Mind Wandering: Effects on Mood and Attention

Sarah Blossom

Haverford College

April 29, 2022
Abstract

The present study investigated the relationship between mind wandering, mood, and EEG neural correlates of attention. Using a mood induction design, positive and negative moods were induced in participants prior to a sustained attention to response task (SART). Thought probes and retrospective questionnaires were employed to measure quantity and type of mind wandering. Overall, this study found that negative moods were more associated with overall mind wandering and reduced P300 amplitudes—an index of attention—at the P3, PZ, and P4 sites indicating perceptual decoupling. Individual differences in positive and negative moods prior to the SART were found to be associated with deliberate mind wandering and overall mind wandering, respectively. Change in mood was not found to be associated with deliberate mind wandering. These results provide more insight into the relationship between mind wandering and mood while adding a novel EEG relationship between negative mood induction and reduced P300 to the literature.
Mind Wandering: Effects on Mood and Attention

During everyday life, the mind tends to wander. In a study by Killingsworth & Gilbert (2010), researchers collected a database of a quarter of a million real time responses from 5000 people across 83 countries at random moments of the day. They found that of these responses, approximately 50% of the time, the people surveyed reported that they were mind wandering. These wandering thoughts could be about a variety of topics on a variety of different time scales. They could take place at school, in the car, at home—basically at any location and moment of the day. This study shows the immense presence that mind wandering has in our everyday lives.

Mind wandering has been described as a form of spontaneous thoughts or task unrelated thoughts, but the defining characteristic of mind wandering is the turning inward of attention and the dampening of attention to the outside world (Handy & Kam, 2015). That is, people who mind wander are blocking out the world in favor of paying attention to their inner thoughts. Perceptual decoupling has been posited as a mechanism for this and describes the inhibition of external information that is unrelated to the internal train of thought (Smallwood & Schooler, 2015). This inward orientation of attention has significant consequences when it comes to performance on various tasks. In laboratory settings, researchers have found that mind wandering leads to more errors on attention tasks (Christoff et al., 2009). These detrimental effects of mind wandering could prove to be dangerous in everyday settings like driving or aviation where attention is key.

However, mind wandering isn’t entirely bad. Mind wandering has been described as part of a family of spontaneous thought that includes creative thoughts and dreaming (Christoff et al., 2016). Thus, mind wandering has also been associated with increased creativity and mental breaks which help relieve boredom (Smallwood & Schooler, 2015). In recent years, mind wandering research has also turned to investigate mind wandering and its relationship with
MIND WANDERING: EFFECTS ON MOOD AND ATTENTION

mood. This study aims to look at this relationship between mind wandering and mood and propose a therapeutic use of mind wandering towards emotion regulation.

Mind Wandering: Deliberate and Spontaneous

The literature on mind wandering is vast and often conflicting. The contradictory nature of the mind wandering literature may reflect the fact that mind wandering is not a single process but includes multiple different subtypes that may have different correlates. In this study we focused on deliberate and spontaneous mind wandering. Deliberate mind wandering has been defined as mind wandering that engages controlled processes for internal processing or an intentional shift to inward thoughts (Seli et al., 2015; Vannucci & Chiorri, 2018). In everyday life an example of this would be sitting in a boring class and choosing to think about your to-do list rather than paying attention. Meanwhile, spontaneous mind wandering has been referred to as a failure of executive control (Seli et al., 2015). An example of this would be sitting in a boring class and finding yourself mind wandering without meaning to. Thus, the main defining characteristic between deliberate and spontaneous mind wandering is the element of intentionality. This differing degree of intentionality seems to be the main element deciding whether mind wandering is adaptive or maladaptive.

Mind Wandering and Mood

One way that mind wandering has been characterized as adaptive or maladaptive is through its relationship with mood. Mind wandering in general has been correlated with worsening mood. Killingsworth & Gilbert (2010) surveyed 2250 adults in the United States and found that regardless of activity, minds wandered frequently, and that people often reported feeling less happy while mind wandering. Interestingly, even when people mind wandered to
pleasant thoughts, they reported the same levels of happiness as when they were focused on their current activity suggesting that mind wandering does not add happiness (Killingsworth & Gilbert, 2010).

In contrast, Poerio et al. (2013) found that rather than mind wandering leading to negative mood, a negative mood led to mind wandering. Using an app to obtain real time experiences, they found that sadness was a precursor to mind wandering and mind wandering didn’t have a mood lowering effect. This was also shown in a study by Smallwood (2009) where he looked at the effect of mood states on mind wandering. He found that a negative mood induction led to more task unrelated thoughts (mind wandering) and more performance errors than positive mood inductions (Smallwood, 2009). His study is especially important in that it used experimental manipulations to demonstrate the causal relationship between mood and mind wandering. His findings replicated the results from the aforementioned correlational studies.

Alternatively, other studies have found mind wandering to lead to mood improvement (Huffziger & Kuehner, 2009; Welz, 2018). A study by Huffziger & Kuehner (2009) used a negative mood induction and observed the effects of rumination, distraction, and mindful self-focus on future mood. They found that participants assigned to mindful self-focus and distraction showed significant mood improvements while rumination led to an extended depressed mood. Since mind wandering has similar effects to distraction—worsened performance, perceptual decoupling—and is often correlated with distraction, it can be argued that mind wandering could also have a positive effect on negatively induced mood (Unsworth & McMillan, 2014).

