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The Influence of Negative Mood on Mind Wandering as Observed Through Reach Tracking Techniques

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Dedication

To Connecticut College for allowing me to meet my wonderful friends.
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For my thesis advisor, Jeff Moher, who helped me see the completion of this project.
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Always,
for my parents.

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Abstract

In two experiments, the influence of inducing negative mood on cognitive performance was explored by analyzing physical arm reaching movements as indicators of mind wandering. Mood was induced by viewing a series of six photos per mood condition that were previously established for their emotionally valenced and arousal ratings. A reach tracking device recorded three metrics of arm movement that were expected to reflect instances of mind wandering: initiation latency, movement time, and arm curvature. In the first experiment, 29 participants were randomly assigned into one of two induced-mood groups, negative mood (n = 15) or neutral mood (n = 14). Participants performed a simple Go/No-go task in which arm movements were detected by the reach tracker. The first experiment indicated that the mood inducement was successful but the effect of negative mood on either self-reported mind wandering or variances in arm movement were not significant. Thus, the second experiment prompted the change to a visual-search target-selection task in which variances in initiation latency, movement time, and curvature were expected to be more pronounced. The second experiment consisted of 23 participants who were also randomly assigned to either negative (n = 12) or neutral (n = 11) mood condition. The second experiment revealed that the mood induction was still successful but that there were still no significant effects observed between mood and indicators of mind wandering. Though the results of this study did not reflect initial predictions, it may suggest that low-arousing negative moods in healthy individuals are not associated with increased mind wandering.

Keywords: mood induction, mind wandering, reach tracking, go/no-go, visual search

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Major depression is one of the most common mood disorders in the United States and affects an estimated 17.3 million American adults aged 18 or older, representing about 7% of all US adults (National Institute of Mental Health [NIMH], 2019). Its symptoms can be mild to severe, affecting how an individual thinks, feels, and behaves in everyday settings. Ultimately, depression has an effect on an individual's ability to function in daily life. Depression may exist in many forms and can present itself across different points across the lifespan, yet the persistent feelings of sadness and general negativity are similar across all versions of the disorder. Although the primary symptom of depression is sadness, sadness alone is not sufficient to define depression. Thus, this is not suggesting that all occurrences of negative moods are attributed to depression, but that those affected by depression will experience many instances of negative mood. As an integral feature of depression, this study focuses on the impact of negative affect on cognitive functionality.

The Depressed Brain

Functional neuroimaging studies have shown considerable anatomical overlap in brain regions regulating sad mood and cognitive processes (Austin et al., 1999; Cabeza & Nyberg, 2000; Chepenik, Cornew, & Farah, 2007; Phan, Wager, Taylor, & Liberzon, 2002). Supporting evidence has shown significantly altered neural structures especially in the prefrontal cortex of participants experiencing melancholic depression (Austin et al., 1999). The prefrontal cortex of the brain is known as the site of higher order cognitive abilities such as processes for working memory, decision-making, and attention (Austin et al., 1999). Deficits in this area, potentially as a result of the neural mechanisms underlying depression, may explain the debilitating cognitive symptoms that define depression. Li et al. (2018) also found that diminished connectivity in the dorsal cognitive control network potentially leads to the cognitive deficits expressed in depressed patients. The study also suggests how a state of negative affect would impact cognitive abilities and processes such as maintenance of attention, memory, and perception that are important to function in daily life. However, successful treatment of depression seemed to reverse the affected brain regions in the same patients, suggesting that depression was directly associated with impairment in those regions (Li et al., 2018).

Other notable structures altered in depression are structures involved in what is known as the default mode network. Liu, Jiang, and Yuan (2018) found that both structural and functional impairments in the default mode network were associated with the development of late-onset depression. Regions found to be involved in the default mode network include: the posterior cingulate cortex (PCC), superior frontal gyrus (SFG), medial prefrontal cortex (mPFC), hippocampus, and the cerebellum (Liu et al., 2018; Renner et al., 2017; Rodriguez-Cano et al., 2017). The default mode network is an area that is most activated during moments of rest or cognitive inactivity. These moments occur when one is said to think about nothing or performing tasks that are not cognitively demanding. The default mode network has been identified to be heavily involved in self-referential thinking such as autobiographical memory, retrospective past-oriented thinking, future-oriented thinking, planning, thinking of others' perceptions of themselves, and thinking of the intentions of others (Liu et al., 2018; Spreng, Mar, & Kim, 2009). Factors activating the default mode network are reminiscent of a common symptom of both depression and anxiety: rumination.

Rumination

Rumination is the act of repeatedly going over thoughts or problems without reaching a conclusion. Rumination is a difficult experience because it is essentially the repeated thinking of problems without any problem-solving, thus prolonging the burdens experienced in depression. Li et al. (2018) found that rumination was associated with an overactive default mode network. It is possible that the inability to inhibit the activation of areas of the default mode network involved in rumination is associated with the maintenance of negative feelings that perpetuate depression. Ruminative thought was shown to intensify the more one thinks about their failures and other negative thoughts. Jones, Papadakis, Orr, & Strauman (2013) found that failure to accomplish set goals was strongly correlated to increased rumination. This suggests that a negative experience, thus affecting mood, increases the likelihood of ruminating. In these instances of ruminative episodes, it is likely that cognitive capacity is spent on focusing on and maintaining these thoughts which reduces the resources allocated to maintaining attention and careful decision making.

Because the primary symptom of depression is the persistent feeling of negative mood, this study looks closer at the ways in which negative mood influences cognition.
Though temporary states of negative mood are unlike that of the more chronic, general negativity experienced in depression, it is possible that unregulated and repeated exposures to negative mood may result in vulnerabilities to the cognitive deficits that are expressed in depression. This idea is explored further.

Mood-Congruent Biases

Koster, De Raedt, Goeleven, Franck, and Crombez's (2005) eye tracking experiment demonstrated that participants exhibited sustained dwelling at the location of negative words when in an induced negative mood or experiencing dysphoria. In this case, sustained dwelling on negative words could then further intensify the negative mood and sustain ruminative thinking. Research in attentional studies showed that both the experience of dysphoria and experimentally induced negative mood will increase the likelihood of an attentional bias toward negatively valenced words, pictures, and facial expressions (Becker & Leinenger, 2011; Chepenik et al., 2007; Koster, et al., 2005; Mogg & Bradley, 2005). An attentional bias to such stimuli could contribute to the excessive processing of negatively valenced information that is involved in rumination. This idea is supported in a neuroimaging study that showed the amygdala of depressed patients displayed hyperactivity as compared to healthy controls in the same region (Chepenik at al., 2007). This indicates that the amygdala has a role in the over-processing and encoding of emotionally valenced material into memory that contributes to rumination and the continuous allocation of attention towards that information. The same study showed that participants displaying normal sad mood had demonstrated similar hyperactivity in the amygdala. This suggests that continuous occurrences of negative moods could strengthen the neural circuits that signal hyperactivity in the amygdala which further contributes to the risk of cognitive vulnerabilities.

In García-Blanco, Perea, and Livianos (2013), mood was indicated to have a filtering effect on attention, or a mood-congruent bias. When both positive and negatively valenced words were presented to bipolar disorder patients presenting with either a manic or depressive episode, the patients processed words that were consistent with their mood much faster than words that did not. The presence of a mood-congruent bias emphasizes the impact that mood has on the attentional aspects of cognition. Mood thus has the potential to exert a cognitive impairment by selectively taking in more negatively valenced information from the environment and further affects how this information is then interpreted (Brinker, Campisi, Gibbs, and Izzard, 2013). Koster et al., (2005) found that negative mood-congruent biases also made it more difficult for participants to disengage from negative cues the longer they sustained their attention onto the cue. This may explain the difficulty people with depression have in recognizing and shifting their attention away from ruminative thoughts. Perhaps this deficit would also be reflected to a certain degree in instances of negative mood that could have a larger impact upon repeated exposure.

Becker and Leinenger (2011) used an inattentional blindness task to demonstrate the limits of attention in mood-congruent biases. They showed that temporary negative mood shifts had an impact on the attentional filter. When the consumption of attentional capacity was high during focused activity on a cognitively demanding task, an unexpected frowning faced object was noticed by those in the sad mood group but went almost unnoticed by participants in both the happy and neutral mood groups. Thus, a negatively valenced stimulus passed through the attentional filter of participants experiencing negative mood. This suggests that mood influenced the attentional filter that subsequently selectively attended to information congruent to that mood which was also a finding supported by Bredemeier, Hur, Berenbaum, Heller, & Simons (2014). The use of the inattentional blindness task was essential because it required participants to maintain attention on prespecified objects, yet the unexpected mood-congruent stimulus still passed the attentional filter. Passing of the attentional filter represented an interruption to attention processes and showed to divert attentional resources away that were required for the task at hand, thus resulting in more errors after the onset of the unexpected mood-congruent stimulus.

Mind Wandering

Increased errors due to lapses in attention, as demonstrated in the aforementioned experiments, has also been associated to an experience known as mind wandering (Danckert & Merrifield, 2018; Eastwood, Frischen, Fenske, & Smilek, 2012). Mind wandering is a spontaneous event that can be characterized as the subconscious drift of attention from the task at hand toward thoughts of unrelated concerns (Marchetti, Koster, Klinger, & Alloy, 2016; Mooneyham, & Schooler, 2013). This phenomenon has also been linked to slower and more varied response times in addition to increased errors compared to when the mind is engaged in task (Rosenberg, Noonan, DeGutis, & Esterman, 2013; Smallwood, Fitzgerald, Miles, & Phillips, 2009; Smallwood, & O'Connor, 2011). Monotonous vigilance tasks, which are attentionally draining yet simple to perform, have been used in multiple studies on mind wandering to increase the likelihood of mind wandering episodes. While some studies like Qin, Perdoni, and He (2011) have incorporated tasks with low target frequency and others used tasks involving low distractor frequency, Barron, Riby, Greer, and Smallwood (2011) found that regardless of the stimulus frequency, mind wandering still suppressed the brain’s response to rare stimuli.

Rosenberg, et al. (2013) supported this finding in a continuous performance task in which participants provided responses to the majority of stimuli and withheld responses at the presentation of rare target trials. Failures to inhibit responses to the rare target trials are called errors of commission. The repetitive task of continuous responses revealed to eventually exhaust sustained attention in that increased errors of commission were observed as the task progressed over time. Sustained attention to response tasks (SART) as such are associated with exploring mind wandering because they demonstrate key indicators of mind wandering such as variances in response latency and response time. Faster and more erratic responses have been shown to predict errors as it is often associated with failures to inhibit responses to rare stimuli which reflect reduced attention to the task at hand. Fast response times also indicate predicted and routinized responding rather than intentional responding which also expresses indications of failures of attentional control, or rather, instances of mind wandering.

