stimuli presented (Christoff et al., 2009; Smallwood et al., 2007). This variable was manipulated between-subjects such that I exposed each participant to either a low probability or high probability of no-go stimuli throughout the experiment. Mind-wandering should occur more often when the no-go stimuli appear at a 5% rate than when the no-go stimuli appear at a 20% rate since more attention is required for more frequent appearance of the no-go stimuli (Christoff et al., 2009; Smallwood et al., 2007; Smallwood et al., 2009).

I also set stimuli to appear at either a fast rate or a slow rate. The fast rate was set at 1500ms for each stimulus and the slow rate was set at 3000ms for each stimulus (Christoff et al., 2009; McVay & Kane, 2009; Smallwood, et al., 2008; Smallwood et al., 2009; Smallwood et al., 2011). I manipulated this variable between subjects. Mind-wandering should vary by the speed of the task such that I predict less mind-wandering will occur for participants who are given a stimuli rate of 1500ms than those given a stimuli rate of 3000ms (McVay & Kane, 2009; Smallwood et al., 2008; Smallwood et al., 2007).

Participants in the control condition were given a go/no go task that only had the target stimulus appear once in the beginning and never reappeared within each section of the task. The participants in the control condition only received the slow stimuli speed (3000ms), and did not receive probes.

Participants completed six sections of the go/no-go task that were each 3 minutes long. The number of stimuli each group received was set so that both stimuli presentation speeds (1500ms or 3000ms) groups spent the same amount of time on the go/no-go task. Those in the 1500ms group received a total of 720 stimuli whereas those in the 3000ms group received a total of 360 stimuli. Equal completion time was chosen over an equal number of trials for two reasons. First, it gives enough time to measure mind wandering for both groups. Second, the number of errors on the task are from task difficulty level rather than mental fatigue (Baumeister, Bratslavsky, Muraven, & Tice, 1998).

Since the go stimuli occur more often than the no-go stimuli, people develop a tendency to respond quickly and will often fail to withhold a response when presented with a no-go stimulus due to attention disengagement. The go/no-go task is a continuous measure of reaction time as well as attention related mistakes on go/no-go stimuli. Slower reaction times and a greater number of mistakes are usually indicative of mind wandering (McVay & Kane, 2009; Smallwood et al., 2007; Smallwood et al., 2011).

Since people are not always aware of their mind wandering, the most common way to measure how frequently the mind wanders is through thought sampling (Smallwood & Schooler, 2006). Thought sampling is where thoughts are collected by asking the participant to describe their current internal experience. The two types of thought sampling are probe-caught and self-caught mind wandering. In self-caught reporting methods, people report their mind wandering when they notice it. This requires people to be aware of their mind wandering. By contrast, probe-caught sampling uses a series of probes to find when people are mind wandering and requires people to report their mind wandering only when prompted. Takarangi, Strange, and Lindsay (2014) argued that there is a discrepancy in the frequency of mind wandering reported and experienced by these two methods.  Probe-caught measures may exaggerate reports of mind wandering since multiple probes may be measuring a continuation of the same episode. Similarly, self-reports may underestimate since people do not always become aware of their thoughts, especially fleeting ones.

A performance-based task, such as the go/no-go task, measures correct and incorrect responses to a series of target or non-target stimuli which can more accurately indicate being off-task than self-report measures (Takarangi et al., 2014).   Incorrect responses are indications of being off-task and are a possible indication of mind wandering.  Musical mind wandering has been found through other methods such as probe-caught (Bailes, 2007) and self-caught methods (Halpern & Bartlett, 2011).  However, Bailes (2007) found that people reported about 12 episodes of earworms a week on average through probe-sampling whereas Halpern and Bartlett (2011) found that people reported five episodes per week on average when asked to use self-caught measures (see also Floridou & Mullensiefen, 2015).  The discrepancy between these occurrence rates support using several methods of reporting for comparison.

