Examining the Conjoint Impact of Depressive Symptomatology and Mind Wandering on Affective Dynamics in Response to Emotionally Salient Visual Stimuli

By

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Abstract

Background. Clinical depression is defined in part by a dysfunction in the temporal dynamics of affect, which often entails the sustainment of negative mood states and attenuated experiences of positive emotion. Investigators have identified several negatively-biased cognitive processes that appear central to depressive affect dysregulation, including the aberrant function of attention, memory, and reward systems – particularly as they pertain to the direct interpretation of external stimuli and life events. More recent work has begun to elucidate connections between depressive symptomatology and *mind wandering* (i.e., thought content that is internally generated and unrelated to any immediate contextual stimuli), as several studies have reported robust positive associations between the frequency of mind wandering and the presence of depressive symptoms. However, it remains unclear the degree to which: (a) increased depressive symptomatology is predictive of mind wandering frequency (and content) across different emotional contexts (i.e., the experience of negative, positive, or neutral affect); or (b) the effect of depressive symptomatology on affective dynamics is moderated by the specific *contents* of mind wandering. Overall, the primary aim of the current investigation was to help elucidate the conjoint effects of mind wandering and depressive symptomatology on the temporal dynamics of affect.

Method. A stratified sampling technique was used to sample individuals (N = 173) with minimal-to-elevated levels of self-reported depressive symptomatology. Following a questionnaire to measure current depressive symptoms at the time of the study, participants completed a computer task designed to be low in cognitive demand (i.e., to elicit mind wandering), with intermittent thought probes inserted at regular intervals to assess for the frequency and content of mind wandering. Each trial of the task began with the presentation of

an emotionally-charged (i.e., positively-valent, negatively-valent) or neutral-image stimulus followed by several iterations of the low-demand task. Participants reported on their current affective state at two time-points per trial: (a) immediately following stimulus presentation, and (b) approximately 45 seconds later, at the end of each trial. Multilevel modeling for repeated measures was utilized to examine the resulting interrelationships between reported depressive symptomatology, mind wandering, and dynamic affective responses, with an emphasis on affective decay in the brief temporal window following presentation of the emotionally-salient images.

Results. In a replication of previous research, increased levels of depressive symptomatology were associated with significantly greater mind wandering frequency across the task. Additionally, it was found that participants mind wandered more frequently following the display of both positively- and negatively-charged images, compared to neutral-image controls, but this effect did not interact with the level of depressive symptoms. Nevertheless, experimental condition *was* a significant moderator in the relationship between depressive symptoms and the *content* of off-task thinking that occurred: generally, negative stimulus presentation strengthened the depressive relationship with negative-content mind wandering and perseveration on the negative stimulus, whereas positive stimulus presentation weakened the relationship between depressive symptoms and positive-content mind wandering. In the prediction of affect decay over time following stimulus presentation, increased levels of depressive symptomatology were associated with significantly greater negative affect *sustainment* following the presentation of negative stimuli. Critically, this relationship was significantly moderated by mind wandering frequency, which strengthened the depressive effect. Alternatively, negative-content mind wandering and negative image perseveration were found to have significant main effects in

promoting negative affect sustainment across participants, but did *not* have significant interactions with level of depressive symptoms. Mind wandering frequency was not a significant moderator of the relationship between increased depressive symptomatology and stronger decay of positive affect following positive stimulus presentation. Instead, perseveration on the positive-stimulus was more *helpful*, and negative-content mind wandering was more *harmful*, in terms of the decay of positive affect over time for those with elevated depressive symptoms.

Conclusion. The results of this investigation provide preliminary evidence of processes by which mind wandering may impact affective dynamics, and particularly those that characterize the experience of elevated depressive symptomatology. Mind wandering in and of itself, regardless of its content, interacted with depressive symptoms to reduce the decay of negative emotion following exposure to a negative stimulus. Alternatively, following exposure to positively valent stimuli, it was mind-wandering of negative content that most directly contributed to depressive positive affect decay. Future replication of these results among clinical samples – particularly those with and without a diagnosis of major depressive disorder – would be a welcome extension of the present findings, as would the investigation of mind wandering and associated affective dynamics in more ecologically valid (non-experimental) real-world contexts.

Keywords: affective dynamics, attention, depression, emotion regulation, mind wandering, perseverative cognition, rumination

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Examining the Conjoint Impact of Depressive Symptomatology and Mind Wandering on Affective Dynamics in Response to Emotionally Salient Visual Stimuli

Major depressive disorder and related clinical syndromes are characterized by a complex web of etiological factors that span multiple levels of analysis: genetic, neurophysiological, hormonal, cognitive, behavioral, and social (Chen et al., 2000; Hankin, 2012). One fundamental, nearly universal feature of clinical depression, however, is the dysregulation of *affect*; that is, abnormalities in the intensity and valence of moods, emotions, and subjective feeling states (Barrett & Russell, 1999). Specifically, diagnosis of a major depressive episode requires a two week period of either strong, negative mood or diminished experiences of interest or pleasure (American Psychiatric Association, 2013).

Decades of research into the cognitive features of clinical depression point to a set of hallmark patterns of information processing that contribute to the disorder's characteristic affective dysregulation, and that usually distinguish between depressed and non-depressed individuals (Beck & Clark, 1988; Ingram, 1984; Rock et al., 2014). Most relevant studies, for example, have revealed consistent negative biases among depressed individuals in their interpretations of environmental stimuli, life events, and self-referent material (Brown & Siegel, 1988; Gotlib et al., 2004; Sweeney et al., 1986). These biases appear to arise from dysfunctions in underlying attentional and memory systems (Disner et al., 2011; Peckham et al., 2010), which yield negatively skewed accounts of experience, as measured both in-the-moment and retrospectively. Additionally, reward system dysfunction among depressed individuals has been implicated in their notable lack of engagement with pleasurable stimuli and activities (Martin-Soelch, 2009; Naranjo et al., 2001). Such reward deficits are evident in reduced activation of the nucleus accumbens – a key nexus of the brain's reinforcement circuitry – to positively-valent stimuli (Pizzagalli et al., 2009), together with decreased attentional and emotional responses to these stimuli at the behavioral level (McFarland & Klein, 2009).

The Dynamics of Affect

Beyond dysregulation of affect, both in terms of its intensity and valence, diagnostic and empirical conceptualizations of clinical depression highlight a separate, critical property of affect that may delineate between depressed and non-depressed populations – change in affect over time (Davidson, 2015). The study of affect as it changes over time, either naturally or in response to external stimuli, is known as *affective dynamics*, with individual differences in this construct referred to as *affective style* (Davidson, 1998; Zillmann, 2003). Research on affective dynamics can be differentiated from more basic studies of emotion by its longitudinal nature; relevant investigations aim to capture and compare affect, via neurophysiological or self-report measures, at multiple time-points (Davidson & Irwin, 1999). Specifically, studies of affective dynamics typically break down affective responses to external stimuli into two key structural components – emotion reactivity and emotion regulation (Davidson, 2004).

Previous research comparing the dynamics of emotion reactivity between depressed and non-depressed individuals has produced results that add considerable nuance to classic theories of affect dysregulation in depression. For example, a meta-analysis of 19 studies capturing affect through various measures (e.g., self-report, physiological, and behavioral) has found that clinical depression is associated with *reduced* emotion reactivity to negative events, in comparison with healthy participants, despite higher baseline levels of negative affect (Bylsma et al., 2008). This same analysis also found support for reduced emotion reactivity to positive stimuli, raising the possibility that depressive mood is maintained by an *emotional context insensitivity* (ECI); that is, reduced reactivity to both negative and positive stimuli (Bylsma et al., 2008). ECI theory also has some support at the neurophysiological level, inasmuch as reduced activity in the left frontal cortex is an established marker of depressotypic affective style – one believed to bias attentional networks away from the individual's immediate situational context (Wheeler et al., 1993). Such results are congruent with the well-established finding of dysregulated negative affect among depressed individuals, but they also suggest that such dysregulation may not be explained merely on the basis of initial reactions to negative stimuli.

Research on the dynamics and chronometry of emotion regulation suggests, for example, that clinical depression is associated with more rapid rates of positive affect decay and slower rates of negative affect decay, following the presentation of affective stimuli (Davidson, 1998; Davidson, 2004; Hemenover, 2003). In other words, abnormal *durations* of affective response – either positive or negative in valence – appear to characterize depression, and may play a role in the disorder's hallmark affective dysregulation. Although disordered depressive emotion regulation is likely the result of multiple processes, one cognitive finding is particularly notable in this context: depressed individuals engage in *perseverative cognition* as a typical response to negative events (Nolen-Hoeksema et al., 2008). Perseverative cognition can take the form of *rumination* (in response to past events) or worry (in response to upcoming events); in both cases it is typically conceptualized as intrusive, repetitive processing of negative experiences or negative aspects of an experience (Brosschot et al., 2006). Thus, perseverative cognition can be seen as a maladaptive form of depressive information processing that can extend the duration of a negative affective response beyond the experience of the stimulus itself (Aldao et al., 2010; Joormann & D'Avanzato, 2010).

Beyond Stimulus and Response: Mind Wandering

Although a substantial share of human attention and subsequent higher-order cognitive processing is allocated to interpreting the moment-to-moment flow of immediate environmental stimuli, some cognitive events have been long-known to be completely uncoupled from the environment (Taylor & Fiske, 1978). Neuroimaging work has supported this contention with the discovery of distinct neural pathways for stimulus-driven and personal-salience processing, respectively, with competition between these two networks resulting in attentional states that shift fluidly between task-related and unrelated thought content (Corbetta & Shulman, 2002). Additionally, neuroscientists have elucidated a baseline state of synchronized neural processing across distributed cerebral circuits, termed the *default mode network* (DMN), derived in part from the finding that non-task resting states (e.g., eyes-closed but awake; Greicius et al., 2003) elicit uniform patterns of brain activation (Raichle et al., 2001). It also appears that "resting" DMN brain states consume nearly as much metabolic energy as stimulus-driven attentional states (Raichle & Mintum, 2006). Taken together, the aforementioned findings provide support for the idea that the brain engages in important information processing even in the absence of environmentally supplied information, or, attention to external stimuli (Raichle, 2015).

Mind wandering refers to the cognitive process through which an individual's attention is internally directed away from outward sensory experience towards thought content unrelated to the task at hand (Smallwood & Schooler, 2015). The phenomenon may be further sub-divided into its individual components such as stimulus-independent thought (SITs), task-unrelated thought (TUTs), self-generated thought, or spontaneous cognition (Christoff et al., 2016). All forms of mind wandering appear to engage several underlying cognitive processes, including attention, working memory, long-term memory systems, perceptual decoupling, and sensorygating (McVay & Kane, 2009). Unsurprisingly, mind wandering is also associated with activity in the DMN (Christoff et al., 2009), as well as non-DMN brain regions such as the prefrontal cortical areas that mediate executive functions (Fox et al., 2015).

Based on ecological studies utilizing experience sampling methodologies among healthy adults, researchers have estimated that 30-50% of wakeful experience is spent in mind wandering states (Killingsworth & Gilbert, 2010; Smallwood & Schooler, 2015). Although mind wandering is generally considered a normal, ubiquitous phenomenon, it can have both positive and negative consequences for cognitive functioning (Mooneyham & Schooler, 2013). Accordingly, researchers continue to debate if mind wandering is best conceptualized as an adaptive function or as a failure of frontal executive control (McVay & Kane, 2010; Smallwood, 2010), and it remains unclear the degree to which individual differences in mind wandering contribute to clinical pathology (Ottaviani et al., 2013).

Observing the Wandering Mind

The potential impact of mind wandering on cerebral information processing and affective dysregulation appears to be influenced principally by two distinct mind wandering components: frequency and content (Smallwood & Schooler, 2015). Although recent years have witnessed the incipient development of behavioral and physiological markers of mind wandering, such as EEG (Smallwood et al., 2008), eye-blink (Smilek et al., 2010), and pupillometry (Grandchamp et al., 2014; Siegle et al., 2014), the occurrence and content of mind wandering episodes is most commonly assessed via self-report *thought probes* during the completion of a standardized external task (Mrazek et al., 2013). Thought probes of various forms (e.g., "Was your thinking currently on task;" "Did your off-task thinking contain negative thought content?") have been used both in real-world and laboratory settings to acquire measurements of mind wandering phenomenology. Research on the content of mind wandering episodes has previously examined its affective (i.e., positive or negative), social (i.e., self- or other-related), and temporal (i.e., past- or future-oriented) qualities (Hoffmann et al., 2016; Ruby et al., 2013).

Within a controlled laboratory setting, external tasks are typically employed to provide a reference point in distinguishing between on-task and off-task thinking (Smallwood & Schooler, 2015). The most commonly employed external tasks are Choice Reaction Time (CRT) tests and the Sustained Attention to Response Task (SART), respectively. In these rather boring tasks, simple stimuli (e.g., digits) are sequentially displayed on a computer screen and participants are instructed to provide a simple input (e.g., pressing the spacebar) in response to "target" stimuli (e.g., odd digits), while inputting no response to non-targets (e.g., even digits). Although the ratio of targets to non-targets may vary, studies typically employ relatively low target-to-non-target ratios (e.g., 1:6), thereby lowering the cognitive demand of the task and thus increasing the overall frequency of mind wandering (Smallwood & Schooler, 2015). The task is also briefly interrupted from time to time in order to "sample" the participant's immediately antecedent experience with thought probes (Csikszentmihalyi & Larson, 2014), providing in-the-moment reports of mind wandering and reducing biases associated with retrospective reporting. Although there exist some slight differences between the aforementioned CRT and SART tasks (e.g., in the type and timing of stimuli), they are regarded as more or less functionally equivalent by most mind wandering researchers (e.g., Smallwood & Schooler, 2015).

As research in this area has progressed in recent years, and a dynamic framework of the wandering mind has begun to take form (Christoff et al., 2016), a number of methodological and conceptual questions have come more clearly into focus (Stawarczyk et al., 2011; Weinstein, 2017). For example, as it is typically assessed, frequent mind wandering could be caused either by a large number of brief, distinct mind wandering episodes or by only a few individual episodes of longer duration. Likewise, mind wandering content during any brief assessment window may contain mixed elements of both task-related and task-unrelated thought (a possibility not accounted for in the typical assessment methodology), and these mixed elements may vary in the degree to which they are detached from sensory experience (Schooler et al., 2011). Therefore, much still remains unknown about changes in mind wandering frequency over time, as well as the relationship of mind wandering to various forms of competing sensory experience.

