THE INFLUENCE OF WORKING MEMORY ON THE RELATIONSHIP BETWEEN DEPRESSIVE SYMPTOMS AND ATTENTION FOR DYSPHORIC STIMULI

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Abstract: Cognitive models suggest that depressed individuals display biased attention for depression-relevant information. One factor that contributes to our ability to attend to information is working memory. Research suggests that depressed individuals show deficits in working memory. This study experimentally examined the role of working memory on the relationship between depressive symptoms and attention for dysphoric stimuli. We tested four hypotheses: 1) increased depression would be associated with increased attention for dysphoric emotional stimuli; 2) increased depression symptoms would be associated with deficits to phonological and visuospatial working memory; 3) there would be an indirect effect of working memory on the relationship between depression symptoms and attention for dysphoric stimuli; and 4) a working memory load would moderate the relationship between depression symptoms and attention for dysphoric stimuli such that under a load condition, the relationship between depressive symptoms and attention for dysphoric stimuli would be stronger than in a no load condition. One hundred forty-seven participants completed measures of depressive symptoms, social anxiety symptoms, phonological and visuospatial working memory tasks, and two runs of an eye tracking task measuring attention bias to emotional facial expressions. During one of the eye tracking runs, participants completed The Serial Three's Task as a working memory load. Results supported our first hypothesis, that increased symptoms of depression were associated with increased attention to dysphoric stimuli, but our remaining hypotheses were unsupported. Possible explanations for our results include using non-emotionally valenced working memory tasks and The Serial Three's Task being too difficult. Nonetheless, results contribute to the growing literature examining cognitive factors and depression. Future work could examine differing levels of working memory loads, or use a working memory load that is emotionally valenced.

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INTRODUCTION

Depression is a highly prevalent mental health issue that results in substantial financial burden and life impairment. Approximately 16.5% of adults living in the United States will experience major depressive disorder (MDD) at some point in their lives (Kessler, Berglund, Demler, Jin, & Walters, 2005). Annually, the United States spends more than $210 billion dollars on MDD, which demonstrates the huge economic burden of MDD (Greenberg, Fornier, Sisitsky, Pike, & Kessler, 2015). Furthermore, depression has been characterized as a recurrent disorder, such that once an individual experiences one episode of depression they are at greater risk to experience another (American Psychiatric Association, 2013; Kupfer, Frank, & Wamhoff, 1996). Therefore, proper assessment, prevention, and treatment of MDD are of utmost importance in order to reduce the burden MDD plays within individuals and within the broader US society. Thus, it is important to identify factors that contribute to the onset, maintenance, and recurrence of MDD.

Attention Bias in Depression

Cognitive models of depression suggest that biased attention for depression relevant information is important for the etiology and maintenance of the disorder (Beck, 1976; Teasdale, 1988; Ingram, 1984). While early research examining attention bias in depression implicated a lack of positive bias rather than a bias toward dysphoric stimuli (McCabe & Gotlib, 1995), more recent literature has documented attention biases for depression relevant information at longer stimulus presentation times (Bradley, Mogg, & Lee, 1997; Gotlib Krasnoperova, Yue, & Joormann, 2004; Kellough, Beevers, Ellis, & Wells, 2008; Armstrong & Olatunji, 2012). This suggests that depression relevant attentional biases may use a later, more effortful processing system as compared to biases detected within anxiety disorders (Armstrong & Olatunji, 2012). Using longer presentation times, a large body of literature has implicated attention bias in both depression vulnerability and maintenance (Beevers & Carver, 2003; Beevers, Lee, Wells, Ellis, & Telch, 2011; Wells & Beevers, 2010; Beart, De Raedt, Schacht, & Koster, 2010; Yang, Ding, Dai, Peng, & Zhang, 2015).

However, it is important to note that a mood congruent attention bias is not always observed in depression (e.g., Gotlib, McLachlan, & Katz, 1988; MacLeod, Mathews, & Tata, 1986; Mogg, Bradley, Williams, & Mathews, 1993). Thus, it is important to consider under what conditions a mood-congruent attention bias will be observed in depression. One model that may help explain when an attention bias in will be observed in depression is Beevers' (2005) dual process model. This model borrows from more general cognitive models that articulate two basic types of cognitive processes: associative and reflective processing. Associative processing refers to automatic, effortless processing, which often occurs outside of conscious awareness, but is dependent on previously encoded memories. Conversely, reflective processing involves effortful, sequential, processing which often requires thoughtfulness and planning and takes place within conscious awareness. Research has also suggested that associative processing is often employed first, but that associative processing can be overridden and corrected in certain situations by reflective processing (Beevers, 2005). This model posits that depressed, and depression vulnerable individuals have developed negatively-biased associative processing. Though, under many conditions these individuals are able to “correct” their biased associative processing through reflective processing. For example, a depression-vulnerable individual may initially orient and be predisposed to dwell on depression-relevant information in the environment, but they are able to reflectively disengage and reorient their attention through the use of available cognitive resources. However, if the individual’s cognitive resources are taxed, the individual will not be able to engage in reflective processing and the biased associative processing will prevail. Thus, situations or characteristics that reduce the ability to engage in reflective processing should increase associative processing and the likelihood of observing mood congruent biased attention in depression.