Mind Wandering and Mood

Killingsworth (2013) found that people reported to be mind wandering nearly half the time of their waking day (translating to half of waking life!) and found to be negatively affected when doing so. When internal mentations are congruent with mood, it is possible that people are more inclined to follow those thoughts through rather than continue to spend excess attention on otherwise attentionally undemanding tasks (Smallwood, Nind, & O'Connor, 2009). In Smallwood and O'Connor (2011), unhappy mood not only increased the likelihood of mind wandering events but promoted a greater tendency for participants to draw from past-related thoughts when mind wandering. The indication that unhappy moods would be associated with retrospective and autobiographical mind wandering serves as another possible connection to ruminative thinking, and thus, a vulnerability to depression upon repeated exposure (Ji, Holmes, MacLeod, and Murphy, 2018; Nolen-Hoeksema, 1991). Participants who reported a high degree of negative mood and were previously exposed to high-stress conditions demonstrated to be more likely to express variable response times in the SART, make more errors, and were more likely to report thinking about their stressor than participants in a lower degree of negative mood (Vinski & Watter, 2013). This study showed that acute stress induced a temporary mind wandering state in participants with negative mood. Specifically, this implied that acute stress cognitively overloaded or exhausted cognitive resources, further suggesting that the experience of stressors or negative mood that influence mind wandering can be capable of amplifying cognitive risks (Marchetti et al., 2016).

Nonetheless, negative moods have been shown to not only exacerbate mind wandering, but also increase the likelihood of mind wandering with negative content. Smallwood and O'Connor (2011) studied this relationship by having their subjects watch video clips that were expected to induce moods categorized as positive, negative, or neutral prior to performing a task that demanded sustained attention. They found that the likelihood of mind wandering, characterized by increased errors and slowed response rates, can be increased after inducing negative moods. Smallwood et al. (2009) showed that subjects who were both affected by the induced negative mood and indicated signs of mind wandering would also demonstrate poorer ability to readjust their performance after a mind wandering episode.

Regardless if mind wandering is a cause or consequence of negative mood, it is possible that this form of out-of-the-moment thought processes and inability to readjust performance can be further connected to states of negative rumination (Smallwood, & O'Connor, 2011). Because mind wandering takes people out of their present moment, it is likely that an inability to both pay attention and remain in the present may lead to a greater dissatisfaction in life and continue to perpetuate the cycle of depression.

Reach Tracking

Using reach tracking techniques, inferences about cognitive processes can be made from arm movements by assessing movement timing and movement paths in response to a simple target. (Song & Nakayama, 2008; Song & Nakayama, 2009). Reaching movements require the physical extension of the arm to point at targets rather than discrete responses, such as manual button pushing, as are incorporated in many SARTs (Rosenberg et al., 2013; Smallwood et al., 2009, Smallwood & O'Connor, 2011; Song & Nakayama, 2009). Reaching movements have the advantage in behavioral assessments of SART because they allow for inferences to be made of the full reach trajectory in regard to initiation latency, movement duration, and arm curvature. Reach tracking also allows inferences to be made about brain mechanisms behind target selection. Incorporating neuroimaging into reach tracking studies has shown the dorsal premotor area to be involved in the planning and execution of arm movements (Song & Nakayama, 2009) in addition to subcortical systems like the superior colliculus show to participate when reaching toward objects (Song, Rafal, & McPeek, 2011; Tipper & Baylis, 1992).

Reaching tracking is often employed with a task that requires physical reach movements in response to stimuli or targets and thus, records three key measures of movement (Song & Nakayama, 2007; Song & Nakayama 2008). The first is initiation latency which is defined as the interval of time between when a stimulus is detected to the time it takes to initiate a movement in response to perceiving the stimulus. Mind wandering is associated with inconsistent initiation latencies in key press tasks, therefore reach tracking would potentially be a novel method of measuring mind wandering. The second measure is movement time in which the full duration of the movement is measured starting from the point of initiation of movement to the completion of the full reach. Tradeoffs in initiation latency and movement duration potentially indicates levels of impulsivity because rapid and carelessly initiated movements often results in misdirected target reaches. Misdirected reaches can be associated with longer movement durations due to compensating for the mid-flight corrections. Furthermore, Smallwood et al. (2009) found that recognition of impulsive mistakes are often met with post-error slowing which briefly alerts participants from their inattentive state. This is also referred to as the “Oops Phenomenon” which represents re-engagement to tasks. Lastly, the third measure records reach curvature which tracks the full three-dimensional reach movement from onset to target selection. Variance in the curvature of reach trajectory effectively reveals misdirected target selection (potentially as a result of either impulsivity or mind wandering) and mid-flight redirection. Reaching trajectories showed to be highly curved when hands moved toward distractors instead of the correct target (Song, 2006; Song & Nakayama, 2007; Song & Nakayama, 2009; Tipper & Baylis, 1992; Venkataramani, Gopal, & Murthy, 2018). Curves were more pronounced when distractors changed color and/or location which required active inhibition and revealed the competing movements toward goals.

Consistency in the aforementioned measures should indicate levels of engagement to a certain degree. In contrast, mind wandering is an interruption of attention, thus higher variances of movement should be seen during episodes of mind wandering. As such, the capability to accurately translate selective attention to selective reaching is an important cognitive ability as it incorporates perceptual-motor interactions (Gallivan & Culham, 2015). From what is known about how negative mood burdens cognitive processes, employing a reach tracking technique may elucidate the influence of negative mood on mind wandering by evaluating the capacity to physically respond to one's environment. The present study aims to investigate whether exposure to negative mood can be a determinant of less precise and more varied actions that indicate episodes of mind wandering.

Research in the relationship between emotion and cognitive performance tends to focus on mood disorders like depression and anxiety or mood traits such as dysphoria. This study looks deeper into the negative mood states that are associated with depression and examines how a temporary sudden change towards negative mood may have an effect on cognitions such as attention and decision making. In any given day, there are many instances in which mood can be negatively influenced by either internal or external factors. Therefore, there lies the likelihood that attention and decision making can subsequently be influenced by these negative moods. Thus, if negative mood is shown to have an impact on cognitive performance, it is possible that persistent experiences of negative mood are a precursor to cognitive vulnerabilities.

Because mind wandering is a subjective experience, reach tracking can allow much to be inferred about arm movement to quantifiably indicate instances of mind wandering. Thus, reach tracking has a potential advantage over relying only on self-reported assessments of mind wandering. Although a necessary component of research in mind wandering, subjective measures can be flawed due to dependency on the honesty of participants' responses as well as expecting participants to be internally aware. Therefore, the incorporation of objective measures are also a necessity in mind wandering research. Additionally, understanding how physical responses can be influenced during instances of mind wandering and negative mood could elucidate real-world interactions between individuals and their environments (ie. driving). This study assesses cognitive performance through two computerized tasks that were expected to increase the likelihood of mind wandering after experimentally inducing mood.

The proposed study aims to determine whether negative mood influences mind wandering. In a two part experiment, participants performed two different tasks that were expected to evoke occurrences of mind wandering after they were influenced by either negative or neutral moods. It was hypothesized that those exposed to negative mood would show higher self-reported mind wandering rates as compared to neutral mood. Through objectively measuring mind wandering using reach tracking techniques, it was hypothesized that negative mood would produce more varied output in movement, which would indicate moments of mind wandering. Accordingly, it was also hypothesized that negative mood would produce more task errors as compared to neutral mood counterparts.

Methods

Experiment 1

Research Design

The first experiment examined one independent variable, of which was the mood inducement, involving two conditions: negative and neutral. Mood was induced via the display of a series of photos depicting either of the mood conditions and half of the participants were randomly assigned to each condition.

The dependent variable measured the participants' performance on a simple reach movement task (see Stimuli) and data was recorded using a reach tracking device (see Materials). Three measures of arm movement were recorded by the reach tracker for analysis.

Tracking the variability in initiation latency, movement time, and curvature of arm movements served as the objectifiable indicators of mind wandering in this experiment (see Data Analysis). Consistency in initiation and movement would represent engagement in the task, therefore, higher variances in the measures mentioned would indicate instances of mind wandering. False alarm rates were also considered. Increased errors and variability in movement has been indicative of mind wandering according to previous research (Rosenberg et al., 2013).

Mood manipulation was checked by comparing self-reported mood scores to the corresponding mood condition. Self-reported mind wandering scores were also assessed to compare against variances in movement (see Data Analysis).

Participants

Twenty-nine Connecticut College students volunteered to participate in this experiment and were randomly assigned into either one of two groups: neutral mood (n = 14) and negative mood (n = 15). The average age of participants was 19 years old. Twenty-five of the participants self-identified as female and four identified as male. The majority of the participants self-identified as White (n = 26), with two participants identifying as Black or African American and one participant identified as Asian. For handedness, the majority of participants reported being right-handed (n = 26) and three participants were left-handed. Participants reported their vision as either "normal" (n = 17) or "corrected-to-normal" (n = 12). None of the participants reported any neurological deficits nor color-blindness. There were no exclusionary requirements for participants to take part in this experiment.

Materials

Participants signed their consent form and provided demographic information electronically on a computer that were collected and identified with only a participant number (see Appendix A). At the completion of the study, all participants received either a paper or electronic copy of the debriefing form (see Appendix B). It must be noted that the debriefing form was written before the direction of the present study was changed in Experiment 2. Initially, a mindfulness component was intended to be incorporated into the second experiment of this study as an intervention to offset mind wandering (see Appendix B). However, the results of this study did not justify the need for an intervention (see Results).

A series of twelve photos were collected from the Open Affective Standardized Image Set (OASIS) (Kurdi, 2017, see Appendix C, D) that were used to induce either a neutral or negative mood. Although these photos were used for the purpose of testing implicit association, each photo in this image database was established for its valence and arousal ratings which was beneficial for the target of this experiment. The twelve photos selected from OASIS were separated into two groupings for either the negative or neutral condition, with six photos in each condition. Each of the six photos selected for each condition were able to be matched for arousal and valence ratings according to the OASIS database. All photos were chosen specifically for their low arousal rating. The photos in the negative condition were chosen for having negatively valenced ratings while maintaining low arousal effects. Photos for the neutral condition were chosen for having in-between positive and negative valences while still maintaining low arousal rates as well. All six photos for each condition were shown in random order and were presented automatically.

All participants completed the Current Mood Assessment (CMA) (Sechrist, Gretchen, Swim, & Mark, 2003) which evaluated the efficacy of the mood inducement of each condition (see Appendix E). The CMA listed nine pairs of opposing mood words in which participants were to rate on a scale of one (ie. relaxed) to nine (ie. nervous) how they were feeling at the moment. Three pairings of mood words on the assessment were in reversed order.

All participants completed a simple reach movement task on a digital display with a reach tracking device strapped to the index finger of their right hand via velcro. The reach tracker is a non-invasive electromagnetic sensor that recorded three-dimensional arm movements and positions at a rate of approximately 160 Hz (Moher & Song, 2013). It also recorded the three measures examined in this study: initiation latency, movement time, and curvature.

In the reach task, participants responded to cues using hand and arm reach movements to tap the screen in front of them. The tracker measured multiple metrics of arm movement to predict errors and possibly reflect indicators of mind wandering episodes. Variability in the time required to initiate a movement and the time required to complete the movement was used to predict when participants were more likely to commit an error, and thus, more likely to be mind wandering. This method is an advantageous way to measure mind wandering as it is a more quantifiable method of collecting mind wandering data than self-reported assessments.