Mind Wandering Within Depression: Connections to Perseverative Cognition

A series of studies have reported a significant relationship between the occurrence of mind wandering and concurrent negative affect (Smallwood et al., 2009; Poerio et al., 2013). In fact, at least one study has found mind wandering to be a better predictor of participants' in-the-moment negative affect than the actual type of activity (e.g., at work, at school, etc.) in which the mind wandering episodes occurred (Killingsworth & Gilbert, 2010). A recent review (Konjedi & Maleeh, 2017) has also supported the immediate temporal relationship between mind wandering and negative affect among non-depressed individuals. However, high-quality work on the *causal* relationship between mind wandering and negative affect is more limited. In one notable exception, Ruby and colleagues (2013), utilized a repeated-measures approach with lag analyses and found that the momentary occurrence of mind wandering was a significant predictor of increased negative affect at the next measured time point.

The intriguing observed association between mind wandering and the experience of negative affect has piqued considerable recent interest among depression researchers (Smallwood & Schooler, 2015), especially regarding the potential depressive impact of mind wandering frequency and content. Several studies have found increased mind wandering frequency to be a characteristic of the depressive syndrome (Carriere et al., 2008; Deng et al., 2014; Murphy et al., 2013; Smallwood et al., 2007; Stawarczyk et al., 2012). On the other hand, two methodologically rigorous studies (Hoffmann et al., 2016; Ottaviani et al., 2015) have reported mind wandering to be more frequent among depressed versus control participants only for mind wandering content that is negative in its content. Moreover, the great majority of relevant work has pointed to a substantial association between depressive symptomatology and mind wandering content representing either rumination or worry (Finnbogadóttir & Berntsen, 2013; Marchetti et al., 2014; Ruby et al., 2013; Selby et al., 2007; Smallwood and O'Connor, 2011; although see Marchetti et al., 2012 for a reported a null finding, albeit in a non-clinical sample of merely dysphoric participants).

Critically, however, these previous attempts to disassociate mind wandering and perseverative cognition – for example, on the basis of thought content – have been limited by a lack of consensus about whether or not rumination and other forms of perseverative thought should even be considered forms of mind wandering at all. Mind wandering and perseverative cognition are certainly conceptually linked, inasmuch as they both involve intrinsic thought processes that are often unrelated to the current flow of sensory experience (Smith & Alloy, 2009). However, given the perseverative nature of rumination and worry, some have argued that it is categorically distinct from most other forms of mind wandering, which tend to be more ephemeral and fleeting (Ottaviani et al., 2013). However, consistent with the most widely-accepted conceptualization of mind wandering (Smallwood & Schooler, 2015), perseverative cognition is typically considered a form of mind wandering when it is: (a) unrelated to the current task at hand; and (b) self-generated (rather than triggered by some feature of the environment). Mind wandering and perseverative cognition are also linked through one salient neuroscientific finding: an altered functional connectivity within the DMN of depressed individuals is consistent both with increased rumination frequency and a proclivity for mind wandering (Hamilton et al., 2015).

It remains to be determined the extent to which mind wandering makes a distinctive contribution, above and beyond that of perseveration and negative thinking, to specific affective features of the depressive syndrome (Ottaviani et al., 2015). Previous work, of course, has already established rumination as a risk factor in the onset of depression (Spasojević & Alloy, 2001), as well as a key maintenance factor in depression associated with more severe symptomatology (Nolen-Hoeksema, 2000). However, this established effect of perseverative, ruminative cognition by no means rules out potential depressive effects of mind wandering itself, with or without ruminative content. For example, negative mood may conceivably be promoted by the frequent occurrence of non-ruminative mind wandering episodes that still cause disengagement from external, rewarding stimuli and from associated positive thoughts. In fact, mind wandering episodes have been shown to interfere with the cognitive processing of potentially rewarding educational tasks, such as reading and writing, among non-dysphoric groups (Smallwood et al., 2007; Mooneyham & Schooler, 2013). Additionally, Hoffman and colleagues (2016) found that a lack of positively-valent mind wandering content was a better predictor of depression than was an increase mind wandering that was negatively-valent.

Purpose and Novelty of the Present Study

It appears, on the basis of the above-reviewed set of findings, that a comprehensive explication of affective disturbance in clinical depression may require a better understanding of the relationship between depressive symptomatology and mind wandering. The previous literature has established independent main effects of depression and mind wandering on affect, wherein both are associated with reduced positive affect and greater negative affect. Moreover, previous work has suggested that increased mind wandering frequency is a characteristic of the depressive syndrome, although questions remain about the degree to which this finding is restricted to mind wandering consisting of negative thought content. However, to the author's knowledge no study has yet directly investigated the relationship between depressive symptomatology and mind wandering following the presentation of various kinds of affective stimuli (i.e., neutral, negative, positive). Due to differences in affective dynamics between depressed and non-depressed individuals (e.g., emotional context insensitivity), the presentation of affective stimuli may modify the interplay of depressive symptoms and mind wandering in three fundamental ways: (a) it may modify the strength or direction of the relationship between depressive symptomatology and mind wandering frequency (i.e., the occurrence of off-task thought); (b) it may modify the strength or direction of the relationship between depressive symptomatology and the *content* of off-task thinking that occurs (e.g., positive-content mind wandering, negative-content mind wandering, or perseveration on the affective stimulus); and (c) it may modify the role of mind wandering as a moderator in the relationship between depressive symptomatology and affective dynamics, when accounting for both the occurrence and content of off-task thoughts. Addressing these notable gaps in the published literature constitutes the major aim of the present study.

Study Overview & Hypotheses

A stratified sampling technique was used to recruit individuals with minimal-to-moderately high levels of self-reported depressive symptomatology. Following a questionnaire to measure the presence of acute depressive symptoms at the time of the study, participants completed a modified CRT task, with intermittent thought probes to assess for the frequency and content of mind wandering. Each trial of the CRT task began with the presentation of an emotionally-charged (i.e., positively-valent, negatively-valent) or neutral stimulus and participants reported on their current affective state at two time-points per trial: immediately following stimulus presentation and approximately 45 seconds later following several rounds of the CRT task and a thought probe. Multilevel modeling for repeated measures was then utilized to examine the resulting interrelationships between current depressive symptomatology with observed affect and mind wandering during the different trial types (i.e., neutral, positive, negative) of the task.

Hypothesis 1. For Hypothesis 1, I examine the effects of current depressive symptomatology, visual stimulus valence (positive or negative), and self-reported affect following stimulus presentation, on mind wandering frequency (with the latter defined by off-task thinking relative to the ongoing experimental task). Based on previous work (Carriere et al.,, 2008; Deng et al., 2014; Murphy et al., 2013; Smallwood et al., 2007; Stawarczyk et al., 2012), I hypothesized that the present study would find increased mind-wandering frequency to be a function of: (a) higher levels of depressive symptomatology; (b) lower levels of positive affect following stimulus presentation; and (c) higher levels of negative affect following stimulus presentation. Moreover, I predicted positive-image trials will reduce mind wandering frequency (relative to neutral-image controls), and negative-image trials to increase mind wandering frequency, due to their respective impact on affective state subsequent to stimulus presentation (Davidson & Irwin, 1999).

Of particular novelty to the present study will be the interaction effects involving depressive symptomatology and changes in ongoing affective dynamics in the prediction of mind-wandering frequency. Because emotional reactivity is expected to be blunted for those with higher depressive symptomatology (Bylsma et. al., 2008), negative stimuli may elicit considerably greater increases in negative affect among the non-depressive than among the more depressed participants (the latter of whom are already dysphoric, but not particularly responsive to such stimuli), thereby resulting in more comparable levels of mind wandering across varying levels of depressive symptomatology. Conversely, positive stimuli may carry the potential to *amplify* any pre-existing affective differences among participants. Therefore, the unique effect of present depressive symptoms on mind-wandering frequency could conceivably be attenuated in the presence of negative emotional stimuli and strengthened under a positive emotional context.

Hypothesis 2. For Hypothesis 2, I adopted an identical modeling approach to examine the effects of depressive symptomatology, post-stimulus affect, and experimental condition on the *content* of off-task thinking: positive-content mind wandering, negative-content mind wandering, and perseveration on the recently displayed trial image. Based on previous research, I hypothesized that significant main effects would emerge for affect-congruent mind wandering, with depressive symptomatology, negative affect, and negative-images predicting increased negative-content mind wandering (Ottaviani al., 2015). Conversely, reduced depressive symptoms, positive affect, and positive stimuli were expected to increase positive-content mind wandering (Hoffman et a., 2016). I expected the main effect of depressive symptomatology on *image-based perseveration* to be non-significant when collapsed across experimental conditions, inasmuch as increased depressive symptoms has been found to increase perseveration on negative stimuli (Disner et al., 2011; Peckham et al., 2010) while decreasing continued thought on positive stimuli (Martin-Soelch, 2009; Naranjo et al., 2001). As with Hypothesis 1, the novel interaction effects involving depressive symptomatology and changes in affective dynamics between experimental conditions were hypothesized to attenuate the relationship between depressive symptoms and increased negative-content mind wandering in the presence of negative emotional stimuli, while strengthening the relationship between depressive symptoms and reduced positive-content mind wandering in the presence of positive emotional stimuli (Bylsma et. al., 2008).

Hypothesis 3. For Hypothesis 3, I examined the effects of depressive symptomatology and mind wandering (i.e., off task thinking) on acute affective changes over the course of the experimental trials (specifically, on the difference between affect immediately following stimulus presentation and affect reported 45 seconds later, at the end of each trial). As the temporal dynamics of positive and negative affect may differ (Davidson, 1998; Davidson, 2004; Hemenover, 2003), I analyzed these models separately for positive affect change within positive-image trials and negative affect change within negative-image trials. Inasmuch as the examination of the conjoint effects of depressive symptoms and mind wandering on affective dynamics under experimental affective manipulation represents the novel component of the study, this hypothesis is largely exploratory in nature. However, it can be stated the null hypothesis would be rejected if a significant interaction is observed between depressive symptomatology and mind wandering, as compared to mere the existence of independent main effects, as established in previous work on predictions of concurrent affect at a given point in time (Konjedi & Maleeh, 2017). I hypothesized the existence of a significant interaction effect between depressive symptomatology and mind wandering, in which both phenomena may combine to induce even greater perturbations of affect than would be observed based on their simple main effects alone. Moreover, this analysis was expected to provide information on the degree to which the aforementioned effects may be explained, independently or conjointly, by the specific *form* of off-task thinking that occurs (i.e., positive-content mind wandering, negative-content mind wandering, or perseveration on the affective images).

Method

Participants

A total of 187 participants were recruited for the study. After exclusions (described under "Inclusion and Exclusion Criteria"), the resulting study sample was 173 participants (90 female; *M* Age = 18.79; See Table 1 for full participant characteristics). All participants were undergraduates at the University of Kansas and registered for the University of Kansas Research Participation System (i.e., SONA Systems), which required enrollment in a University of Kansas course that offered credit for research participation and completion of the SONA Systems screening survey. All participants completed the study for course credit.

Inclusion and exclusion criteria. Additional inclusion criteria mandated fluency in English to ensure understanding of task instructions, a minimum 18 years of age at the time of consent, as well as no current use of psychotropic medications (e.g., psychostimulants, anti-depressants). This latter criterion was implemented due to the potential influence of psychotropic medication on variables of interest to the present study (e.g., mind-wandering frequency, depressive symptomatology). In total, 14 participants who consented to the study were excluded from data analysis. Two participants were excluded for taking psychotropic medication on the day of the study. One participant was excluded for withdrawing from the study during the first experimental block due to study-unrelated illness. Finally, eleven participants were excluded from data analysis due to evidence of non-valid responses to the experimental task, including having at least 75% of their thought or affect probe ratings consisting of two or fewer digits (e.g., responding with only 1s or 9s on ≥75% of trials).

Sampling method. A stratified sampling technique was employed to promote variability in the current level of reported depressive symptomatology amongst participants. Two independent strata were recruited on the basis of scores on the Beck Depression Inventory-2nd Edition (BDI-II; Beck, Steer, & Brown, 1996) as administered on the SONA Systems screening survey prior to study enrollment (See “Measures” for psychometric information on BDI-II). The first strata (*N* = 113) was recruited with no restrictions regarding minimum BDI-II score on the screening survey. The second strata (*N* = 60) was recruited with the requirement that participants scored 12 or higher on the BDI-II; a score of 14 is a widely used cutoff for the presence of clinically significant depressive symptomatology (Beck et al., 1996). Participant-level data on BDI-II scores was not made available; researchers utilizing SONA Systems were merely able to select requirements for study inclusion rather than being supplied with an individual’s survey scores. Of additional note, the SONA Systems version of the BDI-II excluded the suicidality question.

To ensure that stratification was successful in promoting sufficient variability in levels of depressive symptomatology among participants, a between-groups analysis testing for differences in depressive symptomatology between strata was conducted utilizing the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977), as assessed at the time of the study. This analysis revealed a significant difference between groups (t (107) = -4.80, $p < .001$), with the elevated BDI-II group (M = 19.90, SD = 9.76) reporting substantially higher depressive symptomatology on the CES-D than the non-BDI-II group (M = 12.74, SD = 8.50). Moreover, strong variability characteristics for CES-D scores (CES-D: M = 15.23, SD = 9.53, Range = 1 – 47) provided further support good dispersion of levels of depressive symptomatology in the study sample (See Figure 1 for graphical display of CES-D scores across participants).

Procedure

Excepting the BDI-II administered as part of the SONA Systems screening survey, participants completed all research activities in a single visit to a research laboratory at the University of Kansas. All participants were run through the study individually. After signing the consent form, participants were seated in front of a computer screen with access to mouse and keyboard. Participants were provided with noise cancelling head phones that were worn for the duration of the experimental task. Using Qualtrics questionnaire administration software, participants completed the CES-D at the beginning of the session and a brief demographics survey at the end of the session.