**Deliberate vs Spontaneous Mind Wandering and Mood**
These contradictory findings can be explained by different types of mind wandering having different effects on mood. The literature has shown that spontaneous mind wandering is associated with negative effects on mood such as less mindfulness, less positive affect, more depressive symptoms, and more anxiety and stress (Deng et al., 2014; Vannucci et al., 2018; Seli et al., 2019; Cariciofo & Jiang, 2021). In contrast, deliberate mind wandering has not shown correlations or rather has negative correlations with depressive symptoms (Seli et al., 2019). Spontaneous mind wandering’s association with less mindfulness, could explain its relationship with negative emotions (Cariciofo & Jiang, 2021). Another explanation goes back to what was mentioned previously about sadness being a predictor for mind wandering. The trend in the literature linking spontaneous mind wandering with more depression, anxiety, and negative affect could be explained by depression, anxiety, and negative affect producing spontaneous mind wandering. Further research should be done to elucidate the directionality of these relationships.

An interesting study by Kruger et al. (2020) found that deliberate mind wandering actually may be a method used to escape negative mood. In this study, participants played a slot machine simulator and completed a vigilance task followed by multiple scales. Researchers found that participants who scored high for problem gambling used mind wandering to cope with the negative affect induced by the highly repetitive and boring vigilance task (Kruger et al. 2020). This study, while much different from the general mind wandering literature, suggests that deliberate mind wandering could be used for emotion regulation. It is this relationship between mind wandering and mood that we are most interested in. A possible explanation for mind wandering as a means of emotion regulation can be found in a study by Vannucci & Chiorri (2018). They found that self-rumination predicted spontaneous mind wandering while
self-reflection predicted deliberate mind wandering. The self-reflection associated with deliberate mind wandering could be the mechanism contributing to emotion regulation. Spontaneous mind wandering does not contribute to emotion regulation since it has been linked to rumination which is shown to lead to negative moods. Thus, deliberate mind wandering could be classified as adaptive while spontaneous mind wandering is maladaptive.

**Mind Wandering, Mood, and Content**

However, is intentionality really the main factor for deciding whether mind wandering is adaptive or maladaptive? What exactly is it about mind wandering that causes positive or negative moods? Researchers have turned to the content of mind wandering to further understand the relationship between it and mood. A study by Killingsworth & Gilbert (2010) found that the specific thoughts that were taking place during mind wandering were a better predictor of happiness than the activity they were doing. This suggests that the content of mind wandering is also linked to mood. Previous research has found that the content of mind wandering mediates subsequent mood. A study by Poerio et al. (2013) found that instead of mind wandering predicting future mood, it was the affective content of the thoughts that predicted it. Factors such as how interesting and useful the thoughts are and the positivity of the thoughts have also been shown to predict a better future mood or affect (Franklin et al., 2013; Welz et al., 2018).

Lastly, the time orientation of the thoughts has been shown to be a predictor as well. In a study by Ruby et al. (2013), they found that when mind wandering was focused on the past, this led to a decrease in mood while thoughts oriented to the future led to an increased in positive mood. This finding has been validated by another study that found that sadness predicted past oriented thoughts (Poerio et al., 2013).
Mind Wandering and EEG

In addition to looking at mind wandering, mood, and content, researchers have also been interested in the neural correlates of mind wandering. Mind wandering has generally been linked to activations in the default mode network and the executive system (Christoff et al., 2009). This parallel recruitment is very similar to the neural recruitment during creativity which ties into the findings on mind wandering and creativity. In addition to using fMRI techniques to study mind wandering, many researchers have also employed EEG.

A study by Compton et al. (2019) investigated the link between mind wandering, performance, and alpha oscillations using EEG and a Stroop task. Mind wandering was distinguished by frequencies in the alpha range (Compton et al., 2019). This finding was further validated in a study by Jin et al. (2019) which aimed to develop a machine-learning classifier of mind wandering. They found that alpha power was the most predictive of mind wandering. Additionally, a study by Martel et al. (2019) found that being off task was associated with reduced attention to external task relevant information, supporting the perceptual decoupling theory.

Multiple studies have also linked mind wandering with a reduction in the P300 (Barron et al., 2011; Martel et al., 2019). The P300 is an event-related potential, a brain peak in response to a stimulus, that is particularly affected by attention. The size of the P300 is thought to correspond with attention to a stimulus: larger size means that attention is being paid, smaller size means attention is directed elsewhere (Handy & Kam, 2015). The P300 has often been linked to perceptual decoupling due to its relationship with attention. Since perceptual decoupling is the turning inwards of attention and ignoring external stimuli, the P300 is a good proxy measurement.
Lastly deliberate and spontaneous mind wandering have been found to have distinct neural correlates. Deliberate mind wandering has been found to have heightened connectivity between the frontal parietal network (FPN) and the default mode network (DMN) while spontaneous mind wandering has been correlated to cortical thinning in adjacent areas of the FPN and DMN (Golchert et al., 2017).

The neural component of mind wandering is an important addition to the mind wandering literature and allows insight into mind wandering’s effect on attention, specifically perceptual decoupling. It also provides more support for the distinctions made in previous sections between deliberate and spontaneous mind wandering. While it does not directly tap into the characteristics making mind wandering adaptive or maladaptive, it does provide insight into the processes that underlie mind wandering’s usefulness.