The task used in this experiment was a type of a Go/No-go task (see Stimuli). The task in its entirety consisted of two blocks of trials with 220 trials in each block. No-go trials were presented rarely whereas Go trials were frequent. Due to the length of the blocks and frequency of the Go trials, participants repeatedly responded to the task by reaching toward the display. Therefore, the task was relatively easy, monotonous, and highly repetitive. As such, this task was designed to be boring and easy in order to encourage mind wandering while still demanding enough attention that required repeated responses.

Data collected from the reach tracker was compared against participants' self-reported rating of mind wandering occurrences from the Cognitive Interference Questionnaire (CIQ) (Bank et al., 2018; see Appendix F). The CIQ consisted of 22 questions which asked participants to rate on a scale of one (never) to five (very often) how often they thought about other things besides the task.

Stimuli

The task used in this experiment is referred to as a Go/No-go task. The task fundamentally had two types of trials, "Go" and "No-go." In this task, participants sat perpendicularly in front of a touchscreen digital display with a reach tracking device calibrated to their right index finger. This display featured the white outline of a box in the center of a black screen and a white ball that moved around the box. A Go trial consisted of the ball moving at a trajectory in which hits the box. In a Go trial, participants were told to respond by tapping the box on the screen with their right index finger. They must have tapped the box before the ball hit the box in order for the response to be counted as correct. A No-go trial was when the movement of the ball was at a trajectory in which did not hit the box. In a No-go trial, participants were to not tap the box, thus inhibiting their response. Tapping the box during a No-go trial was considered an error of commission, or a false-alarm, which was a rate measured in this study (Figure 1). The ball moved consistently so the trials appeared rapidly one after another, thus making the task relatively difficult.

Procedures

After signing the consent form (see Appendix A), participants viewed a series of six photos (see Appendix C and D) for mood induction. Each of the photos were presented individually on the display and stayed for six seconds before automatically showing the next. Self-reported mood data was then collected from participants' responses on the CMA which rated the mood they were currently feeling after the mood inducement (see Appendix E).

Following the mood induction, the reach tracker was attached to the right index finger of the participant and the finger was calibrated to the digital display. Participants then completed a short practice session of the real task in order to familiarize themselves with the rules of the task The experimenter provided feedback on their performance during the practice session. The practice round also gave auditory feedback to the participant in regard to their performance for each trial. A correct response returned a high-pitched beep and an incorrect response returned a low-pitched beep.

The vigilance task involved Go/No-go trials in which participants tapped the monitor in front of them which displayed a box and a moving ball. The participants' objective was to tap the box if the ball's trajectory looked like it would touch the box (Go). The participants were asked to refrain from tapping the box if the ball was not on a path to touch the box (No-go). Participants were also instructed to respond to Go trials before the ball had touched the box. Multiple metrics of the reaching responses were recorded via the reach tracking device.

The practice session was followed by the actual task which consisted of two blocks of trials with 220 trials in each block. The actual task had the same rules and instructions, though neither the experimenter nor the program offered feedback to the participants' performance this time. At the end of the first block, participants were allowed a break and encouraged to rest their arm before preparing for the final block. At the completion of both blocks, participants answered the CIQ self-report of mind wandering thoughts (see Appendix F). The total experiment lasted approximately 30 minutes. At the completion of the study, all participants received a debriefing form (see Appendix B).

Data Analysis

Data collected from the reach tracker was analyzed based off of methods used in Moher and Song (2013). A response was counted as correct when the participant's finger came within approximately 0.5 cm of the screen. The trial was counted as incorrect if the participant did not reach the screen within the time limit at the threshold required. Reach tracking data was analyzed using MATLAB software.

Initiation latency was defined as the interval of time between the presence of the stimulus and the initial movement of the hand. It was calculated as the onset of movement in which hand movement speed surpassed 10 cm/s. Movement time was defined as the duration between the first initial movement and the completion of the full reach movement. It was calculated at the offset of movement in which hand movement speed decreased to 10 cm/s. Curvature was recorded as the three-dimensional trajectory of the full arm reach from initiation to completion. It was calculated as as the maximum point of deviation divided by the length of the start and end points of movement.

The scores rated in the CMA were averaged for each participant with higher scores representing higher indication of negative mood. The scale was reversed ordered for the three word pairings that were flipped. The scores rated in the CIQ were also averaged for each participant.

Ethical Issues

Consent was obtained from all participants prior to taking part in the experiment. There were no known risks associated with this study. The photos chosen from OASIS and used for mood inducement purposes were chosen for exerting negative valence and low arousal. Mood inducement has a short lifespan and any negative affect felt was only temporary. Participants' hands may have felt fatigue from repeated movements and tapping during the tasks. Participants were encouraged to use the breaks in between each block of trials to rest. Participants had the option to terminate the experiment at any point if they felt uncomfortable. Participant data was stored electronically without any identifying information.

Results

An independent samples t-test revealed a significant difference in self-reported mood scores between negative ($M = 4.87$, $SD = .891$) and neutral ($M = 3.94$, 1.08) mood conditions ($t[27] = 2.535$, $p = .018$) (Figure 2). These results suggested that the mood induction was successful. Specifically, our results indicated that participants in the negative mood group reported higher rates of negative mood than did participants in the the neutral mood group.

Results of independent samples t-tests for self-reported mind wandering scores between negative and neutral mood conditions were not statistically significant ($t[27] = .343$, $p = .734$) (Figure 3). This suggested that the mood induction did not have an effect on self-reported scores of mind wandering. Thus, the main hypothesis that negative mood would increase the likelihood of mind wandering failed to be supported.

Additional independent samples t-tests were also conducted on mood conditions between the indicators of mind wandering: the false alarm rate, initiation latency variance, movement time variance, and curvature variance. The tests did not reveal any significant differences in the indicators of mind wandering between the negative group and the neutral group ($ps > .05$). These results suggested that the negative mood induction did not have a significant differences on any of the indicators of mind wandering as compared to the neutral mood induction (Figure 4). Thus, the main hypothesis that participants in the negative mood induction group would present with more variable output was not supported by these results.

Pearson's correlation was also conducted to assess the relationship between self-reported mood scores and self-reported mind wandering scores and there revealed to be no significant correlation ($r = .083$, $p = .669$). This indicated that mood condition did not have a relationship to mind wandering scores. Because negative mood was the focus of this study, self-reported mind wandering scores were compared to only the self-reported scores of participants in the negative mood condition. Although there was not a significant relationship ($r = .173$, $p = .537$), it is possible that there may be a weak trend for correlation between self-reported mind wandering scores and self-reported mood scores of participants in the negative condition (Figure 5). This suggested that for people exposed to negative mood, feeling higher rates of negative mood could be associated with higher rates of mind wandering. In addition, mood scores did not have a significant correlation to any of the indicators of mind wandering ($ps > .05$). This suggested that self-reported mood did not have a relationship to false alarm rates, initiation latency variance, movement time variance, or curvature variance. These results suggested that although the mood induction was successful for the different mood conditions, the mood conditions themselves did not have any relationship to self-reported mind wandering scores nor variables of performance recorded via the reach tracker. These results did not support the hypothesis that participants exposed to negative mood would present with more variable movements than those in the neutral group.

Additional pearson's correlation was conducted to find if there were any correlations of mind wandering scores to false alarm rates, initiation latency variance, movement time variance, and curvature variance. There were not any significant correlations between mind wandering and false alarm rates, movement time variance, and curvature variance (*ps* > .05) but there was a positive relationship to initiation latency variance ($r = .422$, $p = .023$). A scatter plot summarizes this result (Figure 6). This suggested that the higher mind wandering was reported to occur, the the more variance in initiation latency was seen. These results showed that initiation latency was the only valid indicator of mind wandering that had a statistically significant relationship to the mind wandering scores reported by participants in this study. Thus, the objective measurement of initiation latency of arm movements showed to have a relationship to participants' subjective experiences of mind wandering.

There was, however, a very strong, positive relationship between movement time variance and initiation latency ($r = .719$, $p < .001$). A scatter plot summarizes the results (Figure 7). This data suggested that the more that variance in initiation latency was seen, the more variance in the time it would take to complete a full movement. This relationship was explored further in Experiment 2.

Due to lack of support in the results for the main hypotheses, the task was changed in Experiment 2 to account for the potential difficulty of the first task. This Go/No-go task may have been too attentionally demanding for a relationship between mind wandering and mood to be observed. The task employed in experiment 2 was a visual-search target-selection task in which emphasized more curvature in arm movement. This task was expected to allow more utilization of variance in arm curvature as a measure of mind wandering influenced by negative mood.

Methods

Experiment 2

Research Design

The second experiment involved the same mood inducement as an independent variable and consisted of the same two conditions: negative and neutral. Mood was induced by presenting participants with the same six images from the OASIS set that corresponded to their mood condition group (see Appendix C and D) using the same procedures from Experiment 1.

The dependent variables consisted of the same three measures of arm movement recorded by the reach tracker as previously done in Experiment 1: initiation latency, movement time, and arm curvature. The measures will record participants' performance on the visual search target-selection task (see Stimuli). This design was adopted from Song and Nakayama (2008). The change in task for Experiment 2 allowed for emphasis on evaluation of arm curvature that was not apparent in the Go/No-go task from Experiment 1. Errors were expected to be low in this task, in comparison to the Go/No-go task, thus error rates were not considered as a measure in this experiment.

Participants

Twenty-three Connecticut College students volunteered to participate in this experiment and were randomly assigned into either one of two groups: neutral mood (n = 11) and negative mood (n = 12). The average age of participants was 20 years old. Fifteen of the participants self-identified as female and eight identified as male. The majority of the participants self-identified as White (n = 10), with three participants identifying as Black or African American, three participants as Hispanic or Latino, three participants as Asian, one as American Indian or Alaska Native, one as Native Hawaiian or other Pacific Islander, and two participants identified as being multiracial. For handedness, the majority of participants reported being right-handed (n = 22) and only one participant was left-handed. Participants reported their vision as either "normal" (n = 10) or "corrected-to-normal" (n = 13). None of the participants reported any neurological deficits. Participants could not be red/green colorblind to take part in this experiment due to the target colors in the target-selection task (see Materials).

Materials

Participants signed their consent form and provided demographic information electronically on a computer that were collected and identified with only a participant number (see Appendix G). At the completion of the experiment, all participants received a paper and electronic copy of the debriefing form (see Appendix H).

The same set of six photos collected from OASIS (see Appendix C and D) used in Experiment 1 were reused in this experiment to induce either the neutral or negative mood. All participants completed the same Current Mood Assessment (CMA) (Sechrist, Gretchen, Swim, & Mark, 2003) which evaluated the efficacy of the mood inducement of each condition (see Appendix E). The same CIQ from Experiment 1 was used to assess self-reported rates of mind wandering (Bank et al., 2018).

All participants completed a simple visual-search target-selection task on the same digital display with the reach tracking device strapped to the index finger of their right hand via velcro as was done in Experiment 1. The reach tracker recorded hand movements and position of participants' fingers as they reached toward objects on the display screen. In the target-selection task, participants responded to cues using hand and arm reach movements to tap their selected target object on the display screen. Unless otherwise noted, materials were identical to Experiment 1.