Experimental task. Following a brief training period (see “Task training”), participants completed the experimental task. Each trial of the experimental task was comprised of two core components: the presentation of an image-based stimulus followed by a task designed to elicit mind wandering (see Appendix A for a diagram of trial structure). At the beginning of each trial, an image from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) was displayed for five seconds. Based on standardized ratings (see “Selection of IAPS images” for details), images were neutral, negative, or positive in valence. Participants were instructed to look at the picture the entire time it was on the screen but to otherwise respond to each picture as they would naturally. Immediately following the image, a self-paced affect probe was administered. The affect probe assessed positive (“How positive are you currently feeling?”) and negative (“How negative are you currently feeling?”) affect, both using a nine-point Likert scale (1 = Not at all, 9 = Extremely).

Following completion of the affect probe, participants began a choice reaction time (CRT) task similar to that employed by Ruby and colleagues (2013). In the CRT portion of each trial, black and green digits (i.e., 1-9) were presented serially on the computer screen. Participants were instructed to push one of two buttons to indicate whether the digit was odd or even but only for green digits; participants were instructed not to respond when a black digit was presented. Critically, black and green digits were displayed at an overall ratio of 8:1, lowering the cognitive demand of the task and increasing the likelihood of mind wandering. Black digits were displayed for 1000 ms while green digits were displayed for 2000 ms to allow for response recording. All digits were separated via fixation cross (2000 ms).

During the CRT portion of each trial, participants were interrupted with multiple thought probes to measure the frequency and content of mind wandering. These probes were self-paced and administered sequentially within a single interruption of the task. The interruption occurred once per trial and the timing of the interruption was standardized, so that the thought probe appeared following eight digit presentations of the CRT trial portion. All participants were trained to report on their experience of mind wandering just prior to the interruption of the task.

The thought probe (Appendix B) contained four questions presented on two sequential screens, each using a nine-point Likert scale (1 = Not at all, 9 = Completely). The four questions were presented as follows: “How much were you thinking about the digit task?”, “How much were you thinking about the previous picture?”, “How much were you thinking about PLEASANT events/people/ideas unrelated to the task?”, “How much were you thinking about UNPLEASANT events/people/ideas unrelated to the task?” After both self-paced screens were completed, the CRT trial portion resumed with the presentation of four additional digits, followed by the presentation of another affect probe that was identical in form to the affect probe at the beginning of the trial. Following this second affect probe, a fixation cross would be displayed and the next trial would begin with the presentation of a new IAPS image. The entire experimental task took approximately 40-50 minutes to complete per participant.

Measures

Beck Depression Inventory – 2nd Edition (BDI-II). The BDI-II is a self-report questionnaire that is commonly used in the assessment of depressive symptom severity in both clinical and non-clinical samples (Beck et al., 1996). The psychometric properties of the BDI-II have been reported across a variety of populations (Beck et al., 1996), including good concurrent validity with other depressive measures (*rs* = .76) and strong internal reliability (.90) in undergraduate populations (Storch, Roberti, & Roth, 2004). However, the BDI-II should not be used as a stand-alone measure to separate clinically depressed from non-depressed groups (Jackson-Koku, 2016); rather, the BDI-II is best used to define depressive symptom severity, regardless of clinical status, as minimal (0-13), mild (14-19), moderate (20-28), or severe (29-63; Beck et al., 1996). Therefore, the BDI-II was used as part of the stratified sampling method for the present study to promote variability in depressive symptoms severity amongst participants.

Center for Epidemiological Studies- Depression (CES-D). The CES-D is a 20-item self-report questionnaire designed to assess for the experience of symptoms associated with clinical depression over the past week (Radloff, 1977). Response options range from 0-3 for each item, resulting in a possible range of total scores of 0-60, with higher scores indicating a greater level of current depressive symptoms. Researchers have identified a score of 16 as a clinically useful cut-off for those at-risk for major depression (Lewinsohn et al., 1997), with good sensitivity, specificity, and internal reliability. In the present study, the CES-D was used as a continuous predictor across participants representing current level of depressive symptomatology, although it is worth noting that 75 of the 173 participants (43.4%) scored 16 or above on the CES-D at the time of the study.

Instructions and Stimuli

Task training. Following CES-D administration, participants received training on the upcoming experimental task. This training session was computer-based and utilized pre-recorded audio instructions to provide examples of the stimuli and thought probes the participants would encounter during the task. Participants were instructed that some of the images in the task may make them feel emotional, while other pictures might not make them feel anything at all. Furthermore, participants were instructed to keep their eyes on the digits and pictures while the task was ongoing; however, they were also told that it is typical for attention to shift between the digits, images, and task-unrelated content during the span of the task. It was therefore explained that thought probes would occur throughout the task for participants to report on their emotional and attentional state at the moment of the probe. Participants were given examples of different types of thinking that may occur during the task (i.e., thinking about the digits, thinking about pictures, thinking about unrelated content) and instructed on how they would use the rating scales to report on these different kinds of thought content. This training session took approximately 10 minutes to complete.

Experimental block design. The experimental task was administered in a block design with one block containing neutral and positive-images and the other block containing neutral and negative-images. The task was counterbalanced between participants so that approximately half of participants were presented with positive stimuli in the first and third blocks (i.e., ABAB) and half were presented with negative stimuli in the first and third blocks (i.e., BABA). Each block contained eight trials (four neutral, four positive/negative), beginning with a neutral trial and alternating between neutral and affective images throughout. This alternation is being employed, rather than a randomization, to limit carryover effects of affect from trial to trial. Each experimental block took approximately 10 minutes to complete and participants were given a one-minute break between each block. In total, the task included 32 trials (8 positive-image trials, 8 negative-image trials, 16 neutral-image trials).

Selection of IAPS images. The International Affective Picture System (IAPS; Lang et al., 2008) is a standardized set of pictures for use in studies employing stimuli in their measurement of affective responses. The pictures most commonly depict real life scenes, in which humans, animals, and objects are seen in various situations (Lang et al., 2008). Standardization of the picture set involved self-report ratings of the images based on their perceived valence (i.e., positive or negative) as well as induced arousal (Lang et al., 2008).

Thirty-two IAPS images (8 positive, 8 negative, and 16 neutral) were selected for the study based on their standardized valence scores. Cutoffs of valence (V) were used to categorize images as positive ($V > 7$), neutral ($5.5 > V > 4.5$), or negative ($3 > V$). Additionally, image selection excluded images that were likely to cause severe or idiosyncratic reactions, such as pictures containing gore, sexual imagery, or stereotypical phobic material (e.g., snakes, needles, etc.).

Statistical Analyses

Selection of analytical approach. A multilevel modeling approach for longitudinal data was utilized to analyze the relationships between key variables of interest. A multilevel approach was selected because it is well suited to modeling both the variance explained by repeated measurements over time (Level 1) as well as variance explained by differences between participants (Level 2; Shipley, 2009). The primary advantage of such a multilevel framework, over more traditional approaches such as repeated measures ANOVA, is that it allows for more complex model structures in which comparisons can be made between three different types of predictors: a time predictor, time-variant predictors, and time-invariant predictors. This is especially important for the present study, given the emphasis on examining the potential interactions between mind wandering and affect (i.e., time-variant predictors) with depressive symptoms (i.e., a time-invariant predictor). Moreover, it is also important to control for the effect of time, as previous research has demonstrated that mind wandering frequency and negative affect increase over time during the completion of CRT tasks (Ruby et al., 2013).

Model construction. All models were estimated using a restricted maximum likelihood estimator (REML) and the models were run with complete data without imputation (i.e., no missing data), as all measurements throughout the study were self-paced and forced completion. CES-D scores were standardized and all time-variant variables used as predictors (e.g., mind wandering and affect) were centered at the mean. This was done to reduce multicollinearity concerns when assessing for interactions between variables, as well as to account for the non-existence of a true zero point for the time -variant data (i.e., it was measured on a 1-9 scale). All models were analyzed for mixed effects as they investigated fixed slope effects of the predictor variables of interest while allowing for a random intercept at the participant level. Moreover, all models were constructed utilizing a Variance Components covariance structure - the default. Although longitudinal modeling sometimes utilizes an autoregressive structure, this approach was not used for the present analysis because observations closer together in time were not expected to consistently be more closely correlated than those farther apart, given the block design of the experimental task (i.e., ABAB).

Operationalizing study variables. CON will represent the type of trial (i.e., experimental condition) in which a given set of measurements were observed, as defined by the type of image displayed (i.e., neutral, positive, negative) at the beginning of the trial. This variable was categorical with three factors, termed NEUCON, POSCON, and NEGCON, respectively, utilizing neutral trials as the level of comparison (i.e., positive trials will be compared against neutral trials and negative trials will be compared against neutral trials). Neutral trials were collapsed across blocks, so that NEUCON represented all neutral trials in the study; this was done in order to ameliorate the effects of potential affective carryover, wherein affect from a positive or negative-image trial “bled” into the subsequent neutral trial. In sum, NEUCON represented 2,768 observations for each time-variant study variable (16 trials x 173 participants), whereas POSCON and NEGCON represented 1,384 observations for each variable, respectively (8 trials x 173 participants).

TIME was included as a predictor variable in all models, representing the time of trial (i.e., trial number in the experimental task) as has been employed in previous studies to account for variance in affect and mind wandering explained by the longitudinal nature of the task (Ruby et al., 2013). TIME was reduced by one across the dataset so that the first trial represented the zero-point at which TIME would be fixed when interpreting the regression coefficients of key study predictors.

FREQ represented the occurrence of mind wandering, as assessed by ratings on the thought probe: “How much were you thinking about the digit task?” It is critical to note that FREQ was reverse-coded, so that higher scores on FREQ represent *increased* mind wandering frequency, with lower scores representing increased on-task thought. PIC represented the occurrence of perseveration on the previously displayed image and was defined by ratings on the thought probe: "How much were you thinking about the previous picture?" MWPOS represented the occurrence of mind wandering content that was positive and defined by ratings on the probe: "How much were you thinking about PLEASANT events/people/ideas unrelated to the task?" Finally MWNEG represented the occurrence of mind wandering content that was negative and defined by the probe: "How much were you thinking about UNPLEASANT events/people/ideas unrelated to the task?"

Throughout hypothesis testing, separate models were constructed for positive and negative affect. This was due to high correlations between positive and negative affect reported during the experimental task ($r = -.56$ for affect immediately following stimulus presentation; $r = -.40$ for affect reported at the end of each trial) and resulting issues with multicollinearity and model fit. In operationalization, AFFECT 1 represented self-reported affect immediately following IAPS image presentation, whereas AFFECT 2 represented self-reported affect at the end of each trial. Change in affect over the course of the trial is represented by Δ AFFECT, calculated by subtracting AFFECT 2 from AFFECT 1. Therefore, Δ AFFECT can be conceptualized as the magnitude of *affective decay* over time, with stronger reductions in affect over time associated with higher levels of Δ AFFECT. It is worth clarifying that the interpretation of Δ AFFECT is different for positive as compared to negative affect, inasmuch as a reduction of positive affect can be thought of as mood worsening, whereas reductions in negative affect can be thought of as mood improving. For example, it would be theoretically congruent for higher levels of depressive symptomatology to predict greater Δ AFFECT for positive affect (i.e., stronger affective decay, and therefore an attenuation of positive affect over the course of the trial) and reduced Δ AFFECT for negative affect (i.e., weaker affective decay, and therefore a sustainment of negative affect over the course of the trial).

Finally, CESD will represent current depressive symptomatology as calculated by standardized participant scores on the Center for Epidemiological Studies – Depression measure at the time of the study.

Results

Manipulation Check

The primary goal of the present study, as indicated by the study hypotheses, was to examine the relationship between depressive symptomatology and mind wandering in contexts that differed in their ongoing affective dynamics. Therefore, it was critical that the experimental manipulation of affective context was successful in: (a) generating different levels of emotion reactivity between conditions; and (b) generating different levels of affective change over time between conditions. The intended manipulations were checked by conducting Welch Two Sample *t*-tests to determine if AFFECT 1 (i.e., affect measured immediately following stimulus presentation) and Δ AFFECT (i.e., change in affect over the course of the trial) were significantly different between neutral and positive-image trials (i.e., for positive affect) and also between neutral and negative-image trials (i.e., for negative affect).

The manipulation of emotional reactivity for positive affect was supported (t (3074) = -20.77, $p < .001$), as AFFECT 1 in positive-image trials (M = 6.37, SD = 1.82) was significantly greater than AFFECT 1 in neutral-image trials (M = 5.07, SD = 2.05). Likewise, the manipulation of emotional reactivity for negative affect was supported (t (2276) = -27.77, $p < .001$), as AFFECT 1 in negative-image trials (M = 4.66, SD = 2.22) was significantly greater than AFFECT 1 in neutral-image trials (M = 2.76, SD = 1.76). The manipulation of positive affect change over time was also supported (t (2234) = -21.36, $p < .001$), as Δ AFFECT was significantly greater for positive-image trials (M = 1.12, SD = 1.58), as compared to neutral trials

(*M* = 0.09, *SD* = 1.22). Finally, the manipulation of negative affect change over time was also supported (*t* (2079) = -24.28, p < .001), as Δ AFFECT was significantly greater for negative-image trials (*M* = 1.35, *SD* = 1.81), as compared to neutral trials (*M* = 0.03, *SD* = 1.27). Overall, these statistical checks indicate good support for a successful manipulation of affective dynamics, both in terms of reactivity and change over time, between experimental conditions (See Table 2 for descriptive statistics of experimental task variables across trial type).

Notably, visual stimulus trials produced less change on *non-congruent*, as opposed to congruent, affect. In other words, positive affect change in negative-image trials (*M* = -0.75, *SD* = 1.36) and negative affect change in positive-image trials (*M* = -0.32, *SD* = 1.30) were significantly weaker effects than were the congruent affective changes reported in the preceding paragraph: affect congruent to positive-image trials (*t* (2705) = 33.49, p < .001) and negative-image trials (*t* (2510) = -27.93, p < .001), respectively. Although incongruent affective dynamics (e.g., predicting negative affect change following a positive stimulus presentation) may be an intriguing area of investigation for future analysis, these findings support a focus on congruent affective dynamics (e.g., positive affect change in positive-image trials) for the present study.

Hypothesis 1: Predictions of Mind-Wandering Frequency

For Hypothesis 1, mind wandering frequency (FREQ) was modeled as a function of time across the experimental task (TIME), depressive symptomatology (CESD), affect reported immediately following stimulus presentation (AFFECT 1), and experimental condition (CON), as well as theoretically salient interactions: between (a) CESD and AFFECT 1, and (b) CESD and CON. Once again, two models were utilized, each separately accounting for positive and negative AFFECT 1. Full model output for positive affect models is presented in Table 3, with full model output for negative affect models found in Table 4.