**Present Study**

As demonstrated above, much of the mind wandering literature contains conflicting findings. As such, we aimed to clarify some of the relationships between mind wandering and mood with our study. To date, few studies have attempted to combine mood induction, performance, and EEG to look at mind wandering from both a cognitive and neural perspective. The present study intended to investigate the specific type of mind wandering, deliberate or spontaneous, that occurs as a result of mood induction, and look at the effects on post-test mood from each type. It also added a novel aspect to the literature through examining the neural correlates of mood induction on mind wandering. Lastly, the study explored the effects of content on affect.
In our study we partially replicated the Smallwood (2009) study on mood induction and its effects on performance and mind wandering. We added an EEG measure specifically looking at the P300 to understand the effects of negative mood induction on perceptual decoupling. Due to the relationship shown above between negative mood and spontaneous mind wandering, we hypothesized that induced negative mood would lead to increased spontaneous mind wandering as well as its associated effects, such as poorer performance and a reduced P300 response.

We also hypothesized that deliberate mind wandering may be used as a form of emotion regulation due to the literature showing deliberate mind wandering as similar to distraction in regard to emotion regulation, its association with self-reflection, and the findings from the Kruger et al. (2020) study. We expected that participants who report more deliberate mind wandering during the SART would also report a more positive post-test mood than those who report less deliberate mind wandering and more spontaneous mind wandering. People with more deliberate mind wandering should also be reporting more positive content in their thoughts, should have fewer errors during the SART, and should have less of a reduced P300—all common findings in the literature on deliberate mind wandering.

**Methods**

**Participants**

50 undergraduate participants (41 females, 9 males) from Haverford College and Bryn Mawr College were recruited to take part in this study via word of mouth and electronic posting. 1 participant was excluded from all analyses due to program interruption. An additional participant was excluded from EEG data analysis due to an electrode site failing to record.
Participants were separated into two experimental groups: positive mood induction and negative mood induction.

**Procedure**

**EEG**

Prior to mood induction and SART, participants donned a Quik-caps fabric cap with embedded Ag/AgCl electrodes measuring from an array of sites across the scalp. Electrodes were placed around the eyes to measure blinks and eye movement artifacts. EEG data was recorded continuously by NuAmps amplifier at 1000 Hz sampling rate throughout mood induction and SART.

**Mood Induction and Measurement**

Participants had either a positive or negative mood induced through a five minute-long happy or sad video modeled off Smallwood et al. (2009) depending on their assigned experimental group. The happy video was a video short titled “The Present” from the Institute of Animation, Visual Effects and Digital Postproduction at the Filmakademie Baden-Wuerttemberg that showed a boy getting a dog who helped him accept his disability and explore the outside world. The sad video was a clip from the movie “A Dog’s Life” that showed the dog dying. Potential video clips were chosen by experimenters and pilot tested on 21 individuals. Their responses to the videos guided our choice to switch the happy clip to “The Present” and keep the “A Dog’s Life” video.

Mood was measured at three time points during the session. Prior to mood induction, participants filled out a PANAS scale to measure their pre-induction mood. Mood was also
measured post-induction to validate that mood induction occurred successfully, and post-
Sustained Attention to Response Task (SART) to see the effects of mind wandering on mood.

*Sustained Attention to Response Task (SART)*

After mood induction, participants participated in a Sustained Attention to Response Task where they saw a series of numbers and were instructed to only hit a button for the number three and not hit anything for all other numbers. This task was meant to be easy and boring to elicit mind wandering. Participants completed three blocks of the SART and were presented the nontarget stimuli approximately 128 times and the target stimulus approximately 10 times (≈8%) per block. Stimuli were presented every 2,500 ms.

*Thought Probes*

Prior to the task, participants were given definitions of deliberate and spontaneous mind wandering—“Deliberate Mind-Wandering is an intentional shift to inward thoughts” and “Spontaneous Mind-Wandering is an unconscious shift to internal thoughts”—along with two examples for each.

During the SART, participants periodically received thought probes asking them about whether they were mind wandering, the specific type of mind wandering, and the valence of the thoughts. The first screen to appear asked “Which of the following responses best characterizes your mental state just prior to the presentation of this screen?” and possible response options were (1) On task, (2) Deliberately mind wandering, and (3) Spontaneously mind wandering. If participants reported mind wandering, they received a second question asking them to rank the positive/negative valence of their mind wandering thoughts on a scale of 1–7. During each block, participants received four thought probes.
**Retrospective Questionnaire**

After the SART, participants filled out a retrospective questionnaire on the content of mind wandering adapted from Carriere et al. (2013). This questionnaire was intended to get an in-depth measure of frequency of mind wandering, frequency of deliberate vs spontaneous mind wandering, and valence and contents of thoughts during the SART that the thought probes could not ascertain. To assess the frequency of mind wandering participants were asked "*What percentage of time during the tasks do you think you were mind wandering*” and responded on a sliding scale of 0-100%. The frequency of deliberate vs spontaneous mind wandering was assessed through the question “*When you were mind wandering, how often were you deliberately mind wandering versus spontaneously mind wandering?*” with responses on sliding scale anchored by deliberate at one end and spontaneous at the other. For valence, participants were asked “*When you were mind wandering, did the content of your thoughts tend to be negative or positive?*” and responded on a scale anchored on one end by negative and positive on the other. Lastly, for the open-ended response on content, participants were asked “*Describe what you were thinking about during the task*”.