The task consisted of three blocks of trials with 100 trials in each block. This task was also monotonous, highly repetitive, and relatively easy similar to the Go/No-go task in Experiment 1. Therefore this task was designed to be boring enough to encourage mind wandering while still requiring enough attention from the participants to provide continuous and repeated responses.

Stimuli

The task used in this experiment was a variation of a visual-search target selection task. Using the same set up as Experiment 1, participants will perform the task via a touch screen digital display with the reach tracker recording their responses. Participants were instructed to search and respond to the uniquely colored target. Every trial consisted of one target among two distractors.

The display featured a black background with three colored circles positioned at about 10, 12, and 2 o'clock around an imaginary clock. The three colored circles would consist of one target - the uniquely colored circle - amongst two distractors - both in the other color. The target and distractors would either be one green and two red circles or one red with two green circles (Figure 8). The color of the target would be randomly selected for each trial. In addition to changing the color of the target, the location of the target would randomly change as well. The distractors were set in the location and color that the target was not in. This was done so that participants could not predict the color or location of the target's next appearance, thus having to visually search for the target in every trial.

Errors were expected to be low in this task, thus error rate was not measured. However, arm curvature was expected to be more pronounced due to searching for the target amongst distractors. Misdirected and corrected movements were assumed to cause the variances in curvature in this task.

Procedures

After signing the consent form (see Appendix G) and completing the demographic questionnaire, participants prepared to play the target selection task by strapping the reach tracker onto the index finger of their right hand and calibrated their position to the display. In the visual-search target-selection task, the participants' were presented with three colored objects simultaneously. The participants' objective was to quickly select the uniquely colored target. On each trial, participants were randomly presented with either two red circles and one green circle as the uniquely colored target or they were shown two green circles and one red circle with the red circle being the target in this scenario. Participants completed a short training session to familiarize themselves with the task.

Participants had two practice rounds of the task with the first round starting slow and the second task displaying the stimuli closer to the speed of the actual task. Participants received feedback on their performance from both the experimenter and the program. The task produced a high beep when the participant responded correctly and produced a low beep when the response was incorrect.

After the practice session, participants viewed a series of six photos (see Appendix C and D) for a duration of six seconds allocated to each photo to induce the mood of their randomly assigned condition. Participants then answered the CMA (see Appendix E) to self-report their mood in that moment. This was the same assessment for mood used in Experiment 1.

At the completion of the CMA, participants returned to performing the target-selection task. In the actual task, the experimenter no longer provided participants with feedback. The task also stopped providing feedback for correctness, but would produce the same low beep sound when the participant responded incorrectly. Participants completed three blocks of trials with a break in between each block. There were 100 trials in each block. At the completion of the third block, participants answered the CIQ self-report of mind wandering thoughts (see Appendix F). This was the same CIQ used in Experiment 1. The total experiment lasted approximately 30 minutes. At the completion of the study, all participants received an electronic copy of the debriefing form (see Appendix H).

Data Analysis

Methods of data analysis from Experiment 1 was repeated for Experiment 2 to analyze the reaching movements in the visual-search target-selection task.

Ethical Issues

Any ethical issues were identical Experiment 1.

Results

An independent samples t-test once again revealed a significant difference in self-reported mood scores between negative (M = 5.21, SD = 1.66) and neutral (M = 3.29, SD = 1.08) mood conditions [t(21) = 3.248, p = .004)] (Figure 9). These results suggested once more that the mood induction was successful. Specifically, our results indicated that participants in the negative mood group reported higher self-reported rates of negative mood than participants in the the neutral mood group. Results of independent samples t-tests for self-reported mind wandering scores between negative and neutral mood conditions were not statistically significant (t[21] = .580, p = .568) (Figure 10). This again showed that the mood induction did not have an effect on self-reported scores of mind wandering. Therefore, the hypothesis that negative mood would increase the likelihood of mind wandering was still not supported through using the visual-search target-selection task.

Additional independent samples t-tests were also conducted on mood conditions between the indicators of mind wandering, such as the initiation latency variance, movement time variance, and arm curvature variance. The tests did not reveal any significant differences in any of the indicators of mind wandering between the negative mood group and the neutral mood group conditions (*ps* > .05) (Figure 11). These results suggested that the mood inductions did not have a significant effect on any of the indicators of mind wandering measured. The hypothesis that negative moods would produce more variable output failed to be supported again.

Pearson's correlation was also conducted to assess the relationship between self-reported mood scores and self-reported mind wandering scores and there revealed to be no significant correlation ($r = .214$, $p = .327$). This indicated that the mood induction did not have a relationship to self-reported levels of mind wandering. However, when looking at the relationship between self-reported scores of mind wandering to just the self-reported mood scores in the negative mood condition, there seems to be a positive trend ($r = .357$, $p = .254$) (Figure 12). Though, it must be noted that this is still not a significant finding.

In addition, mood scores did not show to have a significant correlation to any of the indicators of mind wandering (*ps* > .05). This suggested that the mood condition did not have a relationship to initiation latency variance, movement time variance, nor curvature variance. These results suggested that although the mood induction was successful for both mood conditions, the mood conditions itself did not have any relationship to self-reported mind wandering scores nor scores recorded via the reach tracker.

A Pearson's correlation test between the indicators of mind wandering, specifically that of initiation latency and movement time variance, showed to have a strong, positive correlation (r = .555, p = .006). A scatter plot summarizes the results (Figure 13). This data suggested that the more that variance in initiation latency was seen, the more variance was seen in the time it took to complete a full movement. This relationship was also seen in the Go/No-go task of the first experiment, suggesting that the inconsistency in one form of movement would also be reflected in another.

General Discussion

Discussion

The overall aim of this study was to examine the influence of induced negative mood on mind wandering. This study had three main hypotheses based on the interaction between mood and cognitive abilities. It was hypothesized that participants in the negative mood inducement group would report higher rates of self-reported mind wandering. It was hypothesized that participants in the negative mood inducement group would also present with more varied output across all measures recorded by the reach tracker, such as initiation latency, movement time, and curvature. Lastly, it was hypothesized that the negative mood inducement group would show to have increased errors in comparison to the neutral mood group.

None of the main hypotheses were supported in this study. However, both the first and second experiments showed that the mood induction was successful. Participants in the negative mood group reported higher rates of self-reported negative mood after viewing the six negatively targeted photos than did those in the neutral mood. Though the mood induction was successful, neither mood condition had an effect on self-reported mind wandering rates and variances in movement. These results were not reflective of the literature. However, when scores from the neutral mood condition were omitted, there was a trend suggesting that negative mood could have had an effect on self-reported mind wandering. This suggested that those who were exposed to negative mood stimuli and had the strongest reaction to the negative images also reported the most mind wandering instances to occur. Although this interpretation still was not statistically significant. Thus, negative mood did not influence participants to mind wander any more than participants in the neutral mood who had naturally mind wandered.

This result could have occurred for three reasons. The first is that the photos selected from OASIS to use for the negative mood inducement were chosen specifically because they were negatively valenced and had low arousal ratings. Although the photos had a temporary effect on inducing negative mood, the induced negative mood could have had a short lifespan due to low arousal and therefore not enough of an influence for the mood to endure throughout the task in order to affect mind wandering.

The second reason considers that the arousal rates of the photos were sufficient but that the lifespan of the induced moods were too fleeting to be maintained over long tasks. Participants only viewed the photos once before performing the tasks and were not reminded of them again throughout the rest of the task. If a second mood assessment had been done, it could have revealed that those in the negative mood group might have leveled out their mood by the end of the task and their mood rates would have looked similar to those in the neutral mood group. Thus, this could indicate why the comparison of mood condition to self-reported mind wandering rates and variances in movement revealed that those in the negative group mind wandered about just as much as those in the neutral group. They were all naturally mind wandering, regardless of the mood they felt when they began the task.

It was suspected at the end of the first experiment that the mood inducement would quickly expire, thus a change was made in the procedures of the second experiment to have the mood induction closer to performing the actual task. But because a relationship between mood condition and measures of mind wandering still did not show to be significant after the change in procedures, it could only be assumed that the strength of the mood induction was either a failure of emotional arousal or a failure of maintaining the mood.

The third reason could simply be due to the possibility that the tasks were not well-suited to help answer the questions of this study. It may have been that the tasks were too easy, thus allowing the capacity for mind wandering to occur while still being able to perform well. Yet, the tasks could have also been too difficult, thus requiring too much attentional capacity for mind wandering to occur regardless of mood influences.

Although mood condition did not have an effect on self-reported mind wandering nor variances in movement, self-reported mind wandering did have a positive relationship to variances in initiation latency. This meant that the higher a participant rated their occurrences of mind wandering, the more inconsistency was seen in their initiated movements. At higher rates of mind wandering, resources dedicated to focusing attention on the main task is weakened. It is possible that in episodes of mind wandering, participants would disregard the information necessary to respond to the task but instead chose to respond hastily without thinking about what they were responding to. It could be that participants had primed themselves to be ready to respond without regard to the stimulus. Again, this relationship was not mediated by negative mood. Despite so, variances in initiation latency showed to be a valid indicator of mind wandering and could be replicated as a measure in a future study. Although this was not one of the main hypotheses of this study, it still draws a direct connection between self-reported mind wandering and variability of goal-directed responses.

The last significant finding showed a positive relationship between variances in initiation latency and movement time in both tasks used in this study. This meant that the more participants were inconsistent in initiating movements, the more they varied in the time it took to complete the movement. Again, this showed an inconsistency in response rates that could demonstrate the lack of attention devoted to performing tasks with precision. However, this relationship was also not a result of mood differences.

A change was also made from using the Go/No-go task to the visual-search target-selection task to try to accomodate for the possibility that the first task was not conducive to mind wandering. However, differences in mind wandering in both self-reported and objective measures were not observed even after the change in task. The fact that differences were still not seen over two different tasks could indicate that instances of low-arousing negative mood may be less harmful to cognitive abilities than previously expected. It could be interpreted that healthy individuals may have protective factors that allow them to process negative feelings differently than those who are vulnerable to or affected by depression in which makes those negative feelings more chronic.

Limitations

It is important to note the limitations of this study. First, the study was significantly underpowered in both experiments, with even less participants in the second experiment than the first. Although this study did not focus on gender or race differences, the population of both studies consisted of a young, white, and female majority. This is mostly due to collecting participants from a convenience sample of students at Connecticut College whom most participated in the study for credit in psychology courses. Thus, the population of participants were not a diverse mix for either experiment.

The results of this study did not support that of the literature in regard to negative mood exacerbating mind wandering to produce increased errors and varied response outputs. It is possible that the tasks used in these experiments could not replicate those findings or they were not attentionally draining enough to lead to a difference in scores.

As mentioned in the discussion, though the mood induction was successful, it might not have been arousing enough to be maintained throughout the duration of the task in which was designed to be attentionally draining. Furthermore, if it was assumed that the arousal of the photos were sufficiently pervasive, the photos were not reminded of again after the mood induction. It is possible that the lack of reminder allowed participants in the negative mood to let go of the negative feelings. Perhaps if the photos were shown at many points within the study, specifically during rest periods between each block of trials, rather than all at once, the negative mood inducement could have been maintained throughout the task and may have produced an effect on the various measures of mind wandering.