Of the four experimental conditions, half of the participants received thought probes between sections of the task while the other half received 10 second breaks (Christoff et al., 2009; McVay & Kane, 2009; Smallwood et al., 2011; Smallwood et al., 2007).  Using Inquisit, I presented thought probes on a white background with black font.  Participants answered two questions then moved onto the next block of trials by pressing spacebar at the bottom of the screen. They were asked, "*What were the contents of your thoughts just before this question?"* (McVay & Kane, 2009).  Options included thinking about the task, task performance, everyday stuff, current state of being, personal worries, music, and other.  I asked participants who received probes to check all that applied.  I gave them limited options on this question so that response time would not vary much across participants. I then asked: *Were you aware where your thoughts were before the last question?* "yes" or "no" (Smallwood et al., 2008). After the two questions, participants were instructed on screen to press the spacebar to continue onto the next block.

The purpose of the break in the group with no probe was to give participants the same amount of time away from the task as those in the thought probe condition. The break may not make participants aware of their thoughts whereas the thought probe may increase awareness. The timing of the break should match the average time to complete the thought probe. During the break, a message instructed participants to wait 10 seconds for the next task set.

After the go/no-go task was completed, all participants filled out a series of surveys. The Earworm Survey (Hyman et al., 2013; Hyman et al., 2014) was used to ask questions about how much time each song was stuck in participants' head with answers in increments of 10% from 0 to 100. They rated how well they know each song on a 7-point scale with 1 being not at all, 3 being not very well, 5 being can sing or hum most, or 7 being know the whole song completely. They were also asked how much they like the song and how distracting did they find the song with a 7-point Likert scale with anchors of 1 (Strongly Dislike and Not Very Distracting, respectively) to 7 (Strongly Like and Very Distracting, respectively). Lastly, they were asked when they last heard the song and if the song reminded them of any memories.

I used other surveys to measure the nature of thoughts during mind-wandering, including the White Bear Suppression Inventory (Wegner, Schneider, Carter, and White, 1998), and the Frequency of Involuntary Thoughts Scale (Hyman, Cutshaw, Hall, et al. 2015). The White Bear Suppression Inventory measures how often people suppress select thoughts. The Frequency of Involuntary Thoughts Scale was created to measure how often people have different types of involuntary thoughts such as thoughts about money or relationships. Hyman, Cutshaw, Hall, and colleagues (2015) found that the White Bear Suppression Inventory correlated with the Frequency of Involuntary Thoughts Scale ($r$ = .48) such that people who have more involuntary thoughts were more likely to suppress those thoughts. And people who suppress their thoughts were more likely to have them return later (Hyman et al., 2013; Wegner 1994).

Once participants had completed the surveys, they indicated demographic information. I then debriefed and thanked the participants.

## Results

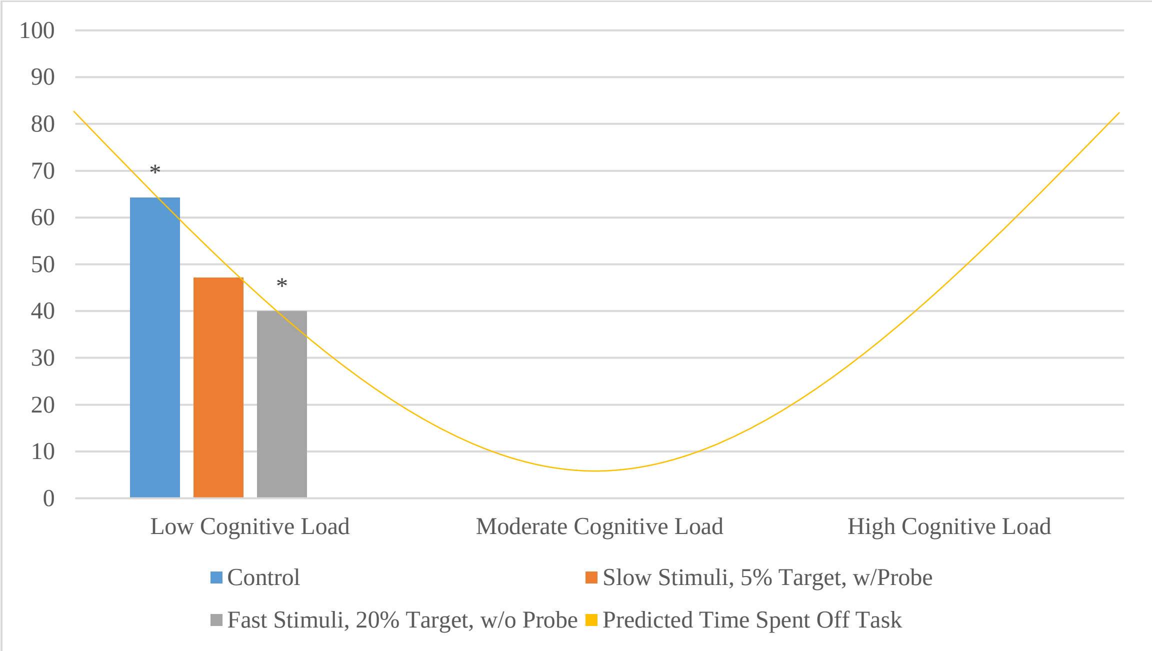
For this study, I predicted that participants in the very slow stimuli, low probability targets, and probe condition would spend the most amount of time with a song stuck in their head. I also predicted that those in the more moderate speed stimuli, high probability targets, and no probes would report less time stuck with a song in their head. To test my hypotheses, I will compare the recorded amount of mind wandering and earworms on the probes between the levels of task difficulty. Next, I will compare the percentage of time spent with an earworm during the experiment as reported on the conclusion survey between all levels of task difficulty and controls. I will follow up by making the same comparison for all levels of task difficulty but without controls to compare those who did and did not receive a probe to verify that receiving a probe did not affect the task difficulty. To validate the task difficulty, I will also analyze participant's go/no-go task performance. Finally, I will correlate the percentage of errors for the target, the White Bear Suppression Inventory, the Frequency of Involuntary Thoughts Scale, the total reported number of earworms on the probe, and the total number of mind wandering including earworms on the probe.