**EEG Data Processing**

After the task, EEG data was processed. Gross artifacts were manually rejected and then data was re-referenced to the average of the two mastoids with the exception of one participant with a faulty left mastoid whose data remained referenced only to the right mastoid. Scan’s regression-based blink reduction algorithm was then applied to reduce the effects of blink artifacts. The continuous file was then segmented into 1200-ms epochs around each event marker, with the epoch beginning 200 ms before the stimulus onset and ending 1000 ms after the stimulus onset. Epochs were then averaged separately for the two trial types (target and
nontarget) to produce event-related waveforms for each participant. The P300 amplitude was extracted from target and nontarget trials from the P3, Pz, and P4 sites of each participant. These sites were chosen because they typically show the P300 most clearly. The P300 was defined as the mean voltage within a window 500-700 ms after the stimulus onset. The amplitudes were then entered into statistical analysis.

**Results**

**Mood Induction**

To determine whether the negative and positive film clips were successful in manipulating participants’ moods, we ran a 2x3 mixed factorial ANOVA on participants’ PANAS data. The first factor was film group and the second factor was time (T1, T2, T3). All results for these tests were significant for all four dependent variables: positive affect, negative affect, happy, and sad mood reports. For positive affect we found a main effect of time - $F(2,94) = 38.85, p < 0.001$ – and film - $F(1,47) = 10.6, p = 0.002$. We also found an interaction effect, $F(2,94) = 7.47, p < 0.001$. For negative affect, there was a main effect of time - $F(2,94) = 5.66, p=0.005$, a time x film clip interaction - $F(2,94) = 15.35, p < 0.001$ and a main effect of film - $F(1,47) = 5.23, p = 0.027$. Mood induction was also significant for happy ratings, time – $F(2,90) = 14.5, p < 0.001$, time x film clip interaction – $F(2,90) = 17.8, p < 0.001$, film – $F(1,45) = 27.7, p < 0.001$. The same was found for sad ratings: main effect of time – $F(2,94) = 26.3, p < 0.001$, time x film clip interaction – $F(2,94) = 14.8, p < 0.001$, and film clip main effect – $F(1,47) = 9.32, p=0.004$. Tukey’s HSD post-hoc tests were then run on the time x film clip interaction for all the dependent variables to further investigate the time x film interaction. These tests found that there was only a significant change for the positive film group in mood from T1 to T2 for negative affect (p=0.006) while the negative film group always had a significant change from T1
to T2. That said, all tests found that there was a significant difference in mood scores at T2 (Positive affect: p<0.001; Negative affect: p=0.002; Happy: p<0.001; Sad: p<0.001) but not at T1 or T3 demonstrating that participants were in robustly different mood states after the mood induction but not at any other time. This supports our finding that mood induction was successful in placing participants in different mood states. As seen in Figure 1, the negative film clip led to decrease in positive affect and happy reports as compared to the positive film clips (1A, 1C) while it led to an increase in negative affect and sad reports (1B, 1D).

**Film and Mind Wandering**

Next, we examined the effect of mood induction on mind wandering variables using independent samples t-tests. The variables we investigated were probe caught reports of overall mind wandering, proportion of deliberate mind wandering, total mind wandering, and valence along with retrospective reports of overall mind wandering, deliberate mind wandering, negative mind wandering, and positive mind wandering grouped by film clip. We found that the film clips generally did not lead to a significant change in mind wandering reports. The film clips did have a marginally significant effect on the retrospective report of overall mind wandering – $t(47)=2.00, p = 0.051$ – which went in the expected direction such that people in the negative film group reported more overall mind wandering (See Table 1).

**Film and SART Performance**

Our second film analysis investigated the effect of film clip on SART performance. Independent samples t-tests were run comparing accuracy with nontargets and targets and reaction time between film groups. These tests indicated a significant relationship between film clip and nontarget accuracy, $t(47)= -2.09, p = 0.042$, and a marginally significant relationship
between film clip and target accuracy, $t(47) = -1.686, p = 0.098$. These results suggest that people in the positive group were more accurate for both targets and nontargets (Table 1). This significant result however should be taken with caution due to the very small difference in means for negative and positive groups as seen in Table 1. The effect of film clip on reaction time was not significant ($p=0.72$).

**Film and EEG/ERP**

Our next analysis aimed to investigate the relationship between mood induction and neural correlates of attention. We specifically looked at the P300 amplitude which has been associated with attention and the perceptual decoupling (Figure 2). During this analysis we used a 2x2x3 mixed factorial ANOVA to look at P300 amplitude. Here the factors were film group (positive, negative), trial type (target, nontarget), and electrode site (P3, Pz, P4). A main effect of trial type ($F(1,46)=112.753, p <0.007$) was found along with significant interactions between trial type and film ($F(46)=5.386, p=0.025$) and between trial type and site ($F(2,92)=3.673, p=0.002$). A Tukey’s HSD post-hoc tests was then performed on the interaction of trial type and film clip to ascertain the relationship between P300 amplitude and targets under mood induction conditions. This test found that there was not a significant difference between targets in the negative film clip and targets in the positive film clip (pTukey=0.124) however, uncorrected there is a significant difference, $p=0.029$. Corrected or not, there was no significant difference for nontargets between negative and positive film groups (pTukey=0.998, $p=0.851$).