Positive affect model. As anticipated, TIME had a significant main effect of increasing mind wandering frequency as the experimental task progressed over time (β = 0.09, *SE* = .003, *p* < .001). As predicted and in replication of the majority of previous research, there was also a significant main effect of CESD on FREQ (β = 0.37 *SE* = .13, *p* = .005), wherein greater levels of depressive symptomatology predicted greater mind wandering frequency across all experimental conditions considered in aggregate. Additionally, there was a significant main effect of AFFECT 1 on FREQ (β = -0.08, *SE* = .017, *p* < .001), with increased positive affect (reported following stimulus presentation) predicting decreased mind wandering frequency. There were also remarkably similar, significant main effects of both POSCON (β = 0.21, *SE* = .060, *p* = .001) and NEGCON (β = 0.21, *SE* = .060, *p* = .001) on FREQ, wherein mind wandering frequency was greater in both positive-image trials and negative-image trials, as compared to neutral-image control trials. Intriguingly, although mind wandering decreased *overall* as a function of positive emotion, positive-image trials actually contributed to greater mind wandering frequency than did the neutral-images. There was also a statistically significant interaction between CESD and AFFECT 1 on mind wandering frequency (β = -0.03, *SE* = .016, *p* = .033), in which the mean effect of depressive symptomatology on mind wandering frequency was *weakened* (i.e., inhibited) as positive affect following stimulus presentation increased. The two-way interactions between CESD and POSCON (β = 0.05, *SE* = .060, *p* = .389), and, between CESD and NEGCON (β = 0.01, *SE* = .060, *p* = .902) were not statistically significant.

Negative affect model. Once again, TIME had a significant main effect of increasing mind wandering frequency as the experimental task progressed over time (β = 0.09, *SE* = .003, *p* < .001). Moreover, even when accounting for negative affect following stimulus presentation, CESD remained a significant positive predictor of mind –wandering frequency (β = 0.36 *SE* =

.13, *p* = .006), There was also a significant main effect of AFFECT 1 (*β* = 0.10, *SE* = .016, *p* < .001), with increased negative affect (reported following stimulus presentation) predicting increased mind wandering frequency. The main effects of both POSCON (*β* = 0.16, *SE* = .057, *p* = .006) and NEGCON (*β* = 0.13, *SE* = .064, *p* = .048) were both statistically significant, again indicating that positive- and negative-image trials contributed to increased mind wandering frequency as compared to neutral control trials. There was also a statistically significant interaction between CESD and AFFECT 1 (*β* = 0.04, *SE* = .016, *p* = .010), in which the overall positive association between depressive symptomatology and mind wandering frequency was strengthened (i.e., enhanced) as negative affect following stimulus presentation increased. Interactions between CESD and POSCON (*β* = 0.02, *SE* = .057, *p* = .670) and CESD and NEGCON (*β* = -0.02, *SE* = .063, *p* = .720) once again failed to reach statistical significance (See Figure 2 for a visualization of mind-wandering frequency as a function of depressive symptoms and experimental condition).

Hypothesis 2: Predictions of Off-Task Thought Content

For Hypothesis 2, an identical modeling approach was taken as described above for Hypothesis 1. In these analyses, however, positive –content mind wandering (MWPOS), negative-content mind wandering (MWNEG), and perseverating thoughts about the most recently presented IAPS image (PIC) were separately modeled as a function of time across the experimental task (TIME), depressive symptomatology (CESD), post-stimulus affect (AFFECT 1), and experimental condition (CON), as well as the theoretically salient interactions between CESD and AFFECT 1 as well as CESD and CON. In total, six models were utilized for Hypothesis 2, with full model output for positive affect models presented in Table 3, and full model output for negative affect models found in Table 4.

The prediction of positive-content mind wandering: positive affect model. In the prediction of positive-content mind wandering (MWPOS), TIME had a significant main effect, increasing positive-content mind wandering as the experimental task progressed over time (β = 0.03, *SE* = .003, $p < .001$). The main effect of CESD (β = 0.11 *SE* = .107, $p = .302$) was not statistically significant, but there was a significant main effect of AFFECT 1 (β = 0.28, *SE* = .017, $p < .001$), with increased positive post-stimulus affect predicting increased positive-content mind wandering. There were also significant main effects of both POSCON (β = 0.25, *SE* = .060, $p < .001$) and NEGCON (β = -0.48, *SE* = .060, $p < .001$) on MWPOS, but in opposing directions: positive-image trials increased positive-content mind wandering (relative to neutral-image control trials), whereas negative-image trials decreased positive-content mind wandering. There was also an intriguing, statistically significant interaction between CESD and post-stimulus affect (β = 0.03, *SE* = .016, $p = .045$), in which the association between positive post-stimulus affect and positive-content mind wandering was strengthened as depressive symptoms increased. Moreover, the interaction between CESD and POSCON (β = -0.12, *SE* = .060, $p = .045$) was also statistically significant, with the impact of positive-images, as compared to neutral-images, on increased positive-content mind wandering becoming *weaker* as depressive symptoms increased. Finally, the interaction between CESD and NEGCON (β = -0.06, *SE* = .060, $p = .311$) was not statistically significant, indicating that the effect of negative-image trials on decreased positive-content mind wandering was not moderated by depressive symptomatology.

The prediction of positive-content mind wandering: negative affect model. As expected, TIME had a significant main effect of increasing positive-content mind wandering as the experimental task progressed over time (β = 0.03, *SE* = .003, $p < .001$). The main effect of CESD (β = 0.02, *SE* = .112, $p = .827$) was not statistically significant but there was a significant main effect of post-stimulus negative affect (β = -0.18, *SE* = .016, $p < .001$), with increased negative affect predicting decreased positive-content mind wandering. There were also significant main effects of both POSCON (β = 0.52, *SE* = .058, $p < .001$) and NEGCON (β = -0.51, *SE* = .065, $p < .001$) in opposing directions: positive-image trials increased positive-content mind wandering, relative to neutral-image control trials, whereas negative-image trials decreased positive-content mind wandering. The interaction between CESD and post stimulus affect (β = -0.07, *SE* = .016, $p = .562$) was not statistically significant. Moreover, neither the interaction between CESD and POSCON (β = -0.07, *SE* = .057, $p = .204$), nor between CESD and NEGCON (β = -0.08, *SE* = .064, $p = .186$) reached statistical significance, indicating the effect of experimental manipulation on positive-content mind wandering was not moderated by depressive symptomatology (See Figure 3 for a visualization of positive-content mind wandering as a function of depressive symptoms and experimental condition).

The prediction of negative-content mind wandering: positive affect model. TIME had a significant main effect of increasing negative-content mind wandering as the experimental task progressed over time (β = 0.02, *SE* = .002, $p < .001$). Combined with previous results, this finding is indicative of time having a universal effect, wherein as time spent in the experimental task increases, mind wandering increases, both in its positive and negative forms. There was a statistically significant main effect of CESD (β = 0.17 *SE* = .081, $p = .034$), with increased depressive symptomatology predicting increased negative-content mind wandering. There was also a significant main effect of post-stimulus affect (β = -0.21, *SE* = .015, $p < .001$), with increased post-stimulus positive affect predicting decreased negative-content mind wandering. There were also significant main effects of both POSCON (β = 0.12, *SE* = .054, $p = .022$) and NEGCON (β = 0.80, *SE* = .054, $p < .001$) in identical directions: positive- and negative-image trials, as compared to neutral trials, increased negative-content mind wandering. The interaction between CESD and post-stimulus positive affect was not statistically significant (β = 0.01, *SE* = .014, *p* = .351), nor was the interaction between CESD and POSCON (β = 0.00, *SE* = .054, *p* = .965). However, the interaction between CESD and NEGCON was statistically significant (β = 0.11, *SE* = .053, *p* = .039), indicating the effect of negative-image trials, as compared to neutral-image controls, on negative-content mind wandering was strengthened as depressive symptomatology increased. This result may indicate reduced flexibility of those with elevated depressive symptomatology to avoid mind wandering on negative topics when challenged by negatively-valenced stimuli/events.

The prediction of negative-content mind wandering: negative affect model. TIME had its typical, significant main effect of increasing negative-content mind wandering as the experimental task progressed over time (β = 0.02, *SE* = .002, *p* < .001). There was again a positive, statistically significant main effect of CESD (β = 0.15 *SE* = .067, *p* = .028), and a significant main effect of post-stimulus affect (β = 0.35, *SE* = .014, *p* < .001), with increased negative affect as reported post-stimulus predicting increased negative-content mind wandering. The main effect of POSCON was no longer statistically significant (β = 0.03, *SE* = .049, *p* = .525), whereas the main effect of NEGCON remained (β = 0.41, *SE* = .055, *p* < .001). The interaction between CESD and AFFECT 1 was not statistically significant (β = -0.02, *SE* = .013, *p* = .074), nor was the interaction between CESD and POSCON (β = 0.02, *SE* = .049, *p* = .718). Alternatively, the interaction between CESD and NEGCON remained statistically significant in controlling for negative affect (β = 0.13, *SE* = .055, *p* = .022), again indicating the effect of negative-image trials, as compared to neutral, in increased negative-content mind wandering was strengthened as depressive symptomatology increased (See Figure 4 for a visualization of negative-content mind wandering as a function of depressive symptoms and experimental condition).

The prediction of perseveration on trial image: positive affect model. TIME had a significant main effect of decreasing image perseveration as the experimental task progressed over time (β = -0.01, *SE* = .002, $p < .001$). This result reinforces the effect of time progression during a task in directing attention away from thought content related to current (i.e., the CRT task) or recent (i.e., the image) stimuli. As expected, the main effect of CESD on PIC was not statistically significant (β = 0.08 *SE* = .084, p = .348), potentially due to opposing perseveration on negative and positive stimuli. Moreover, this same interpretation may also explain the main effect of post-stimulus affect not reaching statistically significance (β = -0.00, *SE* = .016, p = .837), as increased positive affect would be expected to increase thinking on positive-images and reduce thinking towards negative-images. There were strong, significant main effects of both POSCON (β = 1.05, *SE* = .058, $p < .001$) and NEGCON (β = 1.82, *SE* = .057, $p < .001$), in that, relative to neutral-images, participants reported increased perseveration on both positive- and negative-image types. The interaction between CESD and positive post-stimulus affect was not statistically significant (β = 0.02, *SE* = .015, p = .161), nor was the interaction between CESD and POSCON (β = 0.07, *SE* = .058, p = .208). Finally, the interaction between CESD and NEGCON was statistically significant (β = 0.12, *SE* = .057, p = .031), indicating the effect of negative-images, as compared to neutral, to increase picture perseveration was strengthened as depressive symptomatology increased.

The prediction of perseveration on trial image: negative affect model. TIME remained a significant predictor of PIC (β = -0.02, *SE* = .002, $p < .001$), with task progression over time being associated with decreased picture perseveration. Once again, the main effect of

CESD was not statistically significant (β = 0.01 *SE* = .080, *p* = .916). However, there was a significant main effect of AFFECT 1 (β = 0.19, *SE* = .015, $p < .001$), indicating that increased negative affect post-stimulus predicted increased image perseveration across experimental conditions. This result highlights the possibility that consequences of picture perseveration may not be equivalent within image type; for example, increased perseveration on positive-images may be harmful if driven by negative affect, and adaptive if driven by positive affect. There were, once again, strong, significant main effects of both POSCON (β = 1.15, *SE* = .053, $p <$ .001) and NEGCON (β = 1.45, *SE* = .060, $p < .001$); relative to neutral-images, participants reported increased perseveration on both positive- and negative-image types. The interaction between CESD and AFFECT 1 was not statistically significant (β = 0.02, *SE* = .014, *p* = .096), nor was the interaction between CESD and NEGCON (β = 0.04, *SE* = .059, *p* = .511), with the However, the interaction between CESD and POSCON was statistically significant (β = 0.12, *SE* = .059, *p* = .017), indicating the effect of positive-images, as compared to neutral-image controls, to increase picture perseveration was strengthened as depressive symptomatology increased. This result is intriguing and suggests the gap between neutral-image perseveration and positive-image perseveration is larger as depressive symptoms increase, potentially highlighting a need for stronger, emotional stimuli to remain engaged with the material. (See Figure 5 for a visualization of image-based perseveration as a function of depressive symptoms and experimental condition).

Hypothesis 3: Predictions of Affect Change Within Experimental Trials

As compared to the prediction of mind-wandering variables in Hypotheses 1 and 2, the primary aim of Hypothesis 3 was to explore the interaction of mind wandering and depressive symptomatology in the prediction of affective dynamics (i.e., the change in affect over the course of the experimental trials). In Hypothesis 3 models, change in affect over the trial (Δ AFFECT) was modeled within the experimental conditions of interest; that is, trials with positive and negative emotionally-charged stimuli, respectively. Δ AFFECT is therefore representative of positive affect decay over the course of positive-image trials, in the respective model, whereas Δ AFFECT is representative of negative affect decay over the course of negative-image trials. Likewise, AFFECT 1 was included in each model, as congruent with the experimental manipulation; in models predicting positive affect change, AFFECT 1 represented positive affect following positive stimulus presentation, and in the model predicting negative affect change, AFFECT 1 represented negative affect following negative stimulus presentation. Other predictors included in both models were time across the experimental task (TIME), depressive symptomatology (CESD), mind-wandering frequency (FREQ), positive-content mind wandering (MWPOS), negative-content mind wandering (MNEG), and perseveration on the most recent IAPS image (PIC). Interaction effects were tested between depressive symptomatology and each mind-wandering variable to assess for moderation of depressive affective dynamics by both mind wandering frequency and varying forms of off-task thought content. The full model output for both models in Hypothesis 3 can be found in Table 5.