First, I looked at how frequently participants indicated they experienced in earworm in response to the thought probes. These analyses are restricted to participants in the thought probe conditions. A 2 x 2 Between Subjects ANOVA was used to look for a main effect of task speed (1500ms or 3000ms), a main effect of target probability (5% or 20%), and an interaction, on the total number of times participants reported thinking about the music on the probe questionnaires. I found no main effects for either Task Speed, $F(1, 79) = .288$, $MSE = 1.238$, $p = .593$, $\eta_p^2 = .004$, Target Probability, $F(1, 79) = 2.226$, $MSE = 1.238$ $p = .140$, $\eta_p^2 = .027$, nor an interaction, $F(1, 79) = .068$, $MSE = 1.238$, $p = .796$, $\eta_p^2 = .001$. Although I predicted people would experience more earworms, I did not find any difference in probe reports of earworms among the task levels. See Table 1 for cell means and standard deviations.

Then the total number of times participants reported any type of mind wandering, including music, in the series of probe questions was investigated using a 2 x 2 Between Subjects ANOVA with task speed (1500ms or 3000ms), and target probability (5% or 20%). I found a main effect for Task Speed, $F(1, 75) = 11.382$, $MSE = 18.702$, $p = .001$, $\eta_p^2 = .132$, but no main effect for Target Probability, $F(1, 75) = .495$, $MSE = 18.702$, $p = .484$, $\eta_p^2 = .007$, and no interaction, $F(1, 75) = 1.448$, $MSE = 18.702$, $p = .233$, $\eta_p^2 = .019$. Participants who were given the faster stimuli speed (1500ms) indicated less mind wandering items on the probes ($M = 8.89$, $SD = 3.61$) than participants who were given the slower stimuli speed (3000ms) ($M = 12.05$, $SD = 4.89$). Since I had used mind wandering methods for this study, it makes sense that mind wandering took priority in people's thoughts rather than earworms. See Table 2 for cell means and standard deviations.

In the next analyses, I used 3 t-tests to compare the groups of interest according to my hypothesis. I predicted that the control group, which had zero target stimuli (no-go) trials, would report spending more time with a song stuck in their head in the experiment compared to the group that received the slow stimuli, low probability of a target stimuli, and no probe, and the group that received fast stimuli, high probability of a target stimuli, and probes. I also predicted that the group that received the slow stimuli, low probability of a target stimuli, and no probe would report spending the least amount of time with a song stuck in their head compared to the other experimental condition and control. I found that the control group ($M = 65.24$, $SD = 42.73$) reported spending significantly more time in the experiment with earworms than the fast stimuli, high probability of a target stimuli, and probes group (*M* = 40.00, *SD* = 20.47), $t(41) = -2.488$, $p < .05$. The plot of the means does follow the u-shape that I had predicted as shown in Figure 2.