These findings are demonstrated in Figures 3 and 4. Figure 3 displays the trial type and film clip interaction, showing greater P300 amplitude for target than nontargets and the elicitation of greater P300 amplitudes by positive film clips, especially for targets despite the insignificant findings found in the corrected post-hocs. Figure 4 shows the interaction between
trial type and site, with the nontargets showing a lower P300 amplitude than targets and the differences being starkest at Pz. We also found a main effect of film clip, $F(1,46)=3.19, p=0.081$, where the amplitudes for positive clips were marginally higher than the amplitudes for negative clips. This effect however was qualified by the trial type interaction reported above.

**Individual Differences**

Lastly, we looked at individual differences using a series of correlation matrices. We first asked how the pre-SART mood (T2) predicted mind wandering during the SART. While there was a general trend of no significance, we found that under the positive film condition, positive mood at T2 predicted the proportion of deliberate mind wandering reported on the probes ($r=0.487, p=0.018$) and the amount of deliberate mind wandering reported retrospectively ($r=0.433, p=0.034$). Negative mood at T2 also predicted overall mind wandering ($r=0.490, p=0.015$). These results indicate that the participants in the positive film group who reported more positive mood at T2 also reported more deliberate mind wandering in the probes and retrospectively while participants who reported more negative moods at T2 reported more overall mind wandering (Table 2). That said, these results should be taken with caution since they were only found in the positive film group.

We then investigated how a change in mood from pre-SART to post-SART was related to reports of mind wandering. This analysis aimed to address our research question of whether mind wandering could be used as a mood regulator. That is, did mind wandering have an effect on participants’ mood during the SART? Would mood improve or worsen as a result of mind wandering? To assess this, we subtracted mood scores at T3 (postSART) from mood scores at T2 (preSART) and ran correlations with proportion of probes reporting deliberate mind wandering, retrospective deliberate mind wandering reports, and retrospective overall mind wandering
reports. None of our results were significant for the positive or negative film group \((p>0.18)\) suggesting that change in mood is not related to mind wandering.

Our last correlative analysis looked at the effect of deliberate and overall mind wandering on performance to test our hypothesis investigating whether better performance on the SART would occur as result of deliberate mind wandering. We correlated reports of deliberate and overall mind wandering with accuracy to targets and nontargets, reaction times to targets, and the P300 peak difference between targets and nontargets. We found three results that were marginally significant: slower reaction times were correlated with more probe reported deliberate mind wandering \((r=0.252, p=0.087)\) and deliberate mind wandering was negatively correlated with accuracy for nontargets with both probes \((r = -0.268, p = 0.069)\) and retrospective results \((r = -0.275, p=0.056)\). The trend for reaction time was also mirrored by retrospectively reported deliberate mind wandering \((r=0.235, p=0.104)\) however this did not reach significance. These results indicate that the slower the reaction time, the more likely the participant was deliberately mind wandering. They also indicate that participants who deliberately mind wandered more were less accurate for nontargets.

In conclusion, while a general pattern of no significance emerged for individual differences, there were a few exceptions. First, under the positive film group, positive moods at T2 predicted more deliberate mind wandering while negative moods at T2 predicted more overall mind wandering. While mood was a predictor of mind wandering, change in mood during the SART was not found to be related to mind wandering. Lastly, deliberate mind wandering was found to be marginally associated with slower reaction times and lower accuracy for nontargets.

**Discussion**
Building on the prior literature, this study investigated the relationship between mind wandering, mood, and neural correlates. The present study partially replicated the Smallwood et al. (2009) study who found negative mood induction resulted in increased mind wandering and decreased performance on the SART. The current study replicated the mood induction and mood analyses from the Smallwood paper but added a novel investigation of the neural correlates of mood induction. It also asked the novel question of whether individual differences in levels of deliberate mind wandering would have a positive effect on mood.

Overall, this study found that participants in the negative film group tended to mind wander more and were less accurate in performance on the SART. These differences between film groups were also found in the P300 amplitude—an index of attention—with positive film group participants demonstrating higher P300 peaks. Positive film group participants also showed a bigger difference in P300 amplitudes between targets and nontargets. This suggests that positive film group participants were paying more attention during the SART in comparison to the negative film group. Interestingly, the individual differences portion of the study found that mood at T2 but not mood change was predictive of deliberate and overall mind wandering and that deliberate mind wandering was associated with slower reaction times and lower accuracy for nontargets.

These findings partially align with our hypotheses. We hypothesized that the induced negative mood would lead to an increase in spontaneous mind wandering, poorer performance on the SART task, and a reduced P300 response. This was based on the findings of Smallwood et al. (2009) who found that participants in the negative mood induction had more errors on the SART and more task unrelated thoughts. If negative mood induction led to more errors, this suggests that negative mood induction impacted attention which we believed would be demonstrated in a
reduced P300 amplitude based on its relationship with attention and perceptual decoupling. The relationship between P300 amplitude and negative has not previously been explored. Additionally, while Smallwood et al. (2009) only looked at general reports of mind wandering, we were interested in the distinction between spontaneous and deliberate mind wandering. Past literature found that negative affect was associated with spontaneous mind wandering so we hypothesized that the negative mood induction would elicit more reports of spontaneous mind wandering which would in turn explain the performance errors and reduced P300 amplitude (Deng et al., 2013; Ruby et al., 2013; Poerio et al., 2013; Seli et al., 2019, Cariciofo & Jiang, 2021).