It may be just as possible that the lifespan of the mood inducement was too short, regardless of level of arousal or when the photos were seen. Mood states are fleeting in nature, thus making it much more difficult to study in conjunction with task performance. The length of the mood experience might not have been felt long enough to eventually affect action.

Individual differences were also not accounted for in this study. Individually, many participants in this study expressed different ways of coping with their boredom in order to help them pay attention or repress the urge to mind wander. Most of these coping mechanisms involved strategies in which occupied their attention such as singing, humming, or attempting to chat with the experimenter. Other strategies involved trying to make the task more entertaining as seen with some participants who tried to encourage themselves through positive affirmations.

Lastly, the testing location did not allow for a controlled environment. At different points in time, the temperature of the room was either uncomfortably hot or cold due to not being able to manually control the radiator in the room. Additionally, pipes in the room would clank inconsistently for long periods of time in which could have had an impact on the attention of some participants. Some participants heard the clanking pipes more than others while some were able to complete the task under total silence in the room. Thus, there were many distractors coming from the testing environment that could have influenced the results of this study.

Future Directions

Future studies might adjust and account for the limitations mentioned before. If using the same methods as this study, future work might use OASIS to re-select photos in the negative condition in favor of more emotionally arousing photos. Future studies may also present the photos intermittently throughout different points of the task in order to maintain the influence on mood.

Future studies may also consider assigning participants to groups based on the mood they are naturally experiencing as opposed to artificially inducing moods. Although it will most likely take form as a correlational study, the advantage this serves is that mood states do not last as long as mood traits. Additionally, mood traits are not as easily influenced as mood states, therefore it might be found that pre-existing moods may be better maintained throughout attentionally draining tasks. Another advantage in considering pre-existing moods is that it may allow more inferences to be made about individual differences in mind wandering and coping with certain moods.

It may also be useful to ask participants to self-report the emotional content of their mind wandering episodes rather than simply asking for the number of occurrences as was done in the present study. Knowing what participants were thinking about as opposed to knowing how often they thought about other things could allow inferences to be made of mood-congruent biases and how long these biases may present themselves.

Eye tracking techniques would be another interesting measure to consider that was not attempted in this study. Eye tracking could allow for the experimenter to track eye movements when searching for targets. It could allow more inferences to be made in terms of attention.

Lastly, if one is studying mind wandering, it could be equally important to research the role of mindfulness activity during attentionally draining tasks. This is due to the fact that mindfulness activation works in opposition to mind wandering within the same networks of the default mode network. Interventions and educations about strategies in mindfulness training could be utilized in future studies of mind wandering induced by negative moods.

Conclusion

None of our main hypotheses were successful in this experiment. Neither self-reported mind wandering nor variance in arm movements showed to be mediated by negative mood. Error rates were also not shown to be different in either mood condition. However, the mood induction was successful and variance in initiation latency showed to be a reliable indicator of mind wandering, thus validating our methods and can be replicated in future research. A strong relationship between initiation latency and movement time was also revealed which could suggest inconsistencies in performance. Although a relationship was indicated between initiation latency and self-reported mind wandering as well as between initiation latency and movement time, neither seemed to be mediated by induced negative moods.

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Figure 1. Reach responses in a Go and No-go trial

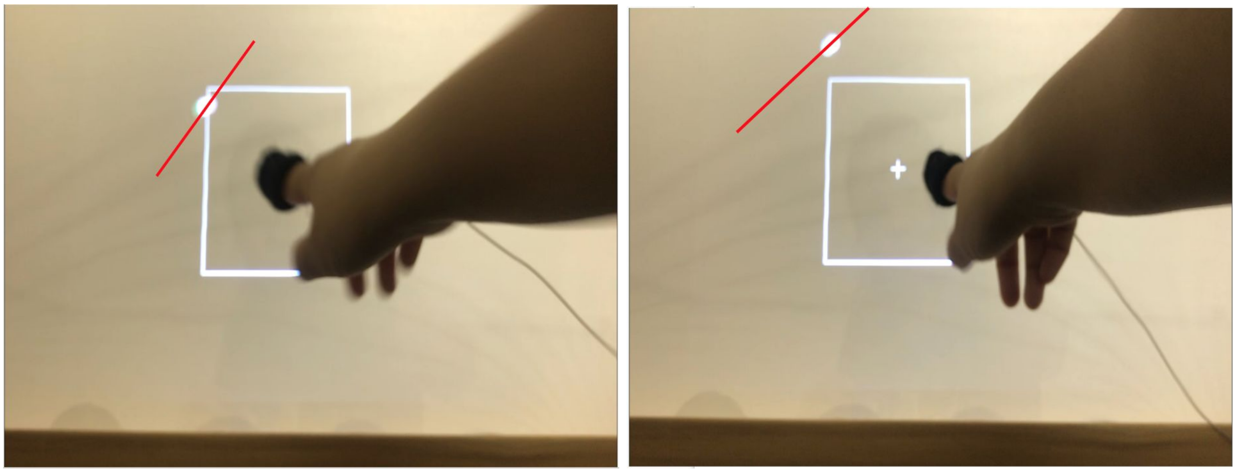

Figure 1. Examples of reach responses in a Go and No-go trial. The photo on the left depicts a correct response in a Go trial. As indicated by the red line, the ball was on a path to hit the box, prompting a reach movement. The photo on the right shows an error of commision, or false alarm. The participant responded with a reach movement for a No-go trial. The red line marks the path of the ball, showing it was not at a trajectory to hit the box.

Figure 2. Self-reported mood scores by mood condition in Experiment 1

Figure 2. Self-reported mood scores by mood inducement condition. Participants in negative mood condition had significantly higher self-reported ratings of negativity than did those in the neutral mood group ($t[27] = 2.535$, $p = .017$).

Figure 3. Self-reported mind wandering scores per mood condition in Experiment 1

Figure 3. Self-reported mind wandering scores by mood condition. There were no significant differences in self-reported rates of mind wandering as a consequence of mood condition group (t[27] = .343, p = .734). MW = mind wandering.

Figure 4. Average variances in movement and false alarm rates per mood condition in Experiment 1

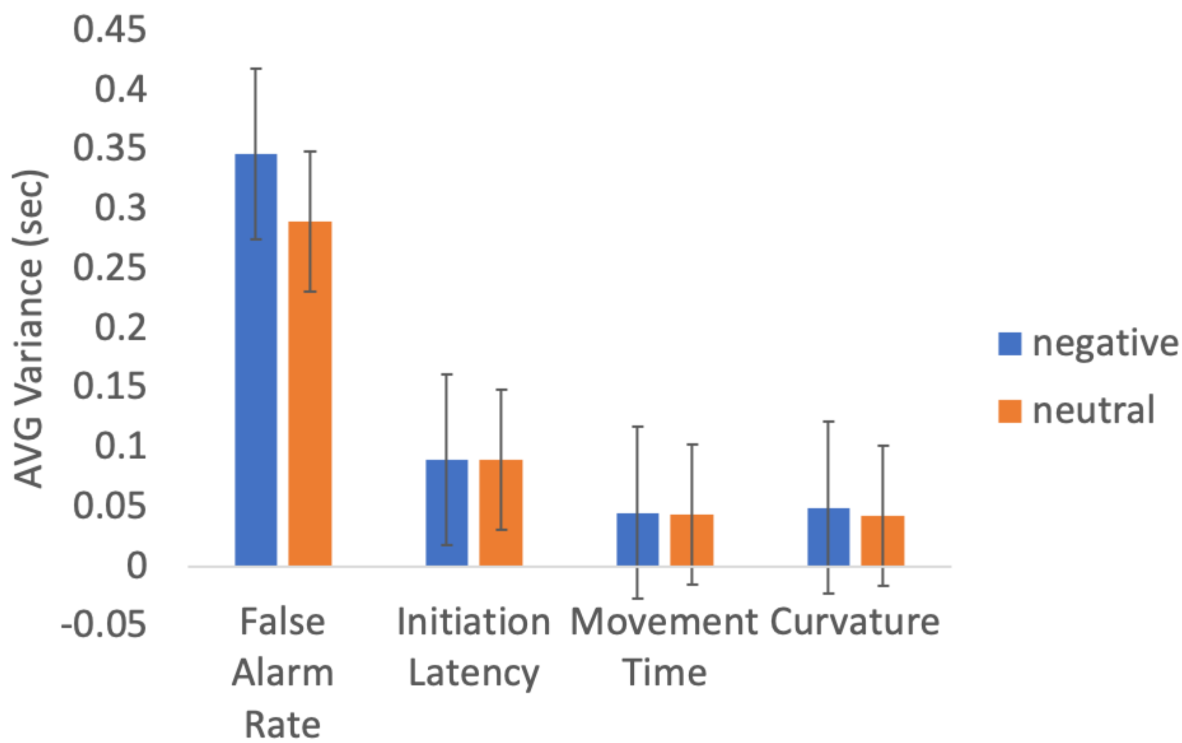

Figure 4. Comparison of movement measures between mood conditions. No significant differences were seen in initiation latency, movement time, or curvature between the negative and neutral mood condition groups. Slight trend showing that participants in negative mood condition made more false alarm errors than did participants in the neutral condition but did not approach significance (*ps* > .05).

Figure 5. Self-reported mind wandering scores compared to self-reported mood scores of participants in the negative mood condition in Experiment 1

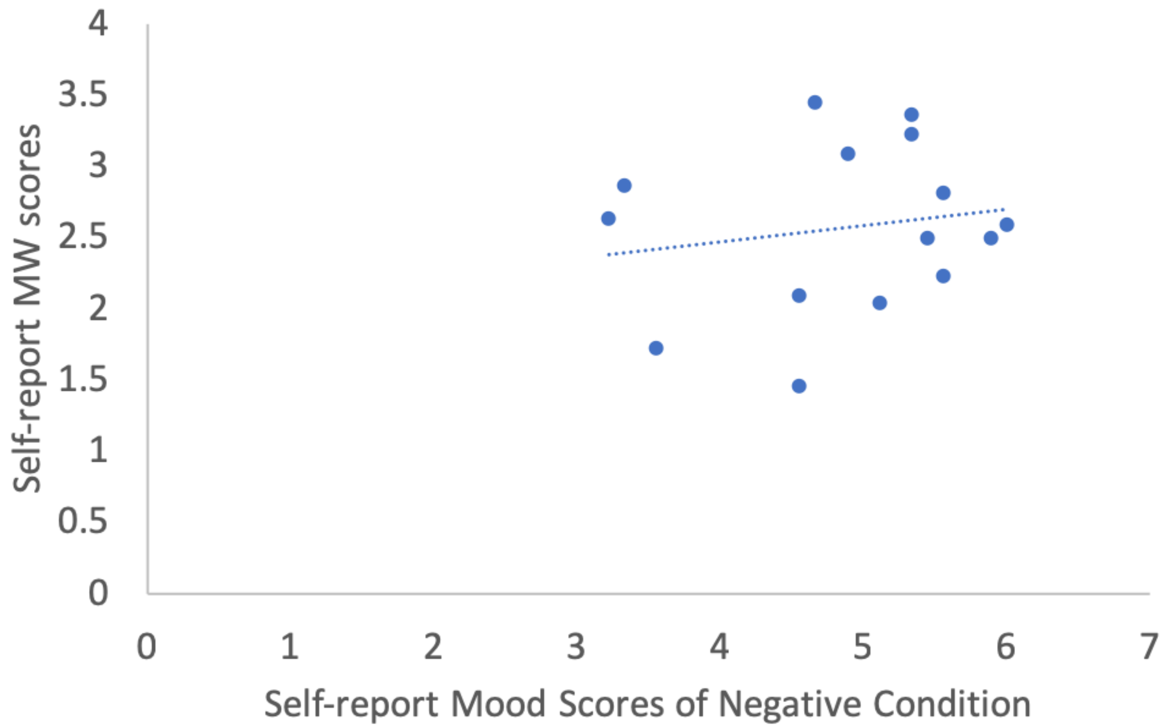

Figure 5. Self-reported mind wandering and mood scores of only participants in the negative mood group. Mind wandering and mood scores had no significant relationship but shows possible positive trend (r = .173, p = .537). MW = mind wandering