Cognitive Resources and Depression

Research has found that depression symptoms can, in fact, deplete the cognitive resources necessary to engage in reflective processing (Wegner, Erber, & Zanakos, 1993). Specifically, a mood induction of depressed and neutral moods, showed that only those in a depressed mood induction state showed impaired comprehension and a reduced ability to recognize contradictions in reading passages (Ellis, Ottaway, Varner, Becker, & Moore, 1997). This suggests that their cognitive resources may have been occupied by negative dysphoric thoughts, and they were unable to be employed in comprehension.

Additional research has shown that depressed and dysphoric individuals show broad cognitive deficits (Austin, Mitchell, & Goodwin, 2001). A recent meta-analysis found moderate cognitive deficits in attention, memory, and executive functioning of individuals with MDD (Rock, Roiser, Riedel, & Blackwell, 2014), and another meta-analysis found deficits in depressed individuals across tasks utilizing executive functions including inhibition, shifting, and working memory (Snyder, 2013). Executive function deficits have been implicated repeatedly in depressed individuals. These executive function deficits maybe related to cognitive deficits and biases for individuals with MDD in attention, memory, and problem-solving (Levin, Heller, Mohanty, Herrington, & Miller, 2007; Nitschke, Heller, Imig, McDonald & Miller, 2001). Furthermore, executive function deficits have been associated with both structural and functional irregularities in the prefrontal cortex (PFC). In depressed individuals specifically, there are documented deficits in several areas of the prefrontal cortex including the dorsolateral PFC (DLPFC), ventrolateral PFC (VLPFC) and the anterior cingulate cortex (ACC) (Fitzgerald, Laird, Maller, & Daskalakis, 2008). Notably, these areas of the brain have been implicated specifically in working memory. As such, it may be particularly fruitful to examine working memory as a cognitive process that may be impaired in depression and could help account for biased attention.

Working Memory in Depression

The National Institute of Mental Health held a workshop in 2010 in order to define and discuss working memory as it relates to the Research Domain Criteria. The taskforce present at this meeting defined working memory as “the active maintenance and flexible updating of goal/task relevant information (items, goals, strategies, etc.) in a form that has limited capacity and resists interference” (National Institute of Mental Health, 2010). In other words, working memory is a system in which simple information is stored and manipulated. It can be posited that working memory is an essential component of reflective processing, as seen in the dual process model. For example, reflective processing requires planning and effortful thought, which appears to be highly related to processes within working memory. As such, examining working memory as a marker of reflective processing may help to elucidate the relationship of biased attention and depression.

Several theories of working memory have been proposed, though the current study employs a model of working memory as originally described by Baddeley and Hitch (1974). In their original model, working memory is comprised as three components of an attentional control system: the visuospatial sketchpad (visual information), the phonological loop (auditory information), and the central executive (assumed to be comprised of the phonological loop and the visuospatial sketchpad). Later models of working memory also include the episodic buffer which serves to help integrate the three components of working memory previously outlined, and integrate it with long term memory (Baddeley, 2007; Baddeley, 2012). Baddeley's model has been supported across a variety of disorders including ADHD and depression (e.g., Rapport et al., 2008; Alderson et al., 2015; Christopher & MacDonald, 2005; Baddeley, 2013). Furthermore, several studies have demonstrated deficits in working memory within depression (Rose & Ebmeir, 2006; Moritz et al., 2002).

Overall, previous research on the relationship between working memory and depression has found both broad and specific deficits (e.g., Christopher & MacDonald, 2005; Rose & Ebmeier, 2006; Moritz et al., 2002). Further, these deficits have been associated with brain regions implicated in working memory (e.g., Fitzgerald et al., 2008). Thus, it is clear that there is a relationship between working memory deficits and depression. However, the relationship between working memory deficits and attention bias in depression remains unexamined.

Current Study

As summarized above, previous literature has suggested that attention bias for dysphoric information is important in the onset and maintenance of depression, and furthermore, that it may play a causal role in the maintenance of depression (e.g., Wells & Beevers, 2010; Beevers & Carver, 2003; Gotlib et al., 2004). Additionally, it is important to examine factors that may impair reflective processing (Beevers, 2005), which would make it more difficult for depressed individuals to utilize reflective processing in order to correct negatively biased associative processing. One such factor to examine in its contribution to impaired reflective processing is working memory. Working memory, the system employed to remember and manipulate relatively simple information, is impaired in depressed individuals (Christopher & MacDonald, 2005). As previously noted, the construct of working memory appears to be very closely related to that of reflective processing, and therefore it is logical to assume that working memory may play an important role in the relationship between depression and attention for dysphoric stimuli. As such, the current study aimed to integrate these literatures to specifically examine the relationships between depression symptoms, working memory, and attention for dysphoric stimuli. In doing so, we used eye tracking methodology to test the following hypotheses:

H1: Consistent with prior literature (e.g., Peckham et al., 2010), we predicted that increased depression symptoms will be associated with increased attention for dysphoric emotional stimuli.

H2: Also consistent with prior literature (e.g., Christopher & MacDonald, 2005; Moritz et al., 2002, Rose & Ebmeier, 2006), we hypothesized that increased depression symptoms would be associated with deficits in working memory.

H3: We hypothesized that there would be an indirect effect of working memory on the relationship between depression symptoms and attention bias, such that working memory would account for a significant portion of the variance between depression symptoms and attention for dysphoric stimuli.

H4: As a stronger test of the relationship between working memory, depression, and attention bias, we experimentally manipulated working memory load during an eye tracking task. Specifically, we hypothesized that a working memory load would moderate the relationship between depressive symptoms and attention for dysphoric stimuli, such that under a load condition, the relationship between depressive symptoms and attention bias for dysphoric stimuli would be stronger than in a no load condition.