While we found that the negative film successfully induced a more negative mood, we did not find any results suggesting that it led to more spontaneous mind wandering as opposed to deliberate mind wandering. Our results found that negative film was associated with more reports of overall mind wandering and that reports of negative mood at T2 in the positive film condition predicted overall mind wandering but not specifically spontaneous mind wandering. While not supportive of our hypothesis, this result aligns with some of the literature. Of the few studies that used mood induction, they found that negative mood induction led to more overall mind wandering (Smallwood et al., 2009). Negative mood has also been shown to predict overall mind wandering in general (Poerio et al., 2013). We originally believed that there would be a relationship between spontaneous mind wandering and negative mood due to the literature on said relationship, but our study was not able to replicate this. This could be because most of the literature on spontaneous mind wandering looked at associations rather than causal relationships (Vannucci et al., 2018; Seli et al., 2019; Cariciofo & Jiang, 2021). Most studies used surveys and self-reports of mind wandering behavior to make correlations with mood while our study used
experimental manipulation in the form of mood induction. This difference in methodology could account for the differences we see between our hypothesis and our findings.

Conversely, the other side of our hypothesis was supported. We believed that negative mood would lead to spontaneous mind wandering, therefore positive mood should lead to more deliberate mind wandering; this was reflected in some aspects of our results. In our analysis of individual differences, we found that at least in the positive film condition, participants who reported more positive moods at T2 also tended to report more deliberate mind wandering in both the probes and retrospective questionnaire. This result reflects the wider literature on deliberate mind wandering’s associations with more positive affect (Seli et al., 2019, Kruger et al., 2020). That said, this finding was limited to the positive film condition which is inexplicable.

Additional hypotheses predicted that induced negative mood would lead to worsened performance on the SART and a reduced P300—characteristics of spontaneous mind wandering—and that deliberate mind wandering would be associated with fewer performance errors and less of a reduced P300. These hypotheses added the novel aspect of examining the neural correlates of mood induction. The first prediction was supported by our results that people in the positive film group showed a higher accuracy during the SART for both targets and nontargets and higher P300 amplitudes to targets than people in the negative film group. These findings reflect the wider literature on positive mood leading to fewer task unrelated thoughts, aka mind wandering, and performance errors (Smallwood, 2009). Additionally, it supports the idea of perceptual decoupling in relation to mind wandering through providing the first examination of neural correlates in relation to mood induction and mind wandering. Thus, participants in the group who showed higher accuracy on the task also showed higher P300 amplitudes and conversely, participants in the group with lower accuracy showed lower P300
amplitudes. With perceptual decoupling, people inhibit external cues in favor of internal cues leading to a turning inwards of attention which is reflected by the increase in errors and reduction in P300 amplitude. Our data supports the idea of decoupling occurring more in an induced negative mood state than a positive mood state.

In regard to our hypothesis on deliberate mind wandering, the P300, and SART performance, we found that deliberate mind wandering was not significantly related to change in P300 amplitude but it was associated with slower reaction times and lower accuracy for nontargets. Given the rest of the findings, the first result aligns with the general pattern of deliberate mind wandering reports not leading to significant effects. Additionally, this hypothesis was made through indirect reasoning based on assumptions from previous studies rather than direct evidence. Currently, no studies have found an explicit link between deliberate mind wandering and the P300 amplitude.

Under individual differences, deliberate mind wandering was associated with slower reaction times and lower accuracy for nontargets. This finding was surprising in that it contradicted our hypothesis on performance for the SART. We thought that deliberate mind wandering would be associated with more accuracy due to its negative correlation with negative affect and negative affect’s negative correlation with performance errors. Based on our assumption that more positive moods would lead to more deliberate mind wandering, we also believed that the finding of positive moods leading to fewer performance errors from the Smallwood et al. (2009) study would apply.

These results are also interesting when compared with the overall association of positive mood induction with more accuracy and positive moods at T2 predicting deliberate mind wandering. One would expect that if positive moods are leading to deliberate mind wandering
and positive moods are also associated with more accuracy, deliberate mind wandering should also be associated with more accuracy. However, this is not the case. This could be due to the T2 results only appearing for the positive film group and therefore not being a strong enough effect to show up on later analyses. It could also be due to most of these results being only marginally significant. More research should be done to understand this anomaly.

Our last hypothesis predicted that deliberate mind wandering could be used as a form of emotion regulation, resulting in more positive post-test moods. This was based on the key study by Kruger et al. (2020) that found that gamblers used deliberate mind wandering to cope with negative affect that was induced by a boring task. Overall, we found no relationship between deliberate mind wandering and change in mood. Given that the Kruger et al. (2020) study was the only study to find this result, our null finding suggests that mind wandering as a form of emotion regulation is not yet well-supported empirically.

Interestingly, aside from the marginally significant association between negative film clip and overall mind wandering, all of the results for individual differences and mood were only found under the positive film condition. In our hypotheses, we expected stronger results to emerge for the negative film induction based off stronger findings in the literature for the effect of negative mood induction: however, the opposite proved to be true. One possible explanation for this effect could be that the positive film induced more variance in the response since it had sad and happy elements to it while the negative film was mostly sad. This variance might account for the results found in individual differences. However, this does not seem likely to be the case due to the error bars for the groups in Figure 1 (A-D) appearing similar in size suggesting similar levels of variance. Another explanation could be that the positive film induced a stronger reaction which could account for the statistically significant findings. However,
anecdotally it seemed that the negative film was more powerful. Additionally, a stronger effect of positive film would have also been found in the initial film and mood analyses, which was not the case. The reason for this pattern is unknown and should be studied more thoroughly in the future.