Figure 6. Self-reported mind wandering scores compared to initiation latency in Experiment 1

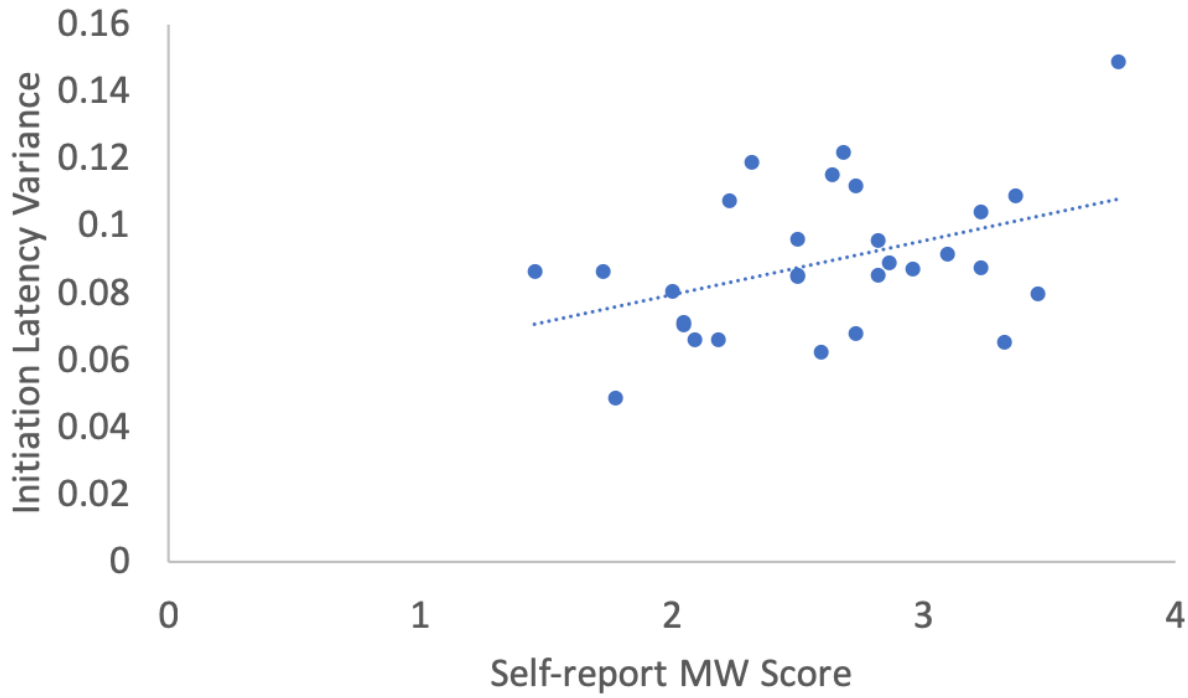

Figure 6. Positive relationship revealed in correlation between self-reported mind wandering scores and variance initiation latency (r = .422, p = .023). The relationship suggests that variances in initiation latency is a valid indicator of mind wandering. MW = mind wandering

Figure 7. Movement time variance compared to initiation latency variance in Experiment 1

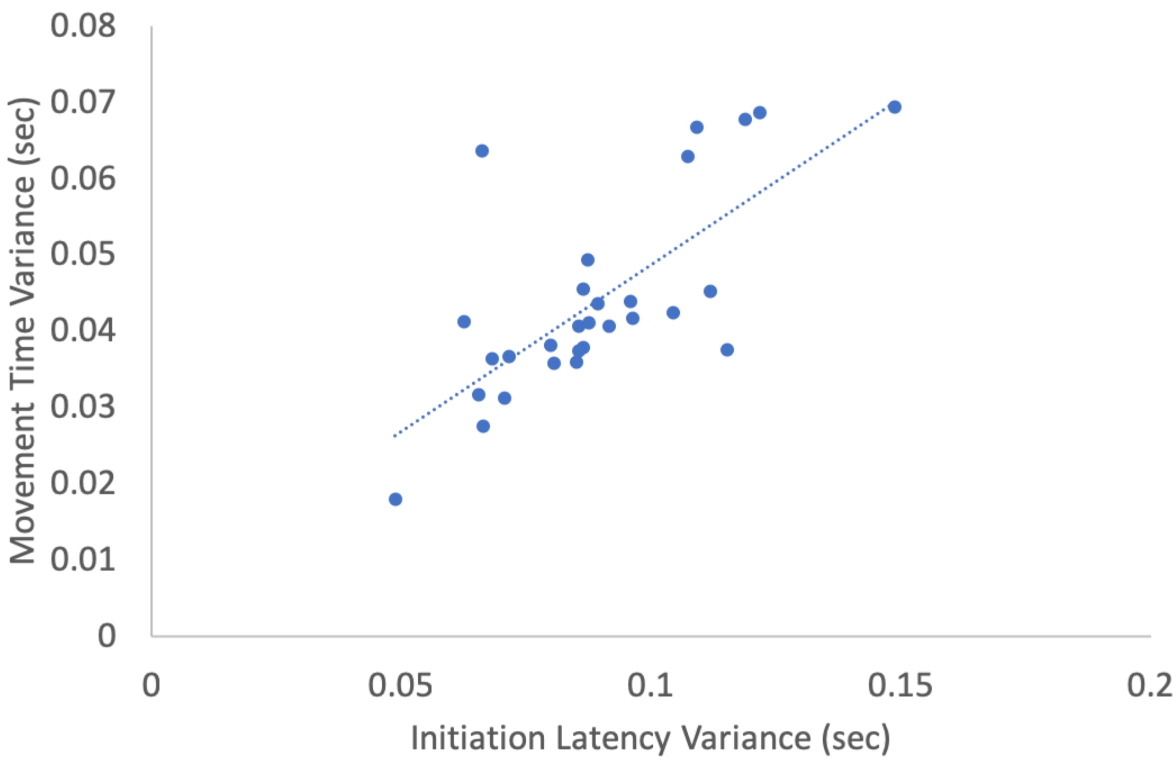

Figure 7. Positive relationship revealed in correlation between initiation latency and movement time (r = .719, p = .000). Relationship suggests that inconsistency in initiating movements is correlated with the total movement time.

Figure 8. Typical trial in the visual-search target-selection task

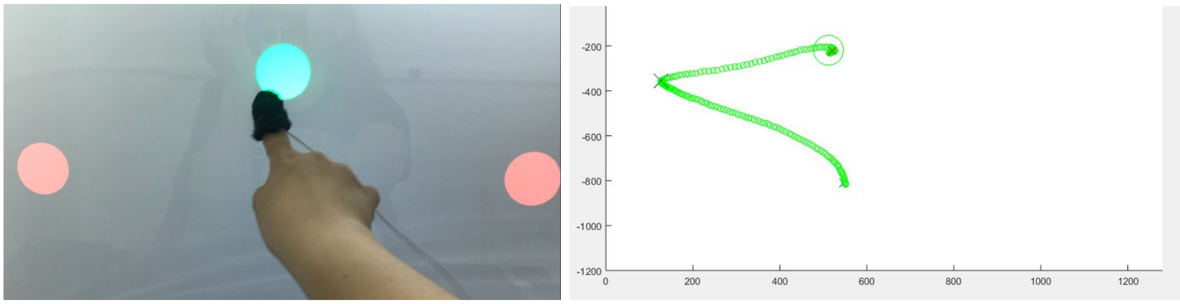

Figure 8. High curvature response to a unique target in the visual-search target-selection task. The photo on the left depicts a correct response to the unique, singly colored green target amongst two red distractors. The photo on the right depicts the curvature of arm movement from on-set to off-set in which the hand initially moved toward the distractor before accurately choosing the target after a mid-flight correction. The green circle represents the location of the target in the task.

Figure 9. Self-reported mood scores per mood induction condition in Experiment 2

Figure 9. Self-reported mood scores after mood induction. Participants in the negative mood group reported significantly higher levels of negative mood than did participants in the neutral mood induction group ($t[21] = 3.248$, $p = .004$). This suggests that the mood induction was successful.

Figure 10. Self-reported mind wandering scores per mood condition in Experiment 2

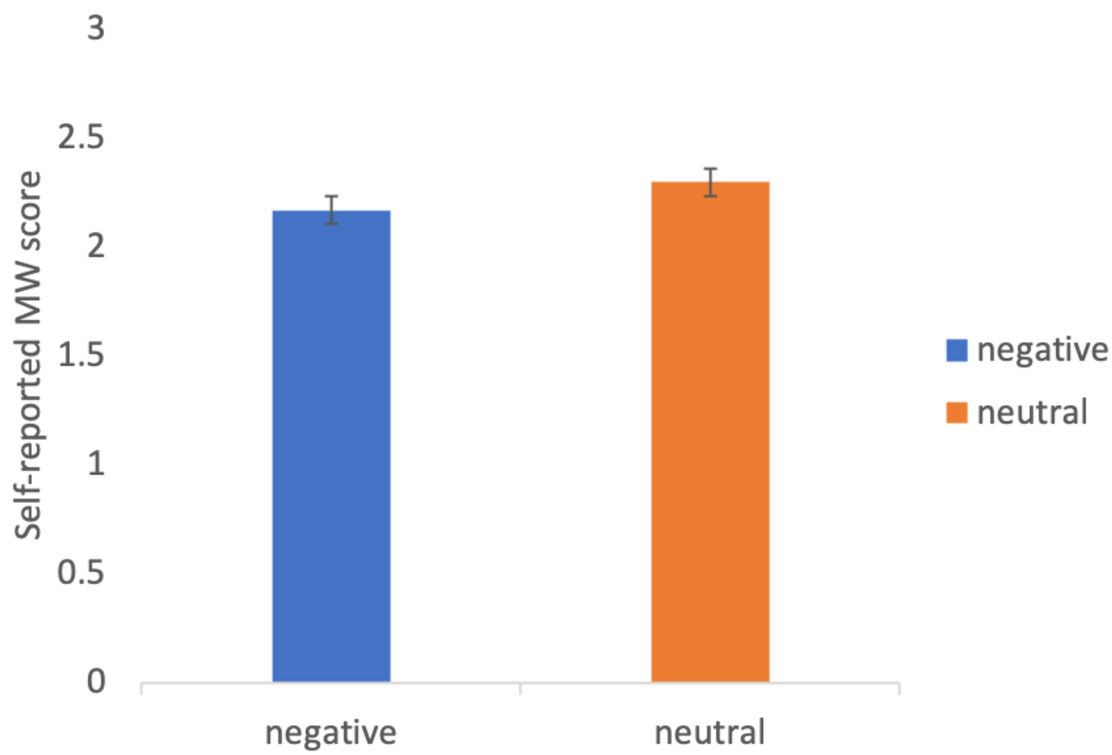

Figure 10. Self-reported mind wandering after mood induction. Negative mood induction did not affect a significant difference on self-reported levels of mind wandering as compared to neutral mood ($t[21] = .580$, $p = .568$).