Prediction of *positive* Δ AFFECT within positive-image trials. Significant main effects were found for both TIME (β = 0.16, *SE* = .003, $p < .001$) and post-stimulus affect (β = 0.64, *SE* = .024, $p < .001$) on Δ AFFECT, with decreases in affect over the course of the trial associated with increased time within the task as well as higher positive affect reported at the beginning of the trial. Furthermore, significant main effects were found for both mind-wandering frequency (β = 0.07, *SE* = .017, $p < .001$) and CESD (β = 0.36, *SE* = .097, $p < .001$), wherein reductions in positive affect over time were associated with greater levels of mind wandering as well as greater levels of depressive symptomatology. Critically, however, the interaction between mind-wandering frequency and CESD was not statistically significant (β = 0.00, *SE* = .017, *p* = .979). Significant main effects also were found for both MWPOS (β = -0.09, *SE* = .016, *p* < .001) and MWNEG (β = 0.10, *SE* = .021, *p* < .001), wherein decreased positive-content mind wandering and increased negative-content mind wandering predicted reductions in positive affect over time. Moreover, a significant interaction was found between CESD and MWNEG (β = 0.04, *SE* = .019, *p* = .031), wherein the effect of depressive symptomatology to reduce positive affect over time became *stronger* as negative-content mind wandering increased (Figure 6). The interaction between CESD and MWPOS was not statistically significant (β = 0.01, *SE* = .016, *p* = .666). The main effect for PIC was statistically significant (β = -0.04, *SE* = .017, *p* = .017), suggesting perseveration on the positive-image predicted sustainment of positive affect over time. This was furthered by a significant interaction between CESD and PIC (β = -0.04, *SE* = .015, *p* = .011), wherein the effect of depressive symptoms on positive affect attenuation was *weakened* as positive-image perseveration increased (Figure 7). Taken together, these model results suggest the relationship between depressive symptomatology and positive affect decay over time was *weakened* by image-based perseveration (i.e., on the positive image), and *strengthened* by negative-content mind wandering. Alternatively, neither general frequency of mind wandering (Figure 8) nor positive-content mind wandering uniquely impacted depressive positive affect decay.

Prediction of *negative* Δ AFFECT within negative-image trials. Significant main effects were found for both TIME (β = -.01, *SE* = .004, *p* = .045) and post-stimulus affect (β = 0.69, *SE* = .022, *p* < .001), with decreases in negative affect over the course of the trial associated with earlier time-periods of the task, as well as higher negative affect reported post-stimulus. Significant main effects were found for both mind-wandering frequency (β = -0.04, *SE*

= .019, p = .047) and CESD (β = -0.21, SE = .080, p = .009) wherein decreases in negative affect over the course of the trial were associated with reduced levels of mind wandering as well as lower levels of depressive symptomatology. Critically, these main effects were qualified by a significant interaction between mind-wandering frequency and CESD (β = 0.05, SE = .017, p = .005), wherein the effect of depressive symptomatology on sustainment in negative affect over time became *stronger* as mind wandering increased (Figure 9). Significant main effects also were found for both MWNEG (β = -0.13, SE = .020, p < .001) and PIC (β = -0.06, SE = .019, p = .001), wherein increased negative-content mind wandering as well as increased negative-image perseveration predicted sustainment in negative affect over time. The main effect for MWPOS was not statistically significant (β = 0.01, SE = .022, p = .518) and moreover, no significant interactions were found between CESD and PIC (β = 0.01, SE = .02, p = .427), CES and MWPOS (β = -0.01, SE = .02, p = .714), or CESD and MWNEG (β = 0.02, SE = .02, p = .231). Taken together, these model results suggest the relationship between depressive symptomatology and negative affect sustainment over time was uniquely moderated by the occurrence of mind wandering away from the digit task, as compared to the across depression main effects of negative-content mind wandering and negative-image perseveration.

Discussion

Because the depressive syndrome is, at least in part, a function of disturbed affective dynamics – e.g., unusually slow decay of induced negative affect (Hemenover, 2003; Davidson, 2004; Davidson, 2015) – it is important to identify the cognitive mechanisms that contribute to such pathological processes and to clarify their specific effects. The primary aim of present study was to further elucidate a possible role of one such cognitive mechanism, mind wandering, in depressive affective dynamics, both with respect to the rate of negative and positive affect decay over time, following exposure to emotionally provocative stimuli.

Review of the Novelty of the Present Study

The current study replicates the landmark affective dynamics findings of Ruby and colleagues (2013) in three main respects: (a) momentary negative affect was found to predict subsequent increases in the frequency of mind wandering, whereas positive affect predicted decreased mind-wandering; (b) negative affect tended to precede negative-content mind wandering, while positive affect was followed by mind wandering of positive content; and (c) depressive symptoms were significantly associated with mind wandering of negative content. But in contrast to the reported findings of both Ruby et al. (2013) and Hoffmann and colleagues (2016), I observed no evidence of an inverse relationship between depressive symptoms and positive-content mind wandering. (This non-replication is further discussed under "Depressive Symptoms, Affective Stimuli, and Off-Task Thought Content").

The novelty of the present study, however, lies in its extension of these previous investigations via the introduction of emotionally provocative affective stimuli throughout the mind-wandering task, as well as an investigation of the interaction of depressive symptomatology and mind wandering (both frequency and content) in their effects on the sustainment or decay of experimentally manipulated affect over time. In essence, my aim was to help clarify the potential role of mind wandering in the affective dynamics typical of individuals who experience prominent depressive symptoms, especially in the context of direct emotional provocations.

Mind Wandering in the Depressive Sustainment of Negative Affect Over Time

The present study found evidence of a significant interaction between off-task thinking (mind wandering) and depressive symptomatology in their conjoint effects on the temporal dynamics of negative affect. Specifically, off-task thinking had a greater overall deleterious effect in sustaining negative affect among those at higher levels of depressive symptoms. Notably, however, no such depression-by-mind wandering interactions were observed among the three measured *facets* of mind wandering: image-based perseveration, negative-content, and positive-content mind-wandering. This is a potentially important set of findings. It suggests that those with elevated depressive symptoms may be adversely affected by off-task thinking, *per se*, regardless of the actual content of such thoughts. But why would all mind wandering (apparently) be created equal in this context, especially considering the well-established existence of characteristic maladaptive thinking patterns inherent to the depressive syndrome (Brown & Siegel, 1988; Gotlib et al., 2004; Sweeney et al., 1986)?

One interpretive possibility: *on-task thought* may be uniquely beneficial for dysphoric individuals (those with elevated depressive symptoms). Such individuals have been shown, even on a neurophysiological level, to have altered homeostatic baselines that characterize their more negative affective style (e.g., right-lateralized frontal asymmetry; Wheeler et al., 1993; Davidson, 1998; Adolph & Margraf, 2017). Therefore, mere attentional engagement in a neutral task, even one that offers no obvious reward (i.e., a task that most would identify as “boring”), may still result in a beneficial alteration of affective state among those whose baseline tendency is otherwise to drift toward the experience of negative affect.

Another possibility worth considering, however, is that there may be some degree of measurement artifact inherent in the study’s assessment of mind wandering (Smallwood &

Schooler, 2015), and that artifactual measurement error may even vary as a function of depressive symptomatology. For example, the study's probe to assess the simple occurrence of off-task thought is likely to impose less cognitive load than the subsequent probes that ask about more fine-grained *contents* of mind wandering (image-based perseveration, negative-content thinking, and positive-content thinking). As a result, those who fare worse under increased cognitive load – including many of those with elevated depressive symptoms (Disner et al., 2011; Peckham et al., 2010) – may have poor differentiation between general mind wandering and the mind wandering circumscribed to negative topics. Moreover, we know that those with elevated depression symptoms tend to mind wander more often, and to do so more frequently with a focus on negative content, thereby potentially raising their risk of conflating the two related constructs.

Mind Wandering in the Depressive Attenuation of Positive Affect Over Time

Consistent with *a priori* expectations, the determinants of positive affect dynamics proved to be distinct from those of negative affect. Notably, the main effect of mind wandering frequency on positive affect was *not* qualified by a significant interaction with depressive symptoms. Overall mind wandering frequency did have a significant main effect on positive affect attenuation, but the effect did not vary as a function of depressive symptom level. Instead, it was the *forms* of off-task thinking, specifically, perseverative thoughts about the positive stimulus and unrelated negative thoughts (i.e., negative-content mind-wandering), that exerted differential effects on positive affect sustainment that varied with the severity of depressive symptomatology.

Overall, higher levels of depressive symptomatology induced greater positive affect decay, with this effect *weakened* by positive-image perseveration and *strengthened* by negative-content mind wandering. If both findings are considered in tandem, one interpretive possibility is that process of perseverating on positive study stimuli may have been particularly helpful (affectively speaking) for participants with dysphoria, inasmuch as it helped prevent the occurrence of their more characteristic negative-content mind wandering. Such an interpretation is consistent with previous work which suggests that *savoring* processes within dysphoric states may be compromised, along with a reduced *broadening* of the congruent cognitive processes that characterize positive emotion (Martin-Soelch, 2009; Naranjo et al., 2001, Pizzagalli et al., 2009, McFarland & Klein, 2009). Likewise maladaptive depressotypic thinking, including perseverative cognition, may in some cases be more easily detected in the context of positive affective states due, in part, to the contrast they present with the more characteristic “baseline” experience of negative affect (Disner et al., 2011; Peckham et al., 2010).

Finally, the magnitude of the observed main effect for depressive symptomatology on positive affect decay was considerably larger than its effect on negative affect decay (β = 0.36 vs β = -0.21), although both effects were statistically significant. This result is congruent with the growing body of research documenting the importance of positive affect disturbances in depressive and dysphoric individuals (Bylsma, 2008). At the very least, it suggests that it may prove important for researchers and clinicians to attend as carefully to processes that promote the sustainment (or decay) of positive affect as they do to the dynamics of negative affect decay (Davidson, 1998; Davidson, 2004; Hemenover, 2003).

Positive-Content Mind Wandering and Negative Affect Decay

In contrast with the observed affective impact of mind wandering itself, negative-content mind wandering, and image-based perseveration on the sustainment of negative affect, positive-content mind wandering had no such role in negative affect decay over time. Even mere active engagement with a relatively boring, low-demand task (i.e., classifying successive digits as either odd or even) emerged as a stronger predictor of adaptive negative affect regulation than was mind wandering onto positive topics. Of course, it is worth noting that the study's negative-affect trials – i.e., those in which a negative stimulus were presented – were characterized by substantially less positive mind wandering than observed in other trials, perhaps due to the increased difficulty of engagement in mood-congruent thought (Siemer, 2005).Accordingly, simple engagement with the neutral task at hand may have proved for participants to be a more manageable, and thus more effective, mood-repair strategy as a transition from negative stimulus engagement. This interpretation is aligned with research supporting the use of both behavioral activation (Jacobson et al., 2001), as well as mindfulness techniques (Brown & Ryan, 2003), in the treatment of heightened negativity in depressive individuals, as compared to more lay attempts at increasing one's "positive thinking".

On the other hand, it is also possible that the aforementioned effect may simply reflect the manner in which emotion was assessed during the task; that is, via prompted self-report. If affect had been assessed less intrusively (for example, during neuroimaging-based estimation), *during* positive-content mind wandering episodes, as opposed to the use of active probes in the present study (which presumably took participants out of each mind wandering state), the results may have differed. In other words, it is possible that positive-content mind wandering promotes adaptive affective changes, but that they are somewhat ephemeral, dependent on the extended continuation of the mind wandering state itself.

Depressive Symptoms, Affective Stimuli, and Off-Task Thought Content

The established finding of a significant association between depressive symptom severity and negative-content mind wandering (Ruby et al., 2013, Ottaviani al., 2015) was replicated in the present study. However, it extended this previous work by identifying a significant interaction effect between depressive symptom severity and affective stimulus valence. Specifically, negatively-charged affective stimuli had a substantially greater ability to induce negative-content mind wandering among those with higher levels of depressive symptoms. This finding was consistent with the voluminous literature on maladaptive thinking patterns in depression, in particular their responses to negative events (Nolen-Hoeksema et al., 2008).

On the other hand, I observed no significant main effect of depressive symptoms on the occurrence of positive-content mind wandering, in contrast with the findings of previous investigators (Ruby et al., 2013; Hoffmann et al., 2016). Instead, I found a significant interaction between depressive symptoms and post-stimulus positive affect, which may suggest that those with elevated depressive symptoms are particularly dependent upon the presence of positive affect as a precursor to mind wandering about positive topics. Interestingly, a related interaction was observed between depressive symptoms and stimulus-valence, with elevated symptoms signaling a decreased sensitivity to the impact of positive stimuli in promoting positive-content mind wandering. It is possible, therefore, that depressive individuals face an unfortunate Catch-22: they need higher levels of positive affect in order to mind wander about positive topics, but they are simultaneously less sensitive to positive-affect promoting stimuli.

Finally, there is strong evidence of connection between depressive symptomatology and perseverative cognition (Brosschot et al., 2006; Aldao et al., 2010; Joormann & D’Avanzato, 2010). The present study results suggest that perseveration on a recently displayed visual stimulus is increased as a function of depressive symptom severity, and this held true for both positive- and negative-valence images. Although it is perhaps surprising that depression symptoms were associated with more perseveration on positive images, I found no evidence that such perseveration had any adaptive consequences: specifically, it was not associated either with greater sustainment of positive affect or with the occurrence of adaptive, non-ruminative cognition.

Time as a Predictor of Mind Wandering and Affect

All study models took into account the measurement of *time*, defined by trial number of the experimental task. Previous work has suggested that mind wandering tends to increase in frequency as the relevant experimental task progresses (Smallwood & Schooler, 2015), and this effect was strongly replicated in the present study: across all forms of off-task thinking and across experimental conditions, the progression of time in the experimental setting was found to increase the occurrence of off-task thought. Moreover, as time progressed, the rate of positive affect decay within positive-image trials was significantly increased, while the rate of negative affect decay within negative image trials was decreased (in other words, the negative affect induced by negative images was more sustained). It remains unknown the degree to which the presence of depressive symptoms may moderate the aforementioned temporal effects, but this may serve as a promising area of future investigation.

Study Limitations

Self-report assessment of variables of interest. A primary limitation of the present study was the reliance on self-report data in assessing mind wandering and affective states during the experimental task. As noted previously, it is possible that the effects of mind wandering on affective dynamics would be significantly changed if assessment conditions did not routinely interrupt task-related and off-task thinking in order to obtain self-report measurements. There does not yet exist, however, a reliable method for categorizing both the frequency and content of mind wandering without *some* amount of self-report. Although behavioral and physiological indices of mind-wandering *frequency* have been developed (Smallwood et al., 2008; Smilek et al., 2010; Grandchamp et al., 2014), they are not yet frequently employed, although at least two studies have reported on associations between behavioral measures of mind wandering and depressive symptoms, finding more commission errors (Murphy et al., 2013) and slower reaction times (Smallwood et al., 2007) to be associated with increased levels of depressive symptomatology. Furthermore, Ottaviani and colleagues (2015) found lower heart rate variability (HRV) to be associated with episodes of perseverative mind wandering, although this finding was non-specific to Major Depressive as compared to non-depressed groups. Future research would benefit from continued development and implementation of less invasive methods for mind wandering assessment, especially those that allow for passive observations of mind wandering over time.