**Strengths and Limitations**

The current study provides a robust exploration into the relationship between mind wandering, mood, and neural correlates of attention. The major strength of our study was its ability to connect mood induction with neural correlates of attention using EEG. Up to this point, no studies, as far as we know, have investigated this relationship between mood induction and the P300 amplitude. Because we found significant results under our EEG analyses, we were able to find empirical support for the concept of perceptual decoupling and link it with mind wandering. As such, the current study adds the novel finding of mind wandering and perceptual decoupling, as measured by the P300 amplitude, occurring more frequently under the negative mood state.

The second major strength of the study was its experimental manipulation as seen in the mood induction methodology. As discussed previously, much of the previous research has used correlative methodologies to examine mind wandering and mood states. Our mood induction design was modelled after Smallwood et al. (2009) and was found to effectively induce the desired mood states during our film and mood analyses. This experimental manipulation allowed us to examine the causality of mood state on mind wandering which correlative studies lacked.

A final strength of the study was our use of intermittent thought probes during SART in conjunction with the retrospective questionnaire. The randomness of the thought probes provided
real time reports of mind wandering while the retrospective questionnaire provided a global perspective of the mind wandering experience. Additionally, using both allowed for comparisons of the two during analyses which added another method to check the validity of the data.

The current study was mainly limited by the sample population. The study was run using students from Haverford College and Bryn Mawr College. In order to attend these colleges, students must have a good academic record which shows that they have higher than average abilities in regard to focusing and one would expect, preventing mind wandering. Since the task in the current study is based on attention and mind wandering, these students may not be the optimal sample to get generalizable findings. This issue however could not be avoided since due to Covid-19, participation was limited to members of the Bi-college community. Future studies should aim to use a more representative sample.

Another limitation could be that the study did not convey the importance of pressing the button as fast as possible in response to the target stimulus. At the beginning of the SART participants were told “When you see the number 3, press the spacebar as quickly as you can” while during the study, participants were only told “Remember to press the spacebar as quickly as you can whenever you see the number 3” at the beginning of each block. This could account for the odd finding of deliberate mind wandering being associated with slower reaction times. Since the task was long and intentionally boring, participants may have forgotten that speed was important thus skewing the data in the opposite direction than anticipated. In the future, it may be best to continue to include more speed related prompts to participants or to have the experimenter give them instructions to encourage them to press the key as soon as possible.

Also, while our study intentionally used a mood induction design to replicate the Smallwood et al. (2009) study, this approach makes it very clear to the participants that they
should be reporting certain moods after the film clips and thus we may have run into the problem of participants reporting what they thought we wanted them to report rather than what was true to their experience. In the future, a more subtle manner of mood induction should be employed.

Lastly, most of our hypotheses regarding differences between deliberate and spontaneous mind wandering were found to be null. A possible limitation responsible for this is the inability of participants to separate the two concepts during the probe and retrospective reports. Naturally, internal processes such as mind wandering are difficult to operationalize. While we provided definitions and examples to participants, participants may still have found it difficult to separate the two when asked to report their experience. Anecdotally, many participants reported difficulty. In the future more definitions or examples could be given or a sample trial of the SART could be run to give participants practice differentiating deliberate vs spontaneous mind wandering.

**Future Directions**

In order to address some of the above limitations, future work should recruit a more representative sample and ensure that speed and mood induction issues are attended to. Participants should also be given more parameters by which they can separate deliberate mind wandering from spontaneous mind wandering. Futures studies should investigate the effect of mind wandering content on type and quantity of mind wandering as well as mood. Due to time limitation, the current study was not able to analyze this set of data but future studies should investigate the effect of content and see how it ties into the current study’s findings. Studies have shown that the importance of content and that the content of mind wandering thoughts are sometimes more predictive of future mood than the type of mind wandering (Franklin et al., 2013; Poerio et al., 2013; Ruby et al., 2013; Welz et al., 2018). In the future it would be
interesting to analyze the open-ended responses of participants and code them based on valence, time orientation, and subject. Experimenters could examine whether participants who report more deliberate mind wandering differ in comparison to participants who report more spontaneous mind wandering in terms of the above content variables. Theoretically, participants reporting more deliberate mind wandering should also be reporting more positively valenced thoughts that would also be more future oriented. Very few studies have looked specifically at subject matter in regard to deliberate vs spontaneous mind wandering but it would be interesting to look at that. The effects on mood would also be interesting to examine.

Future work should also examine our finding of significant results only in the positive film group. This result was surprising and inexplicable by the current literature. It could be related to the mood induction clips so a line of research examining mood induction design may also be interesting to pursue. This research question would be extremely helpful for future studies that wish to employ the mood induction design. One could investigate more subtle forms of mood manipulation and analyze the efficacy of different types of mood manipulations. Research geared towards forming more efficacious mood inductions that address the limitations presented above would be vital to advancing this type of literature.