Figure 11. Mood condition effect across indicators of mind wandering in Experiment 2

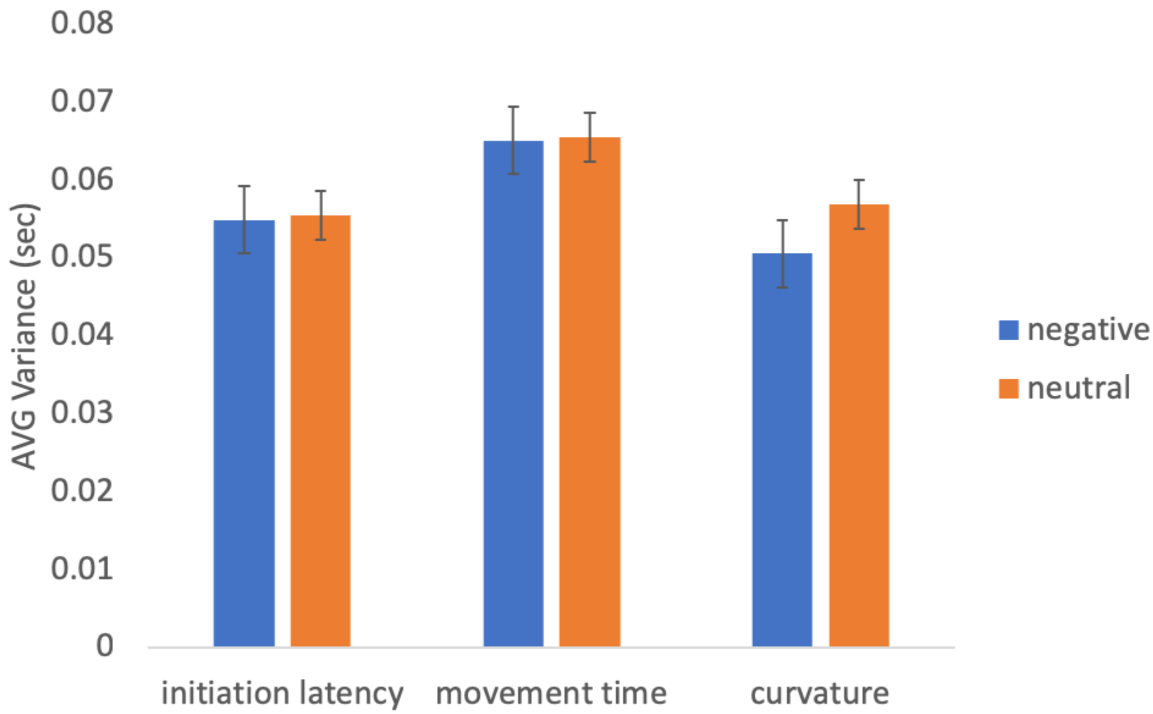

Figure 11. No significant differences across all indicators of mind wandering as a consequence of mood induction (*ps* > .05). Negative mood induction did not result in a significant difference on the different measures of mind wandering such as initiation latency, movement time, and curvature as compared to neutral mood. Neutral mood seems to have had higher variances in curvature but the trend was not approaching significance.

Figure 12. Self-reported mind wandering scores as compared to self-reported mood scores of only the negative mood induction group in Experiment 2

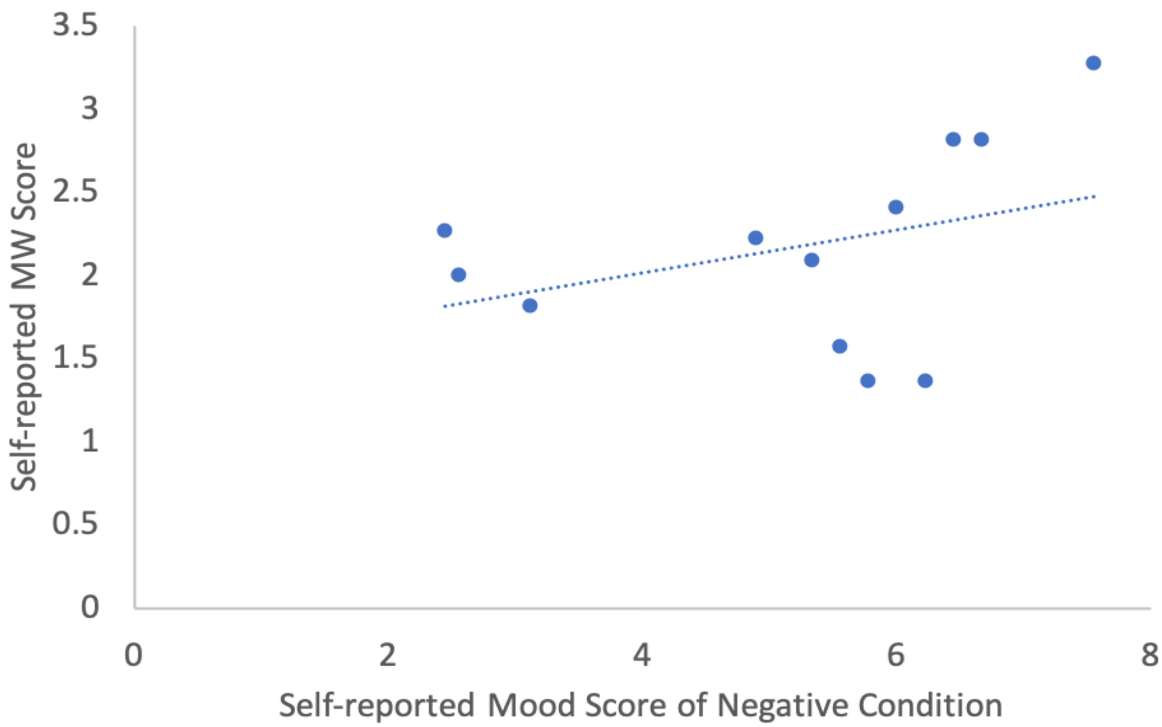

Figure 12. Positive trend in relationship between self-reported mood and self-reported mind wandering. There was not a significant relationship observed between self-reported mood and self-reported mind wandering (r = .214, p = .327). However, when looking at just the mood scores within the negative mood induction group, there showed to be a potential trend towards a positive correlation to self-reported mind wandering (r = .357, p = .254) though this still was not a significant relationship.

Figure 13. Relationship between variances in initiation latency and movement time in Experiment 2

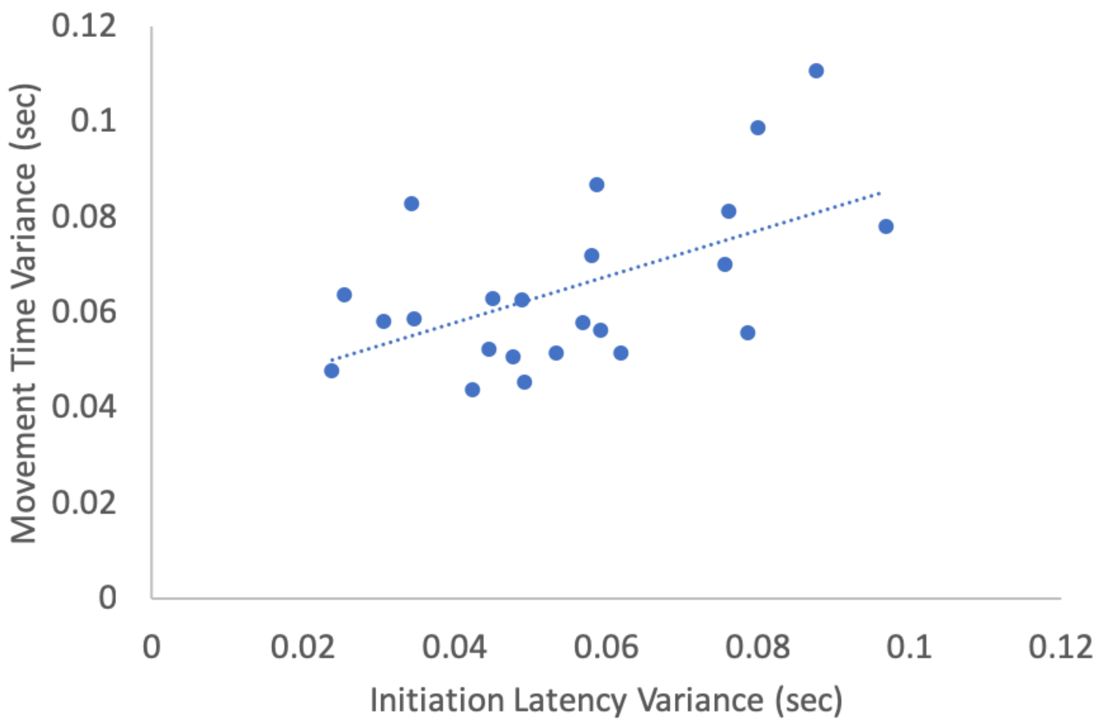

Figure 13. Positive correlation observed between initiation latency and movement time (r = .555, p = .006). Suggests that inconsistencies in one movement affects the other.

Appendix A

Informed Consent

Study Title: Impact of Mindfulness Meditation on Mind Wandering Influenced by Negative Mood

Principal Investigator: Sydney Tran

- This research study is being conducted under the supervision of Professor Jeff Moher as a part of Sydney Tran's honors thesis on mindfulness, mood, and mind wandering.
- The purpose of this study is to better understand the relationship between mood and mind wandering.
- This research will involve viewing a series of photos that have been shown to influence people's mood states. Some people may be more affected by the photos provided in this experiment than others. However, it is expected that any change in mood state will be temporary. After viewing the photos, you will be asked to fill out a short survey about mood.
- You will be presented with a simple game in which visual stimuli will be back-projected on a plexiglass display. You will see a series of trials and be asked to make a response depending on whether you think the moving circle will hit the target box on the screen. We will record 3D hand movements using an electromagnetic sensor attached to your index finger. This method is non-invasive and has no known adverse effects. At the end of the experiment, you will be asked to fill out a short questionnaire about thoughts you experienced during the task.
- There are no known risks or discomforts related to participating in this research beyond those experienced in day to day life. However, your arm may get tired from repeated movements as you respond to the task. We encourage you to rest during breaks, and to inform the experimenter if you need to terminate the study. You will still receive full credit if you terminate the study early.
- This research will take approximately 30 minutes. If you are participating in this study for the research credit requirement, you will receive 30 minutes of research credit.
- Your participation is voluntary, and you may decline to answer any questions as you see fit.
- You may withdraw from the study without penalty at any time.
- The data recorded from this study will be kept confidential. Information you provide will be stored without any identifying information. This study is not meant to gather information about specific individuals but to better understand the relationship between

mood and mind wandering. Your responses will be combined with other participants' data for the purpose of statistical analyses.