Figure 2. *Survey reported time spent with earworms in hypothesized groups with proposed model of frequency of earworms based on cognitive load level*




Note. * = $p < .05$

A 2 x 2 x 2 Between Subjects ANOVA without the control group was used to look for a main effect of task speed (1500ms or 3000ms), a main effect of target probability (5% or 20%), a main effect of the presence of the probe (received or did not), and an interaction, on the total reported percentage of time spent with the music stuck in participants heads. I found no main effects for either Task Speed, Target Probability, Probe, nor any interactions (see Table 3). I had originally predicted that probe reports would exaggerate survey reports of have a song stuck during the experiment, but the results do not support that hypothesis, which means that people are accurately aware of their time spent with a song stuck in their heads.

A 2 x 2 x 2 Between Subjects ANOVA was used to look for effects of task speed (1500ms or 3000ms), target probability (5% or 20%), presence of the probe (received or did not), and interactions, on the percentage of responses where participants failed to withhold a response for the target stimuli. I found a main effect for Task Speed, $F(1, 163) = 41.358$, $MSE = .017$, $p < .001$, $\eta_p^2 = .202$, and a main effect Target Probability, $F(1, 163) = 30.690$, $MSE = .017$, $p < .001$, $\eta_p^2 = .158$, but no effect of the probe questionnaire and no interactions (see Table 4). Participants who were given the faster stimuli speed (1500ms) made a higher percentage of errors ($M = 21.35$, $SD = 16.69$) than participants who were given the slower stimuli speed (3000ms) ($M = 8.83$, $SD = 10.72$). Participants who were given a target stimuli probability of 5% made a higher percentage of errors ($M = 20.52$, $SD = 18.09$) than participants who were given a target stimuli probability of 20% ($M = 9.77$, $SD = 9.50$). Since errors did not increase for an interaction between speed and target stimuli probability, this study is on the very low end of the cognitive load spectrum. For cell means and standard deviations, see Table 5.

I then used correlations to understand the relationships between the different measurements of mind wandering and earworms using all experimental non-control participants. Probe reports of earworms and all mind wandering (including earworms), target error percentage, the earworm reports on the survey, the Frequency of Involuntary Thoughts Scale, and the White Bear Suppression Inventory were all used in the following analyses. The Frequency of Involuntary Thoughts Scale had a Cronbach's Alpha of .744 and the White Bear Suppression Inventory had a Cronbach's Alpha of .864. A correlation was found between the number of times people reported earworms and the number of times people reported any type of mind wandering in the probes ($r = .434$, $p < .001$), such that those who reported more earworms also tended to report more of the other types of mind wandering which makes sense considering that earworms are included in the total mind wandering reports.  Additionally, those who reported having more earworms in the probe also tended to report higher percentages of time spent in the experiment with a song stuck in their head on the survey ($r = .504$, $p < .001$).  No correlation was found between the number of times people reported mind wandering about music on the probe and the scores on the Frequency of Involuntary Thoughts Scale.  Although, people who scored higher on the Frequency of Involuntary Thoughts Scale, tended to report more mind wandering of all types on the probes ($r = .341$, $p = .002$).  Participants who scored higher on the White Bear Suppression Inventory, tended to report more earworms on the probe ($r = .244$, $p = .026$), tended to score higher on the Frequency of Involuntary Thoughts Scale ($r = .384$, $p < .001$), and were more likely to report higher percentages of time spent in the experiment with a song stuck in their head ($r = .264$, $p < .001$).  No correlation was found between the White Bear Suppression Inventory and probe reports of mind wandering for all types.  For all correlational data, see Table 6.