Study sample characteristics. The present investigation did not utilize a sample with clinically defined groups (e.g., Major Depressive Disorder; American Psychiatric Association, 2013) but instead included participants across a broad range of depressive symptomatology levels. Because clinically depressed individuals are likely to differ in countless respects from those with merely heightened depressive symptoms, it remains important to replicate the findings of the present study among those meeting criteria for a major depressive episode and those whom do not. This limitation, in combination with the strength of the current study in statistical power (i.e., modeling of thousands of observations per study variable), as well as a bias towards internal, as opposed to external validity, mandates the present results (which reflect an unreplicated, single experiment) be taken for what they are, an empirical foundation for further research seeking to combine these same constructs, as compared to what they are not: definite conclusions regarding clinical significance and implication.

Nevertheless, the present study utilized a stratified sampling technique that resulted in considerable variability in depressive symptomatology at time of the study (CES-D: $M = 15.23$, $SD = 9.53$, Range = 1 – 47). Moreover, it remains important in itself to gain an understanding of the relationship between mind wandering and varying levels of depressive symptoms. For example, Marchetti et al., (2012) found that mind wandering predicted the accessibility of negative thoughts, but only among individuals with moderate to high levels of depressive symptoms. Therefore, it is possible that particular levels of depressive symptoms, or, and potentially even more significantly, *different* depressive symptoms (e.g., heightened negative mood vs. anhedonia) may alter the process and consequences of mind wandering as it relates to depressive affective dynamics.

The findings of the present study may also be of limited generalizability due to the characteristics of its college student sample. It would be valuable in this respect to see attempted replication among participant samples that reflect greater age variability and racial diversity (Table 1).

Personal-salience of emotional stimuli. It is possible that affectively-charged stimuli personalized to the individual, as has been frequently used in studies of Post-Traumatic Stress Disorder (see Liberzon et al., 1999 for a classic example), or affectively-charged events that occur in the participant's natural life (i.e., non-laboratory settings), might modify ensuing affective dynamics, as well as the potential impact of depressive symptoms on mind wandering. Future work may be able to implement personally salient images into modified CRT tasks, and thus test for effects of personally-salient versus non-salient stimuli. On the other hand, the stimuli used in the current study, pictures from the International Affective Picture System (Lang et al., 2008), benefit from their standardization by valence, and proved to be effective in this study's observed manipulations of affect and induced perseveration on the emotionally-valent images.

Conclusion

The results of this investigation provide preliminary evidence of processes by which mind wandering may impact affective dynamics, and particularly those that characterize the experience of elevated depressive symptomatology. Mind wandering in and of itself, regardless of its content, interacted with depressive symptoms to reduce the decay of negative emotion following exposure to a negative stimulus. Alternatively, following exposure to positively valent stimuli, it was mind-wandering of negative content that most directly contributed to depressive positive affect decay. Future replication of these results among clinical samples – particularly those with and without a diagnosis of major depressive disorder – would be a welcome extension of the present findings, as would the investigation of mind wandering and associated affective dynamics in more ecologically valid (non-experimental) real-world contexts.

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Table 1. Participant- Level Demographic Information

Participant Characteristics

Characteristic	*N* = 173
Gender	*n* (%)
Female	90 (52)
Male	83 (48)
Race	*n* (%)
Caucasian	138 (79.8)
Asian	13 (7.5)
African American	6 (3.5)
American Indian or Alaskan Native	1 (0.6)
Biracial or Multiracial	14 (8.1)
Decline to Answer	1 (0.6)
Ethnicity	*n* (%)
Hispanic/Latino	9 (5.2)
Not Hispanic/Latino	144 (83.2)
Multiple Ethnicities	9 (5.2)
Decline to Answer	11 (6.4)
Psychiatric Medication	*n* (%)
Yes	0 (0)
No	173 (100)
Current Mental Health Treatment	*n* (%)
Yes	3 (1.7)
No	170 (98.3)
Age *M (SD)*	18.79 (1.19)
CES-D *M (SD)*	15.23 (9.56)

Table 2. Descriptive Statistics for Experimental Task Variables

Trial Type / Variable	**Neutral-image Trials (NEUCON)** *M (sd)*	**Positive-image Trials (POSCON)** *M (sd)*	**Negative-image Trials (NEGCON)** *M (sd)*
Positive AFFECT 1	5.07 (2.05) r = -.22	6.37*** (1.82) r = -.21	3.76*** (2.10) r = -.24
Positive AFFECT 2	4.98 (2.04) r = -.25	5.25*** (2.03) r = -.26	4.52*** (2.04) r = -.27
Positive AFFECT Δ	0.09 (1.22) r = .04	1.12*** (1.58) r = .09	-0.75*** (1.36) r = .03
Negative AFFECT 1	2.76 (1.76) r = .18	2.25*** (1.58) r = .15	4.66*** (2.22) r = .18
Negative AFFECT 2	2.73 (1.74) r = .20	2.58*** (1.67) r = .16	3.32*** (1.87) r = .20
Negative AFFECT Δ	0.03 (1.27) r = -.02	-0.33*** (1.30) r = -.02	1.35*** (1.81) r = .01
FREQ	4.20 (2.60) r = .15	4.38*** (2.52) r = .14	4.61*** (2.46) r = .15
MWPOS	3.41 (2.26) r = -.01	4.04*** (2.39) r = -.04	2.60*** (1.95) r = -.07
MWNEG	2.36 (1.81) r = .15	2.22*** (1.76) r = .15	3.46*** (2.17) r = .17

PIC	1.99 (1.59) r = .04	3.03*** (2.10) r = .08	3.80*** (2.31) r = .07

*** represents p < .05 in mean comparison to neutral trial measurement
r = correlation with CES-D as administered at time of study

N	173	173	173
No. of Obs.	2768	1384	1384

Table 3. Positive Affect Model Comparisons Predicting Mind Wandering Variables

	FREQ Estimate (S.E.)	MWPOS Estimate (S.E.)	MWNEG Estimate (S.E.)	PIC Estimate (S.E.)
(Intercept)	6.07***	2.99***	2.03***	2.16***
	(.134)	(.114)	(.089)	(.091)
TIME	0.09***	0.03***	0.02***	-0.01***
	(.003)	(.003)	(.002)	(.002)
CESD	0.37**	0.11	0.17*	0.08
	(.129)	(.107)	(.081)	(.084)
***Positive* AFFECT 1**	-0.08***	0.28***	-0.21***	-0.00
	(.017)	(.017)	(.015)	(.016)
POSCON	0.21***	0.25***	0.12*	1.05***
	(.060)	(.060)	(.054)	(.058)
NEGCON	0.21***	-0.48***	0.80***	1.82***
	(.060)	(.060)	(.054)	(.057)
CESD* AFFECT 1	-0.03* (.016)	0.03* (.016)	0.01 (.014)	0.02 (.015)
CESD* POSCON	0.05 (.060)	-0.12* (.060)	0.00 (.054)	0.07 (.058)
CES* NEGCON	0.01 (.060)	-0.06 (.060)	0.11* (.053)	0.12* (.057)
N	173	173	173	173
# of Obs.	5536	5536	5536	5536

* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

Table 4. Negative Affect Model Comparisons Predicting Mind Wandering Variables

	FREQ Estimate (S.E.)	**MWPOS Estimate (S.E.)**	**MWNEG Estimate (S.E.)**	**PIC Estimate (S.E.)**
(Intercept)	6.03***	2.95***	2.21***	2.28***
	(.134)	(.119)	(.075)	(.088)
TIME	0.09***	0.03***	0.02***	-0.02***
	(.003)	(.003)	(.002)	(.002)
CESD	0.36**	0.02	0.15*	0.01
	(.128)	(.112)	(.067)	(.081)
***Negative* AFFECT 1**	0.10***	-0.18***	0.35***	0.20***
	(.016)	(.016)	(.014)	(.015)
POSCON	0.16**	0.52***	0.03	1.15***
	(.057)	(.058)	(.05)	(.053)
NEGCON	0.13*	-0.51***	0.41***	1.45***
	(.064)	(.065)	(.055)	(.060)
CESD* AFFECT 1	0.04** (.016)	-0.01 (.016)	-0.02 (.013)	0.02 (.014)
CESD* POSCON	0.02 (.057)	-0.07 (.057)	0.02 (.049)	0.13* (.053)
CES* NEGCON	-0.02 (.063)	-0.08 (.064)	0.13* (.055)	0.04 (.059)
N	173	173	173	173
# of Obs.	5536	5536	5536	5536

* $p \leq 0.05$ ** $p \leq 0.01$ *** $p \leq 0.001$

Table 5. Model Comparisons Predicting Affect Decay During Experimental Trials

	Positive Δ Affect Estimate (S.E.)	Negative Δ Affect Estimate (S.E.)
(Intercept)	0.15 (.115)	0.58*** (.099)
TIME	0.02*** (.003)	-0.01* (.004)
AFFECT 1	0.64*** (.024)	0.69*** (.022)
CESD	0.36*** (.097)	-0.21** (.080)
FREQ	0.07*** (.017)	-0.04* (.019)
PIC	-0.04* (.017)	-0.06** (.019)
MWPOS	-0.09*** (.016)	0.01 (.022)
MWNEG	0.10*** (.021)	-0.13*** (.020)
CESD* FREQ	0.00 (.012)	0.05** (.017)
CESD* PIC	-0.04* (0.15)	-0.01 (.017)