CHAPTER II

METHODOLOGY

Participants

An *a priori* power analysis indicated that in order to detect a small to medium effect size (c.f. Armstrong & Olatunji, 2012), we would need to recruit 120 participants to achieve a power of .85. To account for eye tracking data loss, we recruited 147 undergraduates from the student subject pool at a large university. However, we had more data loss than anticipated and ended up with a sample of 100 participants (see results below), which may have reduced our power to detect our hypothesized effects (see results and discussion). We recruited males and females who were at least 18 years old. To help ensure adequate variability and high enough range of depression symptoms, we specifically targeted and recruited individuals who had a PHQ-3 score greater than four.

Materials

Questionnaires.

Demographics. Participants provided basic demographic information such as age, sex, income, race, ethnicity and education. Additionally, participants provided information on mental health history including known diagnoses and treatment history.

Depression symptoms. Depression symptoms were measured using the Patient Health Questionnaire-9 (PHQ-9; Kroenke, Spitzer, & Williams, 2001). This is a 9-item self-report measure which is commonly used for assessing the 9 core symptoms of depression according to the DSM-5. Participants were asked to rate on a 0 to 3 scale how often they experience each symptom within a 2-week period. Possible responses include "not at all," "several days," "more than half the days," or "nearly every day." Participants were then asked to rate how difficult these problems have made it for them to do their work at school, at home, or get along with other people with responses ranging from "not difficult at all," "somewhat difficult," "very difficult," or "extremely difficult." Scores on the PHQ-9 range from 0 to 27, with scores of ≥ 5, ≥ 10, ≥ 15, indicating mild, moderate and severe levels of depression severity, respectively. Several studies have examined the psychometric properties of the PHQ-9 and have revealed Cronbach's alpha internal reliability between .86-.89, and test-retest reliability of .84 (e.g. Kroenke, et al., 2001; Kroenke, Spitzer, Williams, & Löwe, 2010). Consistent with prior studies, the current study revealed Cronbach's alpha of .86.

Anxiety symptoms. Given the high comorbidity of anxiety and depression, we measured anxiety symptoms using the Generalized Anxiety Disorder – 7 Questionnaire (GAD-7; Spitzer, Kroenke, Williams, & Löwe, 2006). The GAD-7 is a 7-item self-report questionnaire that assesses symptoms consistent with generalized anxiety disorder in the DSM-5. Participants were asked to rate on a 0 to 3 scale how often they experience each symptom within a 2-week period. Possible responses include "not at all," "several days," "more than half the days," or "nearly every day." Participants were then asked to rate how difficult these problems have made it for them to do their work at school, at home, or get along with other people with responses ranging from "not difficult at all," "somewhat difficult," "very difficult," or "extremely difficult." Scores on the GAD-7 range from 0 to 21, with scores of > 4, ≥ 8, ≥ 12, ≥ 16, indicating mild, moderate, high, and severe levels of anxiety severity, respectively. Studies have examined the psychometric properties of the GAD-7 and have revealed excellent internal consistency (Cronbach's alpha = .92), and test-retest reliability of .83 (e.g., Spitzer et al., 2006). The current study demonstrated good internal reliability (α = .88).

Laboratory Tasks.

Eye tracking task. Participants completed two runs of an eye tracking task (Run A and Run B; see the Procedure section below for additional information). Each run consisted of 10 trials and each trial contained a total of 5 images of the same male or female actor portraying emotions of sad, happy, neutral, disgusted, and angry faces (See Figure 1 for an example trial). Thus, a total of 100 images (5 images/trial X 10 trials/run X 2 runs) were be selected from the Karolinska Directed Emotional Faces (KDEF) database (Lundqvist, Flykt, & Ohman, 1998). The five emotional faces were counterbalanced in their placement in each trial (e.g., the sad face appeared in the center only twice; once in a female trial, and once in a male trial per task). Between each trial participants fixated on a white fixation cross in the middle of a black screen. The experimenter clicked the mouse to proceed to the trial after the participant fixated on the fixation cross. Participants were instructed to freely view the trials, as if they were viewing a photo album. Each trial lasted for 30 seconds. Participants sat between 60 and 70 cm from the viewing screen. Each of the 5 faces per trial measured 9.19 cm (approximately 8.1° visual angle) X 7.11 cm (approximately 6.2° visual angle). The five faces per trial were evenly distributed on the display screen.

Eye tracking system. Line of visual gaze was assessed using a Tobii T60 eye tracker and Tobii Studio software. The screen measured 17” diagonally and 1280x1024 pixels. The TFT T60 monitor detects the position of the pupils and corneal reflection in both eyes (binocular tracking). Gaze location was sampled every 16.7 ms (60 Hz). Each of the emotional stimuli in a trial was identified as an area of interest (AOI).

Eye tracking outcomes. For each area of interest, several selective attention indices can be calculated using the Tobii Studio software, including total visit duration, number of fixations, number of visits, average fixation duration, and first fixation duration. Previous research in the attention bias literature in depression has often used total visit duration (viz., total fixation duration) as an index of maintenance of attention over an entire trial, as it indicates sustained processing (Armstrong & Olatunji, 2012). A visit is defined as each instance of looking at a particular AOI. Total visit duration is calculated by summing the amount of time an individual views an AOI including fixations and saccades within the AOI. Several previous studies have utilized total visit duration to examine attention bias in depression as this index is able to capture the allocation of attention over time (e.g. Eizenman et al., 2003; Kellough et al., 2008; Sears et al., 2010). As such, total visit duration was used as the index measure of attention in this study. Other eye tracking indices (number of fixations, mean fixation duration, etc.) were also calculated for exploratory analyses, but are not discussed further here.