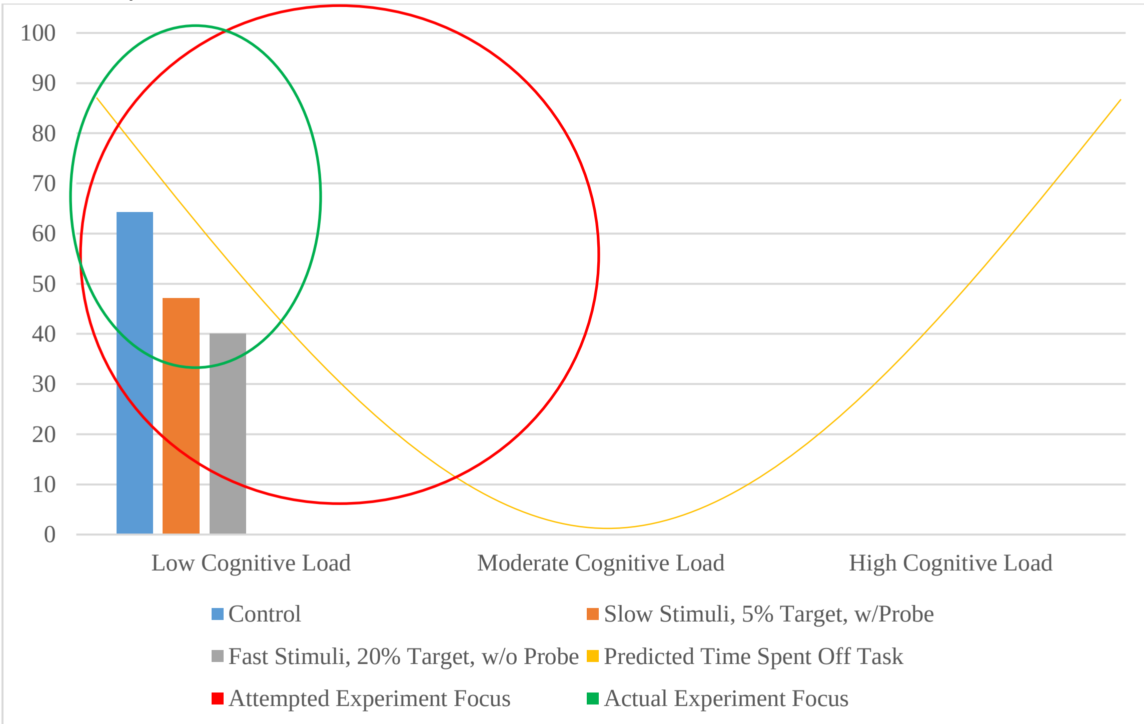
On average, 84.74% of Participants responded on the probe that they were aware of their mind wandering before being asked.  On the first probe, 72.29% of participants reported that they were aware of their mind wandering, 91.57% on the second, 89.16% on the third, 85.54% on the fourth, 87.95% on the fifth, and 81.93% on the sixth.

## Discussion

I had initially hypothesized a Goldilocks effect where too much or too little cognitive load would result in a higher prevalence of earworms and having just the right amount of cognitive load would reduce the prevalence of earworms to a minimal level resulting in a U-shape curve. I did find that participants in the lowest cognitive load controls survey reported spending the most amount of time with a song stuck in their head compared to the participants in the more moderate cognitive load task. Although, I did not find the same pattern in the probe reported earworms. However, I still hypothesize a U-shape continuum, but low cognitive load also allows for other mind wandering thoughts to flow in. I theorize that using a slightly different or more challenging task than I used in this study would find differences in the occurrence of earworms, and less general mind wandering.

Both earworms and mind wandering have been found to occur naturally in low cognitive load situations (Floridou & Mullensiefen, 2015; Hyman et al., 2013; Teasdale et al., 1993). In this study, I found that participants probe reported more overall mind wandering instead of earworms in the slower low cognitive load task. This study was based on general mind wandering methods that use cognitive load levels that are effective for mind wandering episodes but maybe not so for earworms. Previous studies found that general mind wandering only occurred in low cognitive load circumstances whereas earworms occurred in low and more moderate cognitive load situations (Floridou & Mullensiefen, 2015). Based on the findings in this study and in previous work, mind wandering may require more resources than earworms, which would lead to less mind wandering in more moderate cognitive load tasks. This study was aimed at using low to moderate cognitive load tasks but fell to very low to low cognitive load as noted as Actual Experiment Focus versus the Attempted Experiment Focus in Figure 3.