CESD* MWPOS	0.01 (.016)	-0.01 (.023)
CESD* MWNEG	0.04* (.019)	0.02 (.019)
N	173	173
# of Obs.	1384	1384

* p ≤0.05 ** p ≤0.01 *** p ≤0.001

Figure 1. Plot of CES-D Scores Observed in Study Sample

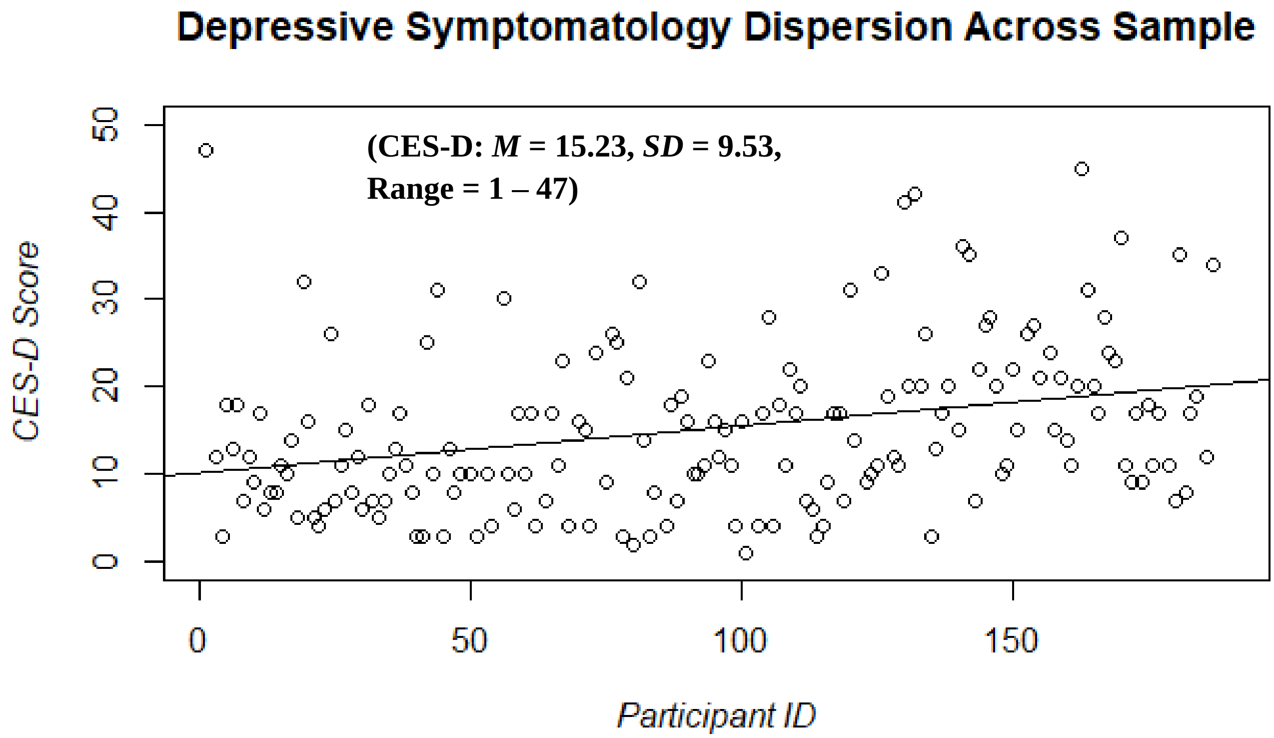
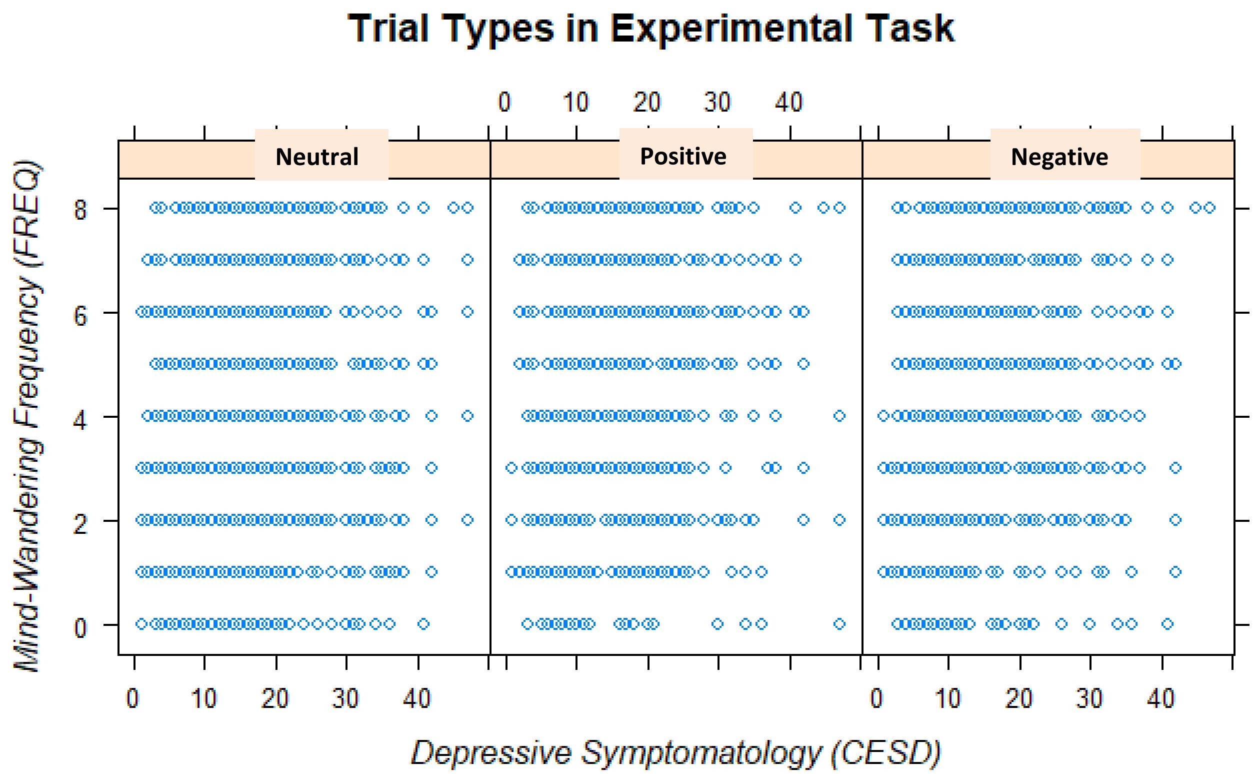
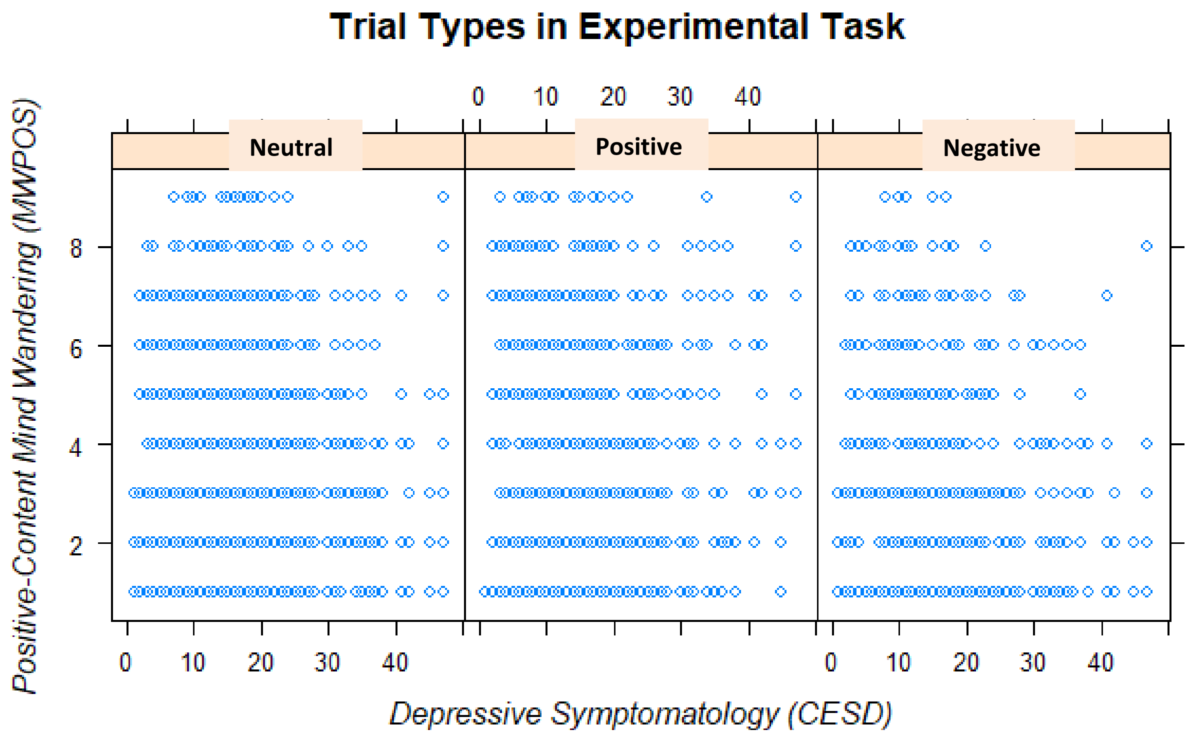


Figure 2. The xyplot of Mind Wandering Frequency (FREQ) as a Function of Depressive Symptomatology (CES-D) by Trial Type in the Experimental Task



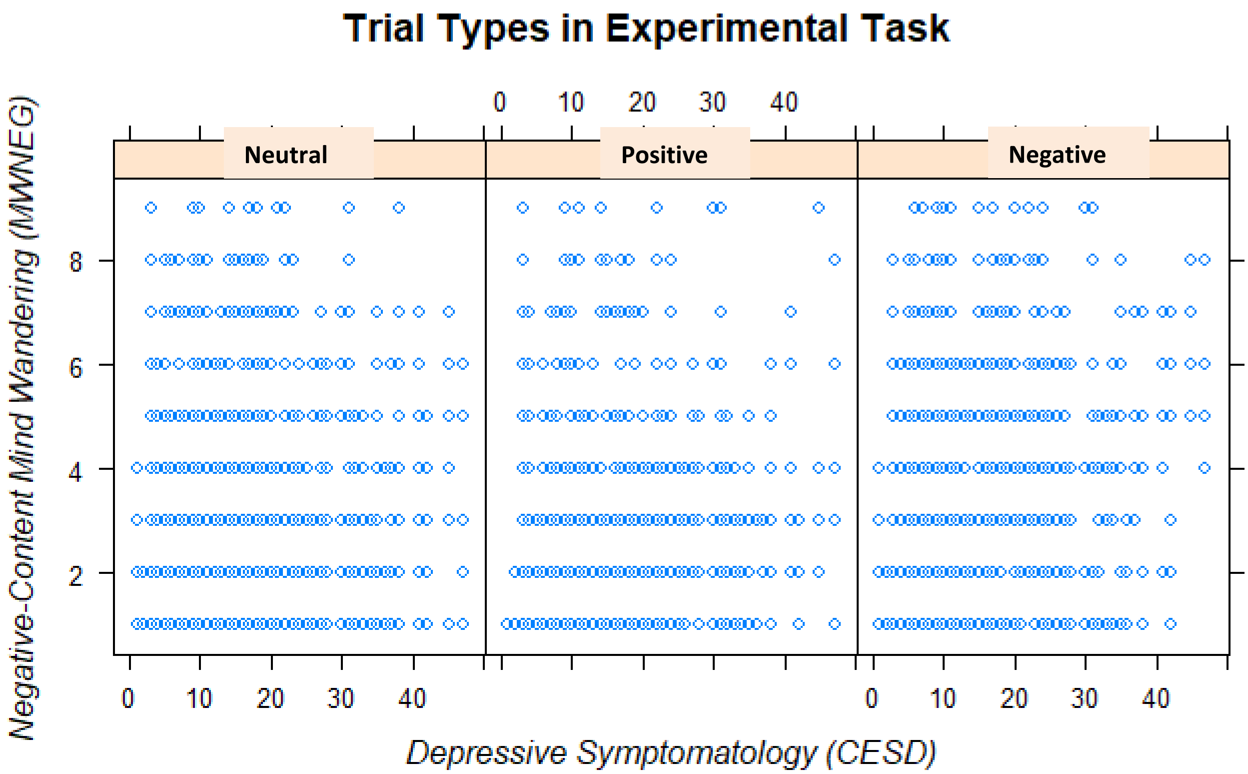
N	**173**	**173**	**173**
No. of Obs.	**2768**	**1384**	**1384**

Figure 3. The xyplot of Positive-Content Mind Wandering (MWPOS) as a Function of Depressive Symptomatology (CES-D) by Trial Type in the Experimental Task



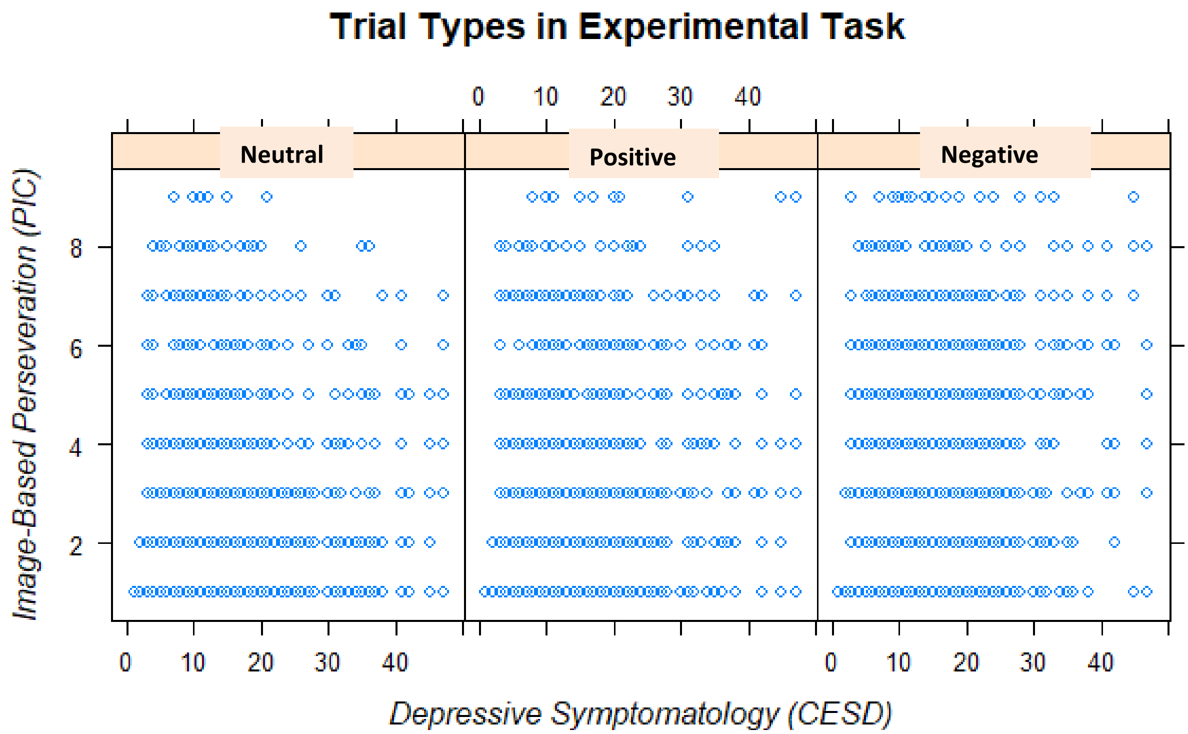
N	**173**	**173**	**173**
No. of Obs.	**2768**	**1384**	**1384**

Figure 4. The xyplot of Negative-Content Mind Wandering (MWNEG) as a Function of Depressive Symptomatology (CES-D) by Trial Type in the Experimental Task



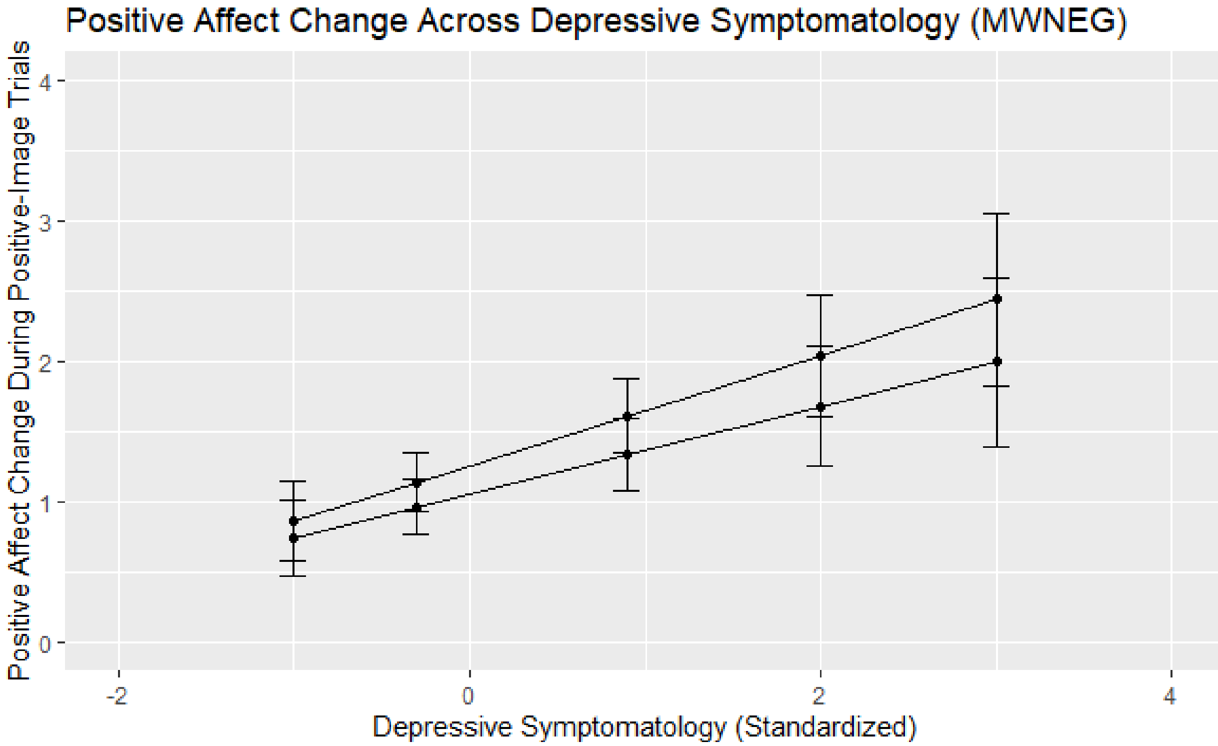
N	**173**	**173**	**173**
No. of Obs.	**2768**	**1384**	**1384**