Visuospatial Working Memory (VS-WM) Task. The VS-WM task was adapted (see, for example, Alderson, Hudec, Patros, & Kasper, 2013) from an original task developed by Rapport et al. (2008). In the task, participants viewed nine identical 3.2 cm squares on a computer screen in three, three square columns. The columns were offset in order to prevent phonological coding of the squares (e.g., like a phone keypad). A series of dots appeared sequentially in one square of each trial. All dots were black except for one red dot which was counterbalanced across trials so that it did not appear in the same square more than once. Each dot appeared for 800 ms, with 200 ms in between each dot's presentation. After each stimulus sequence, participants were asked to report the order in which the black dots appeared, and indicate the location of the red dot last. Participants indicated the placement of the dots by using a mouse to click on a blank diagram of the nine offset squares on the computer screen. Participants completed set sizes of 4, 5, 6, and 7, and completed 10 trials per set size (i.e., 40 trials total). The set sizes were counterbalanced in order to control for order effects. Prior to completing the 40 trials, participants completed 2 practice trials with a set size of 5. Participants repeated the practice trials until they answered both trials correctly. The average correct number of stimuli at each set size (4, 5, 6, & 7) was calculated to provide a measure of composite performance on the VS-WM task.

Phonological Working Memory (PH-WM) Task. The PH-WM task was adapted (see, for example, Alderson et al., 2013) from a task originally developed by Rapport and colleagues (2008), and the task is similar to the Letter-Number Sequencing subtest presented on the WAIS-IV (Wechsler, 2008). Participants completed set sizes of 4, 5, 6, and 7, and completed 10 trials per set size (i.e., 40 trials total). Each set size was counterbalanced to control for order effects. Participants were presented with an auditory recording of a jumbled assortment of numbers (between 0 – 9) and one letter. Participants were then asked to report to a trained research assistant the numbers in numerical order, followed by the letter. Prior to administration of the 40 study trials, participants completed 2 practice trials with a set size of 5. Participants repeated the practice trials until they answered both trials correctly. The average correct number of stimuli at each set size (4, 5, 6, & 7) was calculated to provide a measure of composite performance on the PH-WM task.

Working Memory Load Task. The Serial Threes Test, a modification of the common serial sevens test (Smith, 1967) was used as a working memory load. The Serial Threes Test was adapted from the Serial 7's Test and has been shown to involve substantial cognitive demands (Kennedy & Scholey, 2000). In this task, participants counted backwards from 917 by 3's out loud while simultaneously viewing Run A or Run B of the eye tracking tasks. The fixation cross in the eye tracking class indicated that a participant should begin counting backwards. After each eye tracking trial, participants saw a screen indicating that they should stop counting. Upon presentation of the next fixation cross, participants resumed counting from where they left off. A trained research assistant told the participant the last number they said. If a participant reached 0 before the end of the eye tracking trial, they started counting backwards in 3's from 924 until the task is over.

Procedure

Upon arriving to the laboratory, participants completed the IRB approved consent form. Participants then provided basic demographic information and completed questionnaires assessing depression and anxiety symptoms. Next, participants engaged in assessments of phonological and visuospatial working memory. Each participant then completed two runs of the eye tracking task. Participants were randomized to complete Run A or Run B first. Additionally, participants were randomized to complete the serial 3 task during either Run A or Run B. As such, there were 4 study conditions (see Table 1 below). Upon completing the two runs of the eye tracking task, participants were debriefed on the purpose of the study.

CHAPTER III

RESULTS

Descriptives

One hundred forty-seven participants from a large university completed the study. However, 47 participants were excluded due to poor quality eye tracking data (i.e., < 70% valid eye tracking data on Run A or Run B), resulting in a final sample of 100 participants whose data were used in analyses. Participants had a mean age of 19.39 (SD = 1.7), and were 65% female. Participants were mainly Caucasian (73%), and 7% of the sample were American Indian or Alaskan Native, 7% were Asian or Asian American, 7% identified as multiple races, 5% were Black or African American, and 1% identified as Native Hawaiian or Other Pacific Islander. Six percent of individuals identified as being Hispanic. Mean scores on the PHQ-9 and GAD-7 were 7.01 (SD = 5.01) and 6.34 (SD = 4.9), respectively.

Hypothesized Results

To test our first and second hypotheses – that increased depression symptoms would be associated with increased attention to sad facial stimuli, and that increased depression would be associated with decreased phonological and visuospatial working memory, respectively – we ran bivariate correlations between PHQ-9 scores, total visit duration for sad faces, and composite scores on the phonological and visuospatial working memory tasks. As noted in Table 2, and consistent with our first hypothesis, depressive symptoms were positively associated with attention to sad facial expressions (r = .322, p = .001). However, phonological (r = -.017, p = .871) and visuospatial (r = .036, p = .725) working memory scores were not significantly associated with attention to sad faces.

To test our third hypothesis, we entered phonological and visuospatial working memory scores into a bias corrected bootstrapping model with 5000 resamples as described in procedures by Preacher and Hayes (2008). Total visit duration for sad faces was entered as the dependent variable, while PHQ-9 score was entered as the independent variable. Results indicate that the overall model was statistically significant, R^2 = .116, p = .009, and there was a significant direct effect of PHQ-9 on attention for sad faces, β = 1.4, $p < .001$. However, there was not significant indirect effect of phonological working memory as indicated of a 95% CI that included zero (-.145 to .056), nor was there a significant indirect effect of visuospatial working memory as indicated by a 95% CI that included zero (-.124 to .079).