Figure 3. *Survey reported time spent with earworms in hypothesized groups with proposed model of frequency of earworms based on cognitive load level, and with attempted and actual experimental focus areas*




Another way to investigate the effect of cognitive load in mind wandering and earworms, may be to use a task that competes for the same resources. Halpern and Bartlett (2011) found that people started thinking of another song to rid themselves of a current earworm. In other research, earworms were reduced with articulation interference (Beaman, Powel, & Rapley, 2015; Hyman, Cutshaw, Barker, et al., 2015). Because earworms and intentional thinking of music use the same resources (Farrugia, Jakubowski, Cusack, & Stewart, 2015; Halpern & Zatorre, 1999; Herholz, Halpern, & Zatorre, 2012), articulatory forms of cognitive load may be a more effective way to study the effect of cognitive load on earworms.

Using similar interference methods, we may be able to filter out mind wandering to better focus on the song stuck in people's heads. Interestingly, mind wandering has been found to match the current task such that visual mind wandering increased with visual tasks, and verbal mind wandering increased with verbal tasks (Choi, Geden, &Feng, 2017). Thus, trying to create a task that interferes with the various forms of mind wandering but allows earworms may be challenging.

Total probe reports of earworms were related to the survey reports of time spent with an earworm during the experiment thus we confidently state that use of probes did not have an influence on the survey reports of earworms since no difference was experimentally found. This finding is contradictory to the findings of Takarangi and colleagues (2014). They found that probe caught methods seemed to exaggerate the number of intrusive thought episodes and survey methods seemed to under report. Earworms may not start as an intrusive thought but can become one over time (Hyman, Cutshaw, Barker, et al., 2015). However, earworms may have been less intrusive in this study, or are too different from trauma-related intrusive thoughts to be a good comparison. Future research may want to investigate the two different reporting methods for similar involuntary and intrusive thoughts to make a more direct comparison.

The consistency between earworms reports on probes and the survey also indicate that people have a good sense of how present an earworm is in their thoughts. The reports of awareness on the probe also indicate that people are meta-aware of their mind wandering. These findings are in line with Smallwood, McSpadden, and colleagues (2007) who predicted that people are more meta-aware of their mind wandering when cognitive load is low and mental resources are abundant.

The White Bear Suppression Inventory and Frequency of Involuntary Thoughts Scale were positively correlated with one another which is consistent with previous earworms studies (Hyman, Cutshaw, Barker, et al. 2015). Additionally, those who reported more earworms on the probe or survey tended to score higher on the White Bear Suppression Inventory, a measure of thought suppression.  Furthermore, those who reported more mind wandering of any type scored higher on the Frequency of Involuntary Thoughts Scale, a measure of the frequency of involuntary thoughts. With the White Bear Suppression Inventory correlated with earworm reports but not reports of all topics of mindwandering, more research is needed to understand the relationship of suppression of earworms compared to general mind wandering.

Although I had predicted that low cognitive load would allow for more stuck songs, I found that mind wandering dominated peoples' thoughts.  Given that the methods in this study created an exceptionally low cognitive load task, mental resources were abundant allowing for more types of mind wandering topics to occur.  And because earworms can occur with very minimal resources, future studies should use more moderate cognitive load tasks to filter out general mind wandering.  Additionally, future stuck song research could also use a combination of visual and carefully selected verbal tasks to suppress mind wandering and focus on the song stuck in one's head.  Once general mind wandering is eliminated as an option through mental resource drought or mental suppression, we should find that earworms still follow a U-shape continuum with earworms occurring most frequently at high and low levels of cognitive load while occurring less often during levels of moderate cognitive load.

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Table 1

*Cell Means and Standard Deviations for Task Speed and Target Probability on Total Number that Music was Checked on the Probes*

| | Target Freq 5% | | | Target Freq 20% | | |
|---|---|---|---|---|---|---|
| *Variable* | *N* | *M* | *sd* | *N* | *M* | *sd* |
| Task Speed 1500ms | 19 | .79 | .92 | 22 | 1.09 | 1.23 |
| Task Speed 3000ms | 21 | .86 | 1.11 | 21 | 1.29 | 1.15 |