- You are being asked to consent to publication of the study results as long as the identity of all participants is protected.
- You may contact the researcher who will answer any questions that you may have about the purposes and procedures of this study. Sydney Tran can be contacted at stran@conncoll.edu
- This research has been approved by the Connecticut College Human Subjects Institutional Review Board (IRB). Concerns about any aspect of this study may be addressed to Professor Audrey Zakriski at alzak@conncoll.edu.

A copy of this informed consent will be given to you.

I am at least 18 years of age, have read these explanations and assurances, and voluntarily consent to participate in this research about the relationship between mood and mind wandering.

______________________________	______________________________	________
Name of participant (please print)	Signature of participant	Date
______________________________	______________________________	________
Name of person obtaining consent (please print)	Signature	Date

Appendix B

Debriefing Form

Thank you for participating in this research as the first of a two-part experiment dealing with mindfulness, mood, and mind wandering. In this experiment, mood was expected to be influenced by a series of photos that have shown to produce either a negative or neutral effect. In a semi-replication of Smallwood et al. (2009), the purpose of this study was to reproduce the effect of mood inducement on mind wandering in which episodes of mind wandering were more likely to occur if paired with negative stimuli. We are hoping to find indicators that suggest people are mind wandering, such as losing focus and thinking about things irrelevant to the current task.

The results of this study could help understand the relationship between negative mood and mind wandering which has an important implication on states of rumination, a common symptom of depression. Both mind wandering and rumination are intrusive thoughts that arise during periods of inattention or loss of focus. Because mind wandering takes one out of their present moment, it is likely that an inability to both pay attention and remain in the present may lead to a greater dissatisfaction in life and continue to perpetuate the cycle of depression.

In theory, mindfulness meditation would be an important strategy that can be used to reduce the impact of mind wandering and thus re-engage a person in their present moment. Refocusing attention or snapping back is an important skill in mindfulness to be present with oneself in order to uplift mood and improve focus and learning. In a future study, we intend to use the data from this experiment to examine the effect of mindfulness meditation in offsetting mind wandering states as influenced by negative mood. To my knowledge, no known study has researched the ability of an individual to recover from mind wandering in relation to negative moods.

If you have any questions or concerns about the manner in which this study was conducted, please contact the IRB Chairperson Professor Audrey Zakriski at alzak@conncoll.edu.

If you are interested in this topic and want to read the literature in this area, you might enjoy the following articles:

- Rosenberg, M., Noonan, S., DeGutis, J., & Esterman, M. (2013). Sustaining visual attention in the face of distraction: A novel gradual-onset continuous performance task. *Attention, Perception, & Psychophysics, 75*(3), 426-439. doi:10.3758/s13414-012-0413-x

- Smallwood, J., Fitzgerald, A., Miles, L. K., & Phillips, L. H. (2009). Shifting moods, wandering minds: Negative moods lead the mind to wander. *Emotion, 9*(2), 271-276. doi:10.1037/a0014855

- Smallwood, J., & O'Connor, R. C. (2011). Imprisoned by the past: Unhappy moods lead to a retrospective bias to mind wandering. *Cognition and Emotion, 25*(8), 1481-1490. doi:10.1080/02699931.2010.545263

You may also contact me Sydney Tran at stran@conncoll.edu for additional resources or any questions about this research.

If you have concerns about your mood and its impact on your ability to be mindful and attentive, please consider contacting Student Counseling Services at scs@conncoll.edu or find their location in Warnshuis Health Center. Additional resources on mindfulness and meditation on campus can also be found at Student Counseling Services. If you are interested in online resources, please consider visiting you.conncoll.edu as a 100% anonymous and confidential portal to discover personalized tips and resources for wellbeing.

Appendix C

Negative Mood Stimuli

Appendix D

Neutral Mood Stimuli

Appendix E

Current Mood Assessment

Subject: ___ / ___

Please indicate the extent to which you are feeling the following items on a 1 to 9 scale with the first item at the 1 endpoint and the second item at the 9 endpoint.

Calm	1	2	3	4	5	6	7	8	9	**Angry**
Fatigued	1	2	3	4	5	6	7	8	9	**Alert**
Good	1	2	3	4	5	6	7	8	9	**Bad**
Relaxed	1	2	3	4	5	6	7	8	9	**Nervous**
Happy	1	2	3	4	5	6	7	8	9	**Sad**
Depressed	1	2	3	4	5	6	7	8	9	**Elated**
Contented	1	2	3	4	5	6	7	8	9	**Upset**
Stressed	1	2	3	4	5	6	7	8	9	**Serene**
Excited	1	2	3	4	5	6	7	8	9	**Lethargic**

Appendix F

Cognitive Interference Questionnaire

Subject: ___ / ___

Instructions: This questionnaire concerns the kinds of thoughts that go through people's minds at particular times, for example, while they are working on a task. The following is a list of thoughts, some of which you might have had while doing the task on which you have just worked. Please indicate approximately how often each thought occurred to you while working on the previous task by placing the appropriate number in the blank provided for each question.

1 = Never 2 = Once 3 = A few times 4 = Often 5 = Very often

_____ 1. I thought about how poorly I was doing.
_____ 2. I thought about what the experimenter would think of me.
_____ 3. I thought about how I should work more carefully.
_____ 4. I thought about how much time I had left.
_____ 5. I thought about how others have done on this task.
_____ 6. I thought about the difficulty of the task.
_____ 7. I thought about my level of ability.
_____ 8. I thought about the purpose of the experiment.
_____ 9. I thought about how I felt when I was told how I performed.
_____10. I thought about how I got confused.
_____11. I thought about other activities (for example: assignments, work, tasks, responsibilities)
_____12. I thought about members of my family.
_____13. I thought about friends.
_____14. I thought about something that made me feel guilty.
_____15. I thought about personal worries.
_____16. I thought about something that made me feel tense.
_____17. I thought about something that made me feel angry.
_____18. I thought about something that happened earlier today.
_____19. I thought about something that happened in the recent past (last few days, but not today)
_____20. I thought about something that happened in the distant past.
_____21. I thought about something that might happen in the future.

Please circle the number on the following scale for which best represents the degree to which you felt your mind wandered *during the ball and box task you have just completed.*

Not at all 1 2 3 4 5 6 7 Very Much

Appendix G

Informed Consent

Study Title: The Influence of Negative Mood on Mind Wandering and Impulsivity

Principal Investigator: Sydney Tran

- This research study is being conducted under the supervision of Professor Jeff Moher as a part of Sydney Tran's honors thesis on the influence of mood on mind wandering.
- The purpose of this study is to better understand the relationship between negative mood on mind wandering and impulsivity.
- This research will involve viewing a series of photos that have been shown to influence people's mood states. Some people may be more affected by the photos provided in this experiment than others. However, it is expected that any change in mood state will be temporary. After viewing the photos, you will be asked to fill out a short survey about mood.
- You will be presented with a simple game in which visual stimuli will be back-projected on a plexiglass display. You will see a series of trials and be asked to make a response depending on what the unique object is. We will record 3D hand movements using an electromagnetic sensor attached to your index finger. This method is non-invasive and has no known adverse effects. At the end of the experiment, you will be asked to fill out a short questionnaire about thoughts you experienced during the task.
- There are no known risks or discomforts related to participating in this research beyond those experienced in day to day life. However, your arm may get tired from repeated movements as you respond to the task. We encourage you to rest during breaks, and to inform the experimenter if you need to terminate the study. You will still receive full credit if you terminate the study early.
- This research will take approximately 30 minutes. If you are participating in this study for the research credit requirement, you will receive 30 minutes of research credit.
- Your participation is voluntary, and you may decline to answer any questions as you see fit.
- You may withdraw from the study without penalty at any time.
- The data recorded from this study will be kept confidential. Information you provide will be stored without any identifying information. This study is not meant to gather information about specific individuals but to better understand the relationship between mood on mind wandering and impulsivity. Your responses will be combined with other participants' data for the purpose of statistical analyses.

- You are being asked to consent to publication of the study results as long as the identity of all participants is protected.
- You may contact the researcher who will answer any questions that you may have about the purposes and procedures of this study. Sydney Tran can be contacted at stran@conncoll.edu
- This research has been approved by the Connecticut College Human Subjects Institutional Review Board (IRB). Concerns about any aspect of this study may be addressed to Professor Jason Nier at janie@conncoll.edu.

A copy of this informed consent will be given to you.
I am at least 18 years of age, have read these explanations and assurances, and voluntarily consent to participate in this research about the relationship between mood and mind wandering.

______________________________ ______
Name of participant Date

______________________________ ______
Name of person obtaining consent Date

Appendix H

Debriefing Form

Thank you for participating in this research as the second of a two-part experiment dealing with mood and mind wandering. In this experiment, mood was expected to be influenced by a series of photos that have shown to produce either a negative or neutral effect. In a semi-replication of Song and Nakayama (2008), the purpose of this study was to examine indicators of mind wandering in a simple target-selection task in which participants showed to make faster, less efficient movements when distracted. We are hoping to find objective indicators that suggest people are more likely to mind wander when induced with a negative mood.

The results of this study could help understand the relationship between negative mood and mind wandering which has an important implication on everyday decision making that is influenced by our mood states. In a future study, we intend to use the data from this experiment to examine the effect of mindfulness meditation in offsetting negative states as influenced internal and external factors.

If you have any questions or concerns about the manner in which this study was conducted, please contact the IRB Chairperson Professor Audrey Zakriski at alzak@conncoll.edu. If you are interested in this topic and want to read the literature in this area, you might enjoy the following articles:

- Rosenberg, M., Noonan, S., DeGutis, J., & Esterman, M. (2013). Sustaining visual attention in the face of distraction: A novel gradual-onset continuous performance task. Attention, Perception, & Psychophysics, 75(3), 426-439. doi:10.3758/s13414-012-0413-x
- Song, J.-H., & Nakayama, K. (2008). Target selection in visual search as revealed by movement trajectories. Vision Research, 48(7), 853–861. https://doi.org/10.1016/j.visres.2007.12.015
- Smallwood, J., & O'Connor, R. C. (2011). Imprisoned by the past: Unhappy moods lead to a retrospective bias to mind wandering. Cognition and Emotion, 25(8), 1481-1490. doi:10.1080/02699931.2010.545263

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If you have concerns about your mood and its impact on your ability to be mindful and attentive, please consider contacting Student Counseling Services at scs@conncoll.edu or find their location in Warnshuis Health Center. Additional resources on mindfulness and meditation on campus can also be found at Student Counseling Services. If you are interested in online resources, please consider visiting you.conncoll.edu as a 100% anonymous and confidential portal to discover personalized tips and resources for wellbeing.