Lastly, to test our fourth hypothesis, a repeated measures general linear model was used to examine the effect of a working memory load on the relationship between attention to dysphoric facial information and symptoms of depression. The main effect for load condition on attention for sad faces was not significant, $F(1,98) = .04$, $p = .84$, $\eta^2 < .01$, but there was a significant main effect for depression symptoms, $F(1,98) = 5.29$, $p = .024$, $\eta^2 = .051$. Importantly, there was a significant interaction between load condition and depression symptoms, $F(1,98) = 9.55$, $p = .003$, $\eta^2 = .089$. In contrast to the hypothesis, this moderation is driven by a significant positive relationship between symptoms of depression and attention to sad faces in the no load condition ($r = .322$, $p = .001$), but no such relationship in the load condition ($r = -.004$, $p = .970$). A Fisher r-to-z transformation found a significant difference between the effects, Z = 2.35, $p = .012$.

Exploratory Analyses

Effects of Anxiety

Because anxiety and depression are so highly comorbid, we examined the relationship between anxiety and the study variables. Results revealed a significant relationship between symptoms of anxiety and symptoms of depression, $r = .701$, $p < .001$ (see Table 2). Symptoms of anxiety were also significantly related to attention to sad facial expressions, $r = .304$, $p = .002$, but anxiety was not related to any other facial expressions, nor to phonological or visuospatial working memory (all *p*'s > .05). Therefore, we did not run any additional analyses with anxiety symptoms.

Further Exploration of the Relationship between Depression and Working Memory

Because our second hypothesis (that depression symptoms would be associated with phonological and visuospatial working memory) was not supported and because our final sample size was smaller than anticipated (which may have resulted in reduced statistical power), we ran additional analyses using the full sample, including participants who had poor eye tracking data. As such, we examined our bivariate correlations between PHQ-9, phonological working memory, and visuospatial working memory using 139 participants for the phonological task, and 140 for the visuospatial task. We lost data for 7-8 participants on the working memory tasks due to technological difficulties with the computer running these tasks. Consistent with the results using the smaller sample, symptoms of depression were not related to phonological working memory ($r = -.051$, $p = .553$), nor to visuospatial working memory ($r = .084$, $p = .321$). Visuospatial and phonological working memory were positively associated with each other ($r = .356$, $p < .001$).

Furthermore, because previous research found associations between the central executive (CE) component of working memory and depression but not between other components of working memory and depression (Channon, Baker, & Robertson, 1993), we created a CE variable and examined the relationship between the CE, symptoms of depression, and attention to emotional stimuli. In order to create the CE variable, we followed procedures outlined by Alderson et al. (2013) by regressing PH scores onto VS scores at each set size to obtain unstandardized predicted scores. We then regressed VS scores onto PH scores at each set size and obtained unstandardized predicted scores. We then averaged the eight unstandardized predicted scores that reflect the CE processes. In examining the bivariate correlations between the CE, symptoms of depression, and attention, we found that CE was not significantly associated with any attention variables or depressive symptoms (all *p*'s > .05). Results revealed that the CE was significantly associated with PH scores ($r = .875$, $p < .001$) and with VS scores ($r = .716$, $p < .001$).

Lastly, we examined the bivariate correlations between depressive symptoms, total number of serial three's items said, and total number of correct serial three's items. There were not any significant relationships between depression symptoms and total number of serial three's items said ($r = -.036$, $p = .726$) or total number of correct serial three's items ($r = -.011$, $p = .917$).

Working Memory Tasks

As noted above, the working memory tasks were unexpectedly not associated with depression symptoms or attention to emotional stimuli. In order to further evaluate the working memory tasks and whether they were measuring working memory as expected, we examined the bivariate correlations between scores on the phonological working memory task, visuospatial working memory task, and the performance on the serial three's load task (both number of items said and number of correct answers). Total number of serial three's items said was significantly associated with phonological working memory (r = .460, p < .001) and visuospatial working memory (r = .241, p = .016). Total number of correct serial three's items was also positively associated with phonological working memory (r = .499, p < .001) and visuospatial working memory (r = .323, p = .001).

Further Exploration of Memory Load Effects

We also ran additional analyses to further explore our null results for our fourth hypothesis, that a working memory load would moderate the relationship between symptoms of depression and attention to sad faces, such that under a load condition the relationship between depression symptoms and attention for sad faces would be even more robust. One potential reason why we found a significant moderation effect, but in the opposite direction than predicted is that it is possible that the serial three's task was too difficult, and participants were unable to simultaneously engage in the serial three's task and the eye tracking task. To examine this further, we conducted paired samples t-tests, comparing attention to all five facial emotions by load condition. As seen in Table 3, t-tests were significant for all facial emotions except angry, such that total visit duration was significantly reduced from a no load to a load task. This suggests that overall, during the load task, participants were looking at almost all facial emotions less so during the load task.

Effects of Load Condition Order

Additionally, because participants were randomly assigned to complete the load or no load task first, we ran the repeated measures general linear model to examine the effect of load order (no load first vs. load first) on our analyses. There was no significant main effect of load order on attention to sad faces, $F(1, 97) = .389$, $p = .534$, $\eta_p^2 = .004$, and there were no significant interactions between load order and load condition, $F(1, 97) = 1.52$, $p = .220$, $\eta_p^2 = .015$. Therefore, the order of the load did not affect attention to sad faces.