Table 2

*Cell Means and Standard Deviations for Task Speed and Target Probability on Total Number that any Mind Wandering Items that were Checked on the Probes*

| | Target Freq 5% | | | Target Freq 20% | | |
|---|---|---|---|---|---|---|
| *Variable* | *N* | *M* | *sd* | *N* | *M* | *sd* |
| Task Speed 1500ms | 16 | 7.81 | 2.74 | 22 | 9.68 | 4.00 |
| Task Speed 3000ms | 20 | 12.30 | 5.38 | 21 | 11.81 | 4.49 |

Table 3

*Main Effects and Interactions for Task Speed, Target Probability, and Probe on Total Reported Percentage of Time Spent with Music Stuck in Participants Heads without Control Groups*

| *Interaction Type* | *df* | *F* | *p* | $\eta_p^2$ | *MSE* |
|---|---|---|---|---|---|
| Task Speed | 1 | .814 | .368 | .005 | |
| x Target Freq | 1 | 1.889 | .171 | .011 | |
| x Probe | 1 | .665 | .416 | .004 | |
| Target Freq | 1 | .215 | .643 | .001 | |
| x Probe | 1 | 2.859 | .093 | .017 | |
| Probe | 1 | .691 | .407 | .004 | |
| Interaction | 1 | .000 | .987 | < .001 | |
| Error | 163 | | | | 1317.229 |

Table 4

*Main Effects and Interactions for Task Speed, Target Probability, and Probe on Target Percentage of Incorrect Answers*

| *Interaction Type* | *df* | *F* | *p* | $\eta_p^2$ | *MSE* |
|---|---|---|---|---|---|
| Task Speed | 1 | 41.358 | < .001* | .202 | |
| x Target Freq | 1 | 3.623 | .059 | .022 | |
| x Probe | 1 | 1.809 | .181 | .011 | |
| Target Freq | 1 | 30.690 | < .001* | .158 | |
| x Probe | 1 | .008 | .930 | < .001 | |
| Probe | 1 | .252 | .617 | .002 | |
| Interaction | 1 | .180 | .672 | .001 | |
| Error | 163 | | | | .017 |

********Significant at the level of p < .05.***

Table 5

*Cell Means and Standard Deviations for Task Speed, Target Probability, and Probe on Total Percentage of Incorrect Answers*

| | Probe | | | No-Probe | | |
|---|---|---|---|---|---|---|
| *Variable* | *N* | *M* | *sd* | *N* | *M* | *sd* |
| Task Speed 1500ms | 44 | 19.20 | 15.70 | 44 | 23.34 | 17.49 |
| x Target Freq 5% | 19 | 26.54 | 18.01 | 22 | 31.18 | 19.36 |
| x Target Freq 20% | 22 | 12.87 | 10.63 | 22 | 15.50 | 11.07 |
| Task Speed 3000ms | 42 | 9.68 | 11.27 | 44 | 8.01 | 10.24 . |
| x Target Freq 5% | 21 | 13.59 | 13.89 | 22 | 11.27 | 12.92 |
| x Target Freq 20% | 21 | 5.76 | 5.94 | 22 | 4.76 | 5.08 |
| Target Freq 5% | 40 | 19.74 | 17.07 | 44 | 21.23 | 19.13 |
| Target Freq 20% | 44 | 9.22 | 8.94 | 44 | 10.13 | 10.01 |
| Total | 83 | 14.38 | 14.38 | 88 | 15.68 | 16.20 |

Table 6

*Correlations between Various Measurements of Involuntary Thoughts and Earworms without Control Groups*

| *Measures (N)* | *1* | *2* | *3* | *4* | *5* | *6* |
|---|---|---|---|---|---|---|
| 1. Target Error Percentage (171) | - | -.102 | -.026 | -.217 | -.141 | -.070 |
| 2. White Bear Suppression Inventory (171) | | - | .384* | .161 | .244* | .264* |
| 3. Frequency of Involuntary Thoughts Scale (171) | | | - | .341* | .196 | .061 |
| 4. Total Probe Mind Wandering (79) | | | | - | .434* | .124 |
| 5. Total Probe Earworm (83) | | | | | - | .504* |
| 6. Total Percent of Earworm Survey (171) | | | | | | - |

Note. * = $p < .05$

## Appendix A

***<u>Probe Questionnaire</u>***

*Please answer these questions about your thoughts just before these questions.*

1. What were the contents of your thoughts just before this question?

    ____The task

    ____Task performance

    ____Everyday stuff

    ____Current state of being

    ____Personal worries

    ____Music

    ____Other

2. Were you aware of where your thoughts were before the last question? ***Check only one.***

    ____ Yes ____No

## Appendix B

***<u>Conclusion Survey</u>***

*Please answer these questions about whether you heard either of the songs we played earlier while completing the task.*

***Song 1: Somebody I Used to Know by Gotye***

What percentage of the time did you hear this song in your head?