This type of research could be expanded to participants with atypical attention abilities such as people with ADHD. Some research on ADHD has found that spontaneous mind wandering is more often associated with ADHD so it could be interesting to examine how this affects daily mood and the P300 (Seli et al., 2015). While the current study used what we assume to majority neurotypicals, it would be interesting to see how the mood induction and EEG results would translate to people with ADHD. It would also be interesting to analyze the content of their mind wandering. For people with attention disorders, we may expect to see a difference from
neurotypicals in terms of the number of subjects their thoughts wandered to as well as progression of thoughts. It also would not be surprising if they mind wandered more during the SART, so it would be interesting to examine if this increase in mind wandering also correlated with an increase in negative mood, as is often reported in the literature, or if they had a different mood reaction to mind wandering.

Lastly, it would be interesting to look at the neural correlates of deliberate and spontaneous mind wandering and examine whether there are predictors in the data of each type of mind wandering. The current literature has found that deliberate and spontaneous mind wandering elicit unique neural signatures however no one, to my knowledge, has looked at mind wandering in real time and examined it for neural predictors for the different types. The most relevant study was done by Jin et al. (2019) which used machine learning to predict mind wandering. A study design like this could be used to examine the EEG data for neural signatures or patterns that would predict deliberate or spontaneous mind wandering.

**Implications**

The current study expands the work of Smallwood et al. (2009) and demonstrates that mood induction did have significant effects on mood, performance, and neural correlates. While this study did not support all of the initial hypotheses, it did generally align with the broader literature in terms of negative mood states being associated with an increase in mind wandering and positive mood, under the positive film induction, being associated with deliberate mind wandering. It also adds the novel finding that negative mood inductions are associated with a reduced P300 amplitude. Future work should aim to understand the effects we found in the individual differences sections and should work to hone the mood induction design. Overall, the
current study adds to the literature on the relationship between mood and mind wandering while adding the novel aspect of neural correlates of mood induction.
References


https://doi.org/10.3758/s13415-019-00707-1


http://dx.doi.org/10.1016/j.actpsy.2014/04.001

http://dx.doi.org/10.1016/j.paid.2017.09.022


**Figures**

Figure 1. *The Effect of Time and Film Clip on Mood*

A) Positive affect decreased as a result of negative film clip in comparison to positive film clip.

B) Negative affect increased with the negative film clip and decreased with the positive film clip.

C) Happy ratings increased with the positive film clip and decreased from the negative film clip.

D) Sad ratings increased with the negative film clip but decreased with the positive clip.
Table 1. *Means (SDs) of Positive and Negative Film Groups for All Variables*

<table>
<thead>
<tr>
<th></th>
<th>Negative Film [M(SD)]</th>
<th>Positive Film [M(SD)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retro Overall MW *</td>
<td>57.2 (25.6)</td>
<td>41.7 (28.7)</td>
</tr>
<tr>
<td>Retro MWD</td>
<td>28.8 (23.9)</td>
<td>24.2 (22.2)</td>
</tr>
<tr>
<td>Retro MW Negative</td>
<td>36.0 (28.1)</td>
<td>28.3 (25.1)</td>
</tr>
<tr>
<td>Retro MW Positive</td>
<td>46.0 (30.1)</td>
<td>52.1 (29.3)</td>
</tr>
<tr>
<td>Probe Count On Task</td>
<td>4.840 (3.31)</td>
<td>5.875 (2.98)</td>
</tr>
<tr>
<td>Probe Proportion MWD</td>
<td>0.273 (0.25)</td>
<td>0.234 (0.27)</td>
</tr>
<tr>
<td>Probe Count Total MW</td>
<td>7.160 (3.31)</td>
<td>6.125 (2.98)</td>
</tr>
<tr>
<td>Probe Count MW Valence</td>
<td>3.963 (0.80)</td>
<td>4.237 (0.81)</td>
</tr>
<tr>
<td>SART Accuracy Non Target **</td>
<td>0.998 (0.004)</td>
<td>1.00 (0.0)</td>
</tr>
<tr>
<td>SART Accuracy Target *</td>
<td>0.968 (0.07)</td>
<td>0.993 (0.020)</td>
</tr>
<tr>
<td>SART Reaction Time Target</td>
<td>561.575 (107.8)</td>
<td>550.689 (102.2)</td>
</tr>
</tbody>
</table>

** p < 0.05
* 0.05 < p < 0.1

Table 1 shows the results of the independent samples t-tests looking at the effect of film clip on mood variables and performance data.
Figure 2: P300 at Pz

This figure shows the P300 that occurs for targets and nontarget at the Pz electrode site.
Figure 3: Trial Type x Film

This figure demonstrates the main effect of trial type on overall amplitude as well as the interaction between trial type and film. Targets correlated with higher P300 amplitudes than nontargets and positive clips are seen to elicit greater P300 amplitudes than negative group. Error bars are standard error.
Figure 4: Trial Type x Site

Figure 4 shows the interaction between trial type and electrode site. Nontargets are shown to have a lower P300 amplitude than targets, with difference most apparent at the Pz site.
Table 2: T2 on Mind Wandering – Positive Film Clip

Positive mood at T2 is positively correlated with deliberate mind wandering while negative mood at T2 is positively correlated with overall mind wandering.
Table 3: *Mind wandering and Performance*

Participants with slower reaction times were more likely to report more time deliberately mind wandering during the probes and the retrospective reports. Deliberate mind wandering was also associated with a lower accuracy for nontargets.