CHAPTER IV

DISCUSSION

Based on previous literature, the current study tested several hypotheses which aimed to integrate literature within depression, attention bias, and working memory. Our first hypothesis, that symptoms of depression would be associated with attention for dysphoric facial expressions was supported. This adds to the abundance of literature suggesting that depression is associated with attention bias for depression-relevant information (Peckham et al., 2010; Armstrong & Olatunji, 2012).

Our second and third hypotheses, that depression symptoms would be associated with deficits in phonological and visuospatial working memory and that working memory would account for a significant portion of the variance between depression and attention for dysphoric information, were not supported. This is in contrast to previous studies that have found a negative relationship between deficits in working memory and symptoms of depression. Though it is impossible to know exactly why our results were inconsistent with prior work, there are several differences between our study and previous studies examining these relationships. For example, several studies examining the relationship between working memory and depression have used working memory tasks that contain some type of emotional (i.e., depression-relevant) stimulus (Joormann, 2010; Yoon, LeMoult, & Joormann, 2014). The current study did not utilize working memory tasks that were emotionally valenced. Research examining individuals at risk for depression found that lower working memory capacity was associated with increased symptoms of depression over time, only for tasks that contained negative stimuli, but not for tasks that contained neutral stimuli (LeMoult, Carver, Johnson, & Joormann, 2015). Therefore, consistent with our results, it appears that negatively valenced stimuli are particularly important in detecting relationships between working memory and symptoms of depression. Furthermore, research has found that dysphoric and clinically depressed individuals have difficulty ignoring emotionally relevant stimuli broadly (Gilboa-Schechtman, Ben-Artzi, Jeczemien, Marom, & Hermesh, 2004). In their study, the authors found that dysphoric and clinically depressed individuals appeared to be distracted by emotion, even when they were specifically instructed to ignore emotion. As such, perhaps previous studies examining working memory deficits within depression found effects not because of deficits in working memory per se, but rather due to the use of emotionally valenced stimuli.

Additionally, while Christopher and MacDonald (2005) found that depressed individuals showed impairments in tasks that measured phonological loop, visuospatial sketchpad, and the central executive, the tasks that they used to measure these aspects of working memory differed from the tasks in the current study. One key difference is that both tasks used in Christopher and MacDonald's study that measured the phonological loop, presented stimuli visually (i.e., the phonological similarity effect and the word length effect). The phonological task used in our study only presented auditory stimuli. Therefore, it is possible that the phonological tasks used in Christopher and MacDonald's study are not comparable. The tasks used to measure the visuospatial sketchpad also varied between studies. While our task asked participants to indicate the order of the black dots with the red dot last on a blank grid, Christopher and MacDonald used a recognition task, in which participants were asked to indicate whether a probe appeared in an original set or not (yes no response). As such, it is possible that the tasks actually measured different components of visuospatial working memory (i.e., active manipulation of information vs. simple recognition). Another difference between our study and Christopher and MacDonald's study is that our study examined dysphoric individuals, whereas Christopher and MacDonald examined clinically depressed individuals. Therefore, it is possible that we did not detect significant effects because levels of depression were too low in our sample.

Interestingly, literature from the early 1990's found that deficits in working memory within depression were limited to the central executive and did not affect the phonological loop or visuospatial sketchpad (Channon, et al., 1993; Hartlage, Alloy, Vazquez, & Dykman, 1993). In order to examine the CE in our study, we calculated a CE variable and examined the relationships between the CE, symptoms of depression, and attention in our exploratory analyses. Our results did not reveal any significant relationships between the CE and symptoms of depression, nor between the CE and any of the attention variables. Though we did not find a relationship between CE and depressive symptoms, our results are consistent with this early literature suggesting that there is not a relationship between depression and phonological or visuospatial working memory.

Additionally, it is possible that we did not find relationships between depression symptoms, phonological working memory, and visuospatial working memory because our final sample had fewer participants than proposed (i.e., n = 100 vs. n = 120) due to the loss of more eye tracking data than we predicted. Therefore, it is possible that reduced power was the reason why we did not detect effects. However, our exploratory analyses examined these relationships using the full sample of 147 participants (including those with poor eye tracking data), and still, we did not detect significant effects. Therefore, it is possible that previous studies overestimated the size of the effects and so we were unable to replicate them in our sample, even when we had adequate power to detect effect sizes indicated in prior work.

Our fourth and final hypothesis, that a working memory load would moderate the relationship between symptoms of depression and attention for sad faces such that under a load condition, this relationship would be even more robust, was not supported. While we did detect a significant moderation effect, the direction of the effect was the opposite of what we predicted. As such, results indicated a significant relationship between depressive symptoms and attention for sad faces in the no working memory load condition, but this effect disappeared in the load condition. There are several possible reasons for why our results are in contrast to our hypothesis. One potential reason for this is that perhaps the working memory load utilized in this study (i.e. the Serial Three's Task) was more difficult than tasks used in other studies. Evidence to support this explanation exists within our exploratory analyses, which showed that compared to the no load condition, when participating in the load eye tracking task, total visit duration for all emotional faces except for angry, was significantly reduced. As such, it appears that the load task was so difficult, that participants were unable to fully engage in the eye tracking task under the load condition, and that they spent less time looking at almost all emotional faces under a load condition. If this is the case, future research could try to determine what level of a working memory load would be needed to detect effects, and not be too difficult. Furthermore, we also wanted to examine whether the order of the load or no load task affected our results. Exploratory analyses revealed that there were no order effects.