0 10 20 30 40 50 60 70 80 90 100

***Song 2: Call Me Maybe by Carly Rae Jepsen***

What percentage of the time did you hear this song in your head?

0 10 20 30 40 50 60 70 80 90 100

*Please answer the following questions about the songs that were used in this study:*

***Somebody I Used to Know by Gotye***

How well do you know the song **Somebody I Used to Know**?

1 2 3 4 5 6 7

Not at all Not very well Most of the song Completely

Do you like the song?

1 2 3 4 5 6 7

Strongly Dislike Strongly Like

How distracting do you find the song?

1 2 3 4 5 6 7

Very Distracting Not Distracting

When did you last hear the song before this study?

____Earlier today

____Within the week

____Within the Month

____Within the year

____Within the last 5 years

____Don't know

What type of memories does this song bring back? (Check all that apply)

____Specific person

____Specific place

____Specific life event

____Specific time period in your life

***Call Me Maybe by Carly Rae Jepsen***

How well do you know the song **Call Me Maybe**?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Not at all | | Not very well | | Most of the song | | Completely |

Do you like the song?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Dislike | | | | | | Strongly Like |

How distracting do you find the song?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Distracting | | | | | | Not Distracting |

When did you last hear the song before this study?

____Earlier today

____Within the week

____Within the Month

____Within the year

____Within the last 5 year

____Don’t know

What type of memories does this song bring back? (Check all that apply)

____Specific person

____Specific place

____Specific life event

____Specific time period in your life

## Appendix C

## WHITE BEAR SUPPRESSION INVENTORY

**These questions are about thoughts. There are no right or wrong answers, so please respond honestly to each of the items below. Be sure to answer every item by circling the appropriate answer below each one.**

1. There are things I prefer not to think about.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

2. Sometimes I wonder why I have the thoughts I do.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

3. I have thoughts that I cannot stop.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

4. There are images that come to mind that I cannot erase.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

5. My thoughts frequently return to one idea.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

6. I wish I could stop thinking of certain things.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

7. Sometimes my mind races so fast I wish I could stop it.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

8. I always try to put problems out of mind.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

9. There are thoughts that keep jumping into my head.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

10. Sometimes I stay busy just to keep thoughts from intruding on my mind.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

11. There are things that I try not to think about.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

12. Sometimes I really wish I could stop thinking.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

13. I often do things to distract myself from my thoughts.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

14. I have thoughts that I try to avoid.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

15. There are many thoughts that I have that I don't tell anyone.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral or Don't Know | Agree | Strongly Agree |

## Appendix D

## FREQUENCY OF INVOLUNTARY THOUGHTS SCALE

**Many people have a variety of thoughts come to mind throughout the day. Sometimes these thoughts come to mind without you choosing to think about them. How often do the following types of involuntary thoughts happen to you?**

1. Music (a song stuck in your head)

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Never | Almost Never | Few Times A Month | Few Times A Week | Few Times Each Day | Constantly |

2. Visual Images

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Never | Almost Never | Few Times A Month | Few Times A Week | Few Times Each Day | Constantly |

3. Memories

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Never | Almost Never | Few Times A Month | Few Times A Week | Few Times Each Day | Constantly |

4. Thoughts about the future

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Never | Almost Never | Few Times A Month | Few Times A Week | Few Times Each Day | Constantly |

5. Romantic relationship thoughts

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Never | Almost Never | Few Times A Month | Few Times A Week | Few Times Each Day | Constantly |

6. Thoughts about other relationships

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Never | Almost Never | Few Times A Month | Few Times A Week | Few Times Each Day | Constantly |

7. Work thoughts

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Never | Almost Never | Few Times A Month | Few Times A Week | Few Times Each Day | Constantly |

8. Thoughts about money

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Never | Almost Never | Few Times A Month | Few Times A Week | Few Times Each Day | Constantly |