Figure 5. The xyplot of Image-Perseveration (PIC) as a Function of Depressive Symptomatology (CES-D) by Trial Type in the Experimental Task



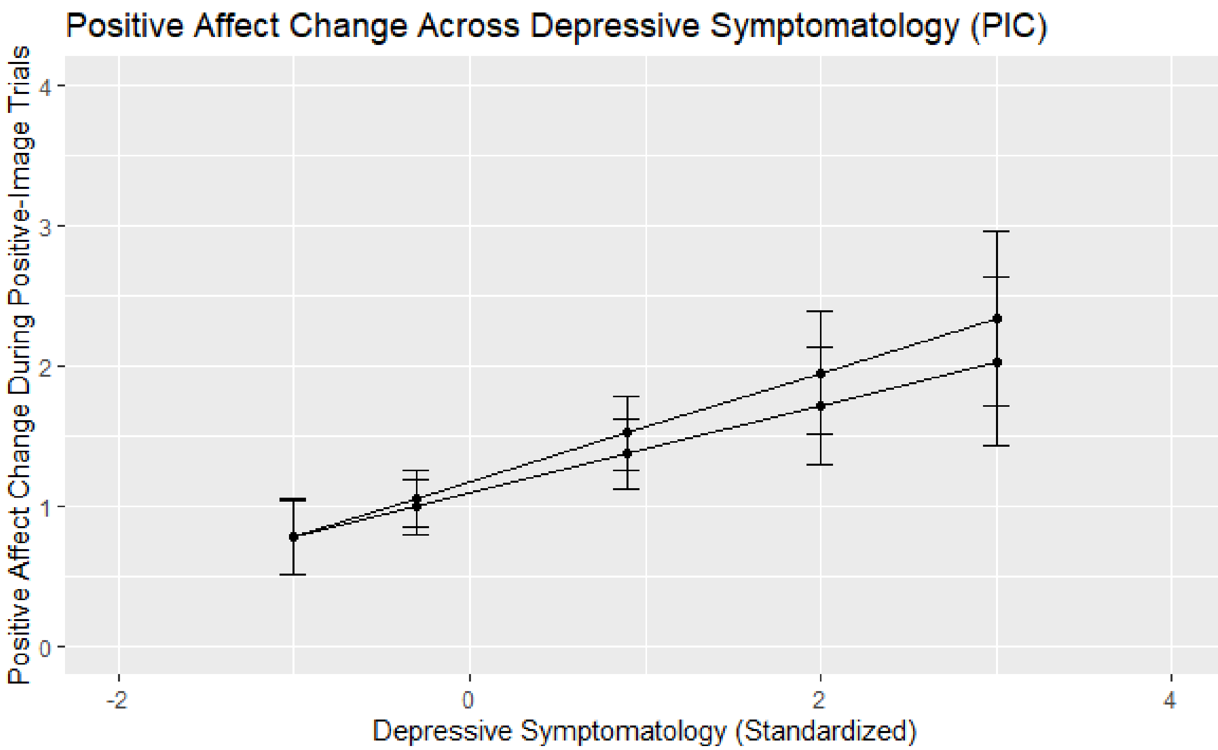
N	**173**	**173**	**173**
No. of Obs.	**2768**	**1384**	**1384**

Figure 6. The Interaction Between Depressive Symptomatology and Negative-Content Mind Wandering on Positive Affect Change



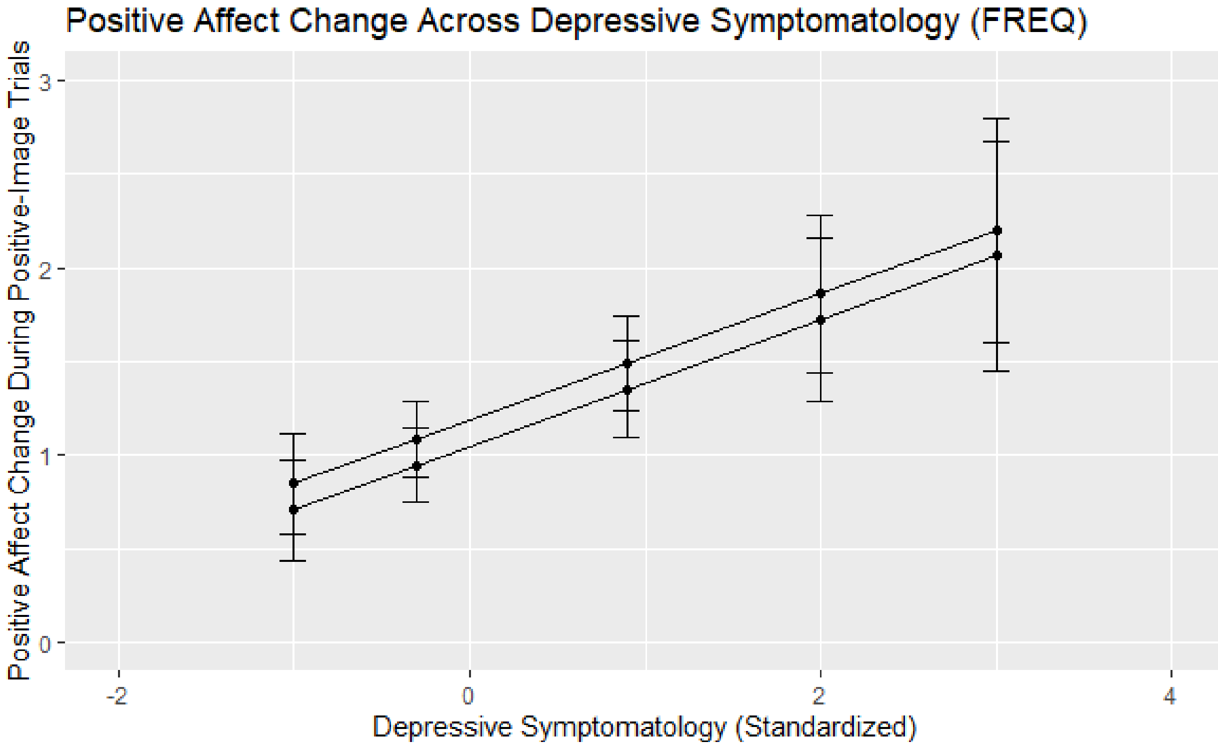
Note: The graph displays, overall, greater positive affect decay as a function of elevated depressive symptoms. It also displays the statistically significant interaction between negative-content mind wandering and depressive symptomatology. The stronger line, ending higher, represents higher ratings of negative-content mind wandering (MWNEG = +1 *SD*). The attenuated line, ending lower, represents lower ratings of negative-content mind wandering (MWNEG = -1 *SD*).

Figure 7. The Interaction Between Depressive Symptomatology and Positive Image Perseveration on Positive Affect Change



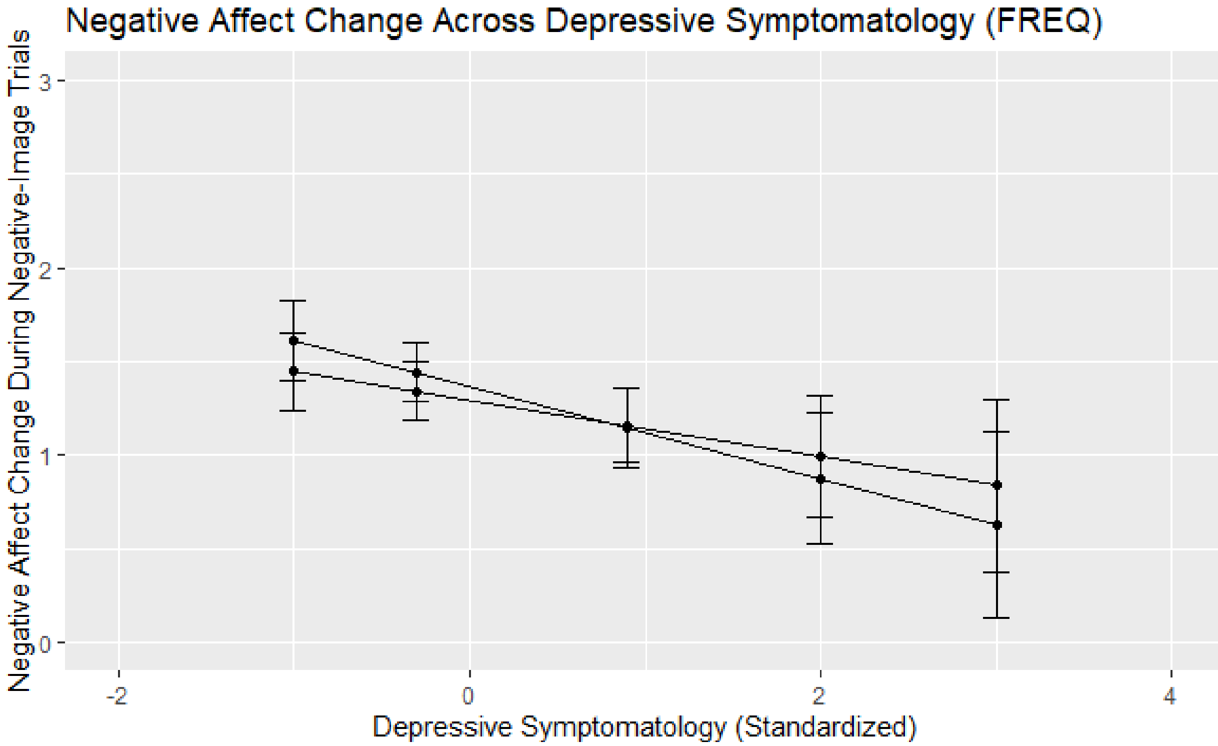
Note: The graph displays, overall, greater positive affect decay as a function of elevated depressive symptoms. It also displays the statistically significant interaction between positive-image perseveration and depressive symptomatology. The stronger line, ending higher, represents less frequent positive-image perseveration (PIC = -1 *SD*). The attenuated line, ending lower, represents more frequent positive-image perseveration (PIC = +1 *SD*).

Figure 8. The Interaction Between Depressive Symptomatology and Mind Wandering Frequency on Positive Affect Change



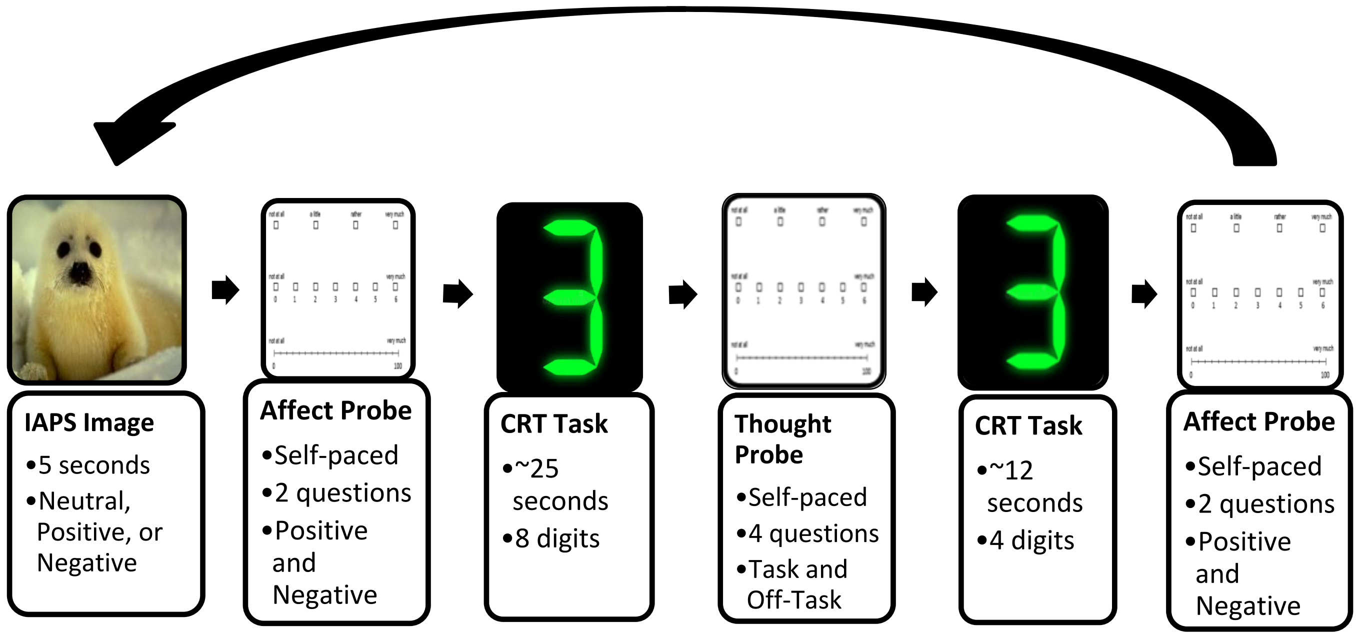
Note: The graph displays, overall, increased positive affect decay as a function of elevated depressive symptoms. It also displays the *not* statistically significant interaction between mind-wandering frequency and depressive symptoms, with the higher line representing more frequent mind wandering (FREQ = +1 *SD*) and the lower line representing less frequent mind wandering (FREQ = -1 *SD*).

Figure 9. The Interaction Between Depressive Symptomatology and Mind Wandering Frequency on Negative Affect Change



Note: The graph displays, overall, *decreased* negative affect decay (i.e., sustainment) as a function of elevated depressive symptoms. It also displays the statistically significant interaction between mind-wandering frequency and depressive symptoms. The stronger line, beginning higher and ending lower, represents more frequent mind wandering (FREQ = +1 *SD*).The attenuated line, beginning lower and ending higher, represents less frequent mind wandering (FREQ = -1 *SD*).

Appendix A. Experimental Task Structure



Appendix B. Thought Probe

The following four questions were presented at each thought probe, on two sequential self-paced screens. Participants were asked to respond using a 9-point Likert scale for each question. For both screens, the prompt was, "At the moment of interruption:" and the Likert scale was anchored:1 = Not at all, 9 = Completely.

Screen 1:

How much were you thinking about the digit task?

How much were you thinking about the previous picture?

Screen 2:

How much were you thinking about PLEASANT events/people/ideas unrelated to the task?

How much were you thinking about UNPLEASANT events/people/ideas unrelated to the task?