Another potential explanation for our null results could be that perhaps eye tracking is actually measuring a reflective process rather than an associative process. In the dual process model, Beevers (2005) proposes that when reflective processing is impaired (as under a working memory load) that biased, associative processing is apparent. Thus, it may be that eye tracking measures a more reflective or "intentional" attention process rather than a more associative, automatic process. However, it should also be noted that the dual process model is primarily focused on explaining depression *vulnerability* and proposes that depression symptoms themselves may reduce working memory capacity and act as a kind of de facto working memory load. So, one could argue that our participants with higher depression scores were already under a cognitive load (as a result of their depression symptoms) and we increased the cognitive load too much via the serial threes task. However, if it were the case that our individuals with higher symptoms of depression were already working under a cognitive load, then we would have expected them to have performed worse on our working memory tasks, which we did not find.

Limitations

Limitations of the current study include the use of an undergraduate student sample and the cross-sectional design. However, despite the use of an undergraduate sample, mean scores on the PHQ-9 were within the mild clinical range, which is above that of which a typical undergraduate sample contains. Future research could employ a longitudinal design in order to examine the relationships between symptoms of depression, working memory, and attention biases over time.

Strengths

The current study had several notable strengths. The study employed a large sample size, was experimental in design, and utilized two measures of working memory which are tied closely to theory. Additionally, the study utilized eye tracking methodology, which is arguably a more ecologically valid measurement of attention bias as compared to tasks such as the dot-probe or emotional Stroop task (Armstrong & Olatunji, 2012).

Conclusions

The current study provides further evidence for the relationship between symptoms of depression and attention for dysphoric information. Furthermore, while we did not find significant relationships between depression symptoms and working memory, we note several methodological differences between the current study and previous studies examining these relationships. We also provide theoretical explanations for our null results, suggesting that perhaps eye tracking methodology does not detect associative processing, but rather only detects reflective processing, and that perhaps previous research detecting a relationship between depression and working memory, were actually detecting effects due to the presence of emotional stimuli. Future studies could employ different levels of working memory loads, or perhaps use a working memory load that is emotionally valenced to further study these relationships.

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APPENDICES

APPENDIX A

REVIEW OF THE LITERATURE

Depression is a highly prevalent mental health issue that results in substantial financial burden and life impairment. Approximately 16.5% of adults living in the United States will experience major depressive disorder (MDD) at some point in their lives (Kessler, Berglund, Demler, Jin, & Walters, 2005). Annually, the United States spends more than $210 billion dollars on MDD, which demonstrates the huge economic burden of MDD (Greenberg, Fornier, Sisitsky, Pike, & Kessler, 2015). Furthermore, depression has been characterized as a recurrent disorder, such that once an individual experiences one episode of depression they are at greater risk to experience another (American Psychiatric Association, 2013; Kupfer, Frank, & Wamhoff, 1996). Therefore, proper assessment, prevention, and treatment of MDD are of utmost importance in order to reduce the burden MDD plays within individuals and within the broader US society. Thus, it is important to identify factors that contribute to the onset, maintenance, and recurrence of MDD.

Attention Bias in Depression

Cognitive models of depression posit that biased attention for depression-relevant information is important in the etiology and maintenance of the disorder (Beck, 1976; Teasdale, 1988; Ingram, 1984). However, early research in the attention bias literature in MDD did not detect a mood congruent information processing bias, but rather detected a lack of the positive bias seen in individuals without MDD (McCabe & Gotlib, 1995). It has since been noted though, that early research in mood congruent biases in MDD did not detect effects due to brief (e.g., under 1000 ms) stimulus presentation times. Research beginning in the late 1990's found different mood congruent effects depending on the presentation time. For example, one study found that when sad words were presented at 500 ms or 14 ms, depressed individuals did not exhibit a bias towards these stimuli (Bradley, Mogg, & Lee, 1997). However, when the same stimuli were presented for 1000 ms, researchers found a relationship between depressed mood and attention for sad words (Bradley, et al., 1997).

Another study also found that depressed individuals differentially attended to sad, but not angry or happy faces at 1000 ms presentation time (Gotlib, Krasnoperova, Yue, & Joormann, 2004). Further, the researchers found that this bias for sad faces at 1000 ms was specific to depressed individuals, and that individuals with generalized anxiety disorder and healthy controls did not exhibit significant biases to any emotional faces at 1000 ms. Therefore, this suggests that this depression relevant bias found in individuals with MDD at 1000 ms is specific to those individuals (Gotlib et al., 2004), and further suggests that depression relevant attentional biases utilize a later, more effortful processing system, as opposed to a brief, automatic processing system that is observed in anxiety disorders (Armstrong & Olatunji, 2012).

Eye tracking studies provided further support for a mood-congruent attention bias in depression at longer presentation times. For example, one early study examined attention bias using eye tracking towards dysphoric, neutral, social, and threatening content in individuals with MDD (n = 8) and healthy controls (n = 9) (Eizenman et al., 2003). The authors found that individuals with MDD had longer fixation times on dysphoric content compared to healthy controls, and further, individuals with MDD had longer fixation times on dysphoric images compared to neutral, social, or threatening images. The latter findings did not characterize the healthy controls. To replicate and extend these findings, another study compared dysphoric (n = 23) and non-dysphoric (n = 20) participants' attention to dysphoric, positive, and neutral images (Caseras, Garner, Bradley, & Mogg, 2007). Similarly, they found that dysphoric individuals exhibited increased biases in gaze time towards dysphoric images, compared to non-dysphoric images.

A comprehensive literature review of biased attention in depression suggested that within depression longer presentation times tended to produce more robust effects (Peckham, McHugh, & Otto, 2010). The specific presentation times necessary to detect attention biases in depression were examined via a study which examined number of fixations and fixation durations over 5-second time increments of 30-second presentation trials depicting sad, threatening, positive and neutral images (Kellough, Beevers, Ellis, & Wells, 2008). Consistent with attention bias literature in depression, the authors found that over the entire 30-second time period, number of fixations towards sad content was increased in depressed individuals compared to healthy individuals. Further, the authors also found that over the 30-second trials, depressed individuals spent significantly more time viewing sad content compared to positive content. Thus, their results suggest that depression related attention biases are sustained over long periods of time relative to biases found in other affective disorders. This further suggests that attention biases in depression require effortful, elaborative processing over time (Kellough et al., 2008).

Additional research has replicated findings suggesting that more robust effects are found in eye tracking with longer presentation times in depression. One study extended this literature by examining attention biases in disengagement and allocation within dysphoric individuals (Sears, Thomas, LeHuquet, & Johnson, 2010). While the authors did not find differences between dysphoric and non-dysphoric individuals in allocation of attention to dysphoric images, they did find that dysphoric individuals were slower to disengage their attention from dysphoric images compared to non-dysphoric individuals. This again suggests that depression related biases are may utilize effortful, later processing systems.

The aforementioned literature on the relationship between MDD and attention for depression-relevant information provides evidence for such a relationship. However, this literature leaves the question of whether attention bias is directly implicated in depression vulnerability. As such, more recent research has begun to examine whether attention bias for dysphoric information is a marker of depression vulnerability, or if it is rather a byproduct of depression. To attempt to examine this question, researchers conducted a study measuring depression symptoms at a 6-8 week follow-up, examining the relationship between attention bias, dysphoric mood, and subsequent stressful life events (Beevers & Carver, 2003). In the study, participants completed two dot-probe tasks: one before and one after a sad mood induction. Results indicated that after controlling for current and past depression symptoms, attention bias moderated the relationship between life stress and depression symptoms, such that for individuals with increased biases for dysphoric information increased stress predicted increased depression symptoms at a 6-8 follow-up, whereas for individuals without biases for dysphoric information, increased stress did not predict increased depression symptoms at the follow-up. This suggests that attention bias for dysphoric information may be directly implicated in depression vulnerability.

In another study, researchers examined attention bias as a moderator of war related stress, post-traumatic stress disorder (PTSD) and MDD in a sample of soldiers deploying to Iraq (Beevers, Lee, Wells, Ellis, & Telch, 2011). Before deploying, soldiers completed an eye tracking task to examine attention towards happy, neutral, fearful, and sad facial expressions. During their deployment, soldiers completed self-report questionnaires on their experiences of war related stress, PTSD, and MDD symptoms. The study found that several indices of sustained attention predicted increased depression symptoms in the context of war related stress. This provides further evidence of attention bias as a marker of depression vulnerability.

Research in the mid-late 2000's indicated that attention bias for dysphoric information is a marker of depression vulnerability. More recently, literature has begun to examine whether attention bias for dysphoric information may play a causal role in the development of MDD. Studies have examined this by directly manipulating attention biases via attention bias modification (ABM). The first study to examine ABM utilized a therapist guided procedure to manipulate attention of depressed individuals in a preliminary intervention (Papageorgiou & Wells, 2000). In the study, the researchers found that therapists were able to successfully decrease depression symptoms and other outcome variables by guiding attention away from dysphoric stimuli. However, due to several limitations of this study (e.g., small sample size), the results at the time were to be interpreted with caution, pending further investigations.

More recently, a study examined ABM in a sample of depressed college students (Wells & Beevers, 2010). Over a 2-week period containing 4 training sessions, they successfully trained attention away from dysphoric stimuli in a modified dot-probe task in a training group. Their results indicated that the training group, as compared to a control group, showed a significant decrease in attention bias for dysphoric stimuli and also exhibited a decrease in reported depression symptoms. As such, this study provides evidence that attention may, in fact, play a causal role in the maintenance of depression.

Additionally, one study used a spatial cuing task to train dysphoric and depressed individuals away from dysphoric stimuli and towards positive stimuli in 10 training sessions over 10 days (Baert, De Raedt, Schacht, & Koster, 2010). Interestingly, the results indicated that only for those with mild to moderate dysphoria, attention training reduced depressive symptoms. Thus, attention training did not appear to reduce depression symptoms of dysphoric individuals with more severe symptoms of depression, nor those diagnosed with clinical levels of depression. This suggests that ABM may only be implicated in individuals with less severe, dysphoric symptoms as opposed to those with more severe depression symptoms.

Even more recently, researchers conducted a randomized controlled trial comparing the effects of ABM, placebo, and assessment only on depression symptoms in a sample of college aged adults (Yang, Ding, Dai, Peng, & Zhang, 2015). In their study, ABM and placebo participants completed eight 12-minute training sessions over a 2-week period in which they completed a dot-probe training exercise. For participants in the ABM group, the majority (90%) of targets appeared at the same location as a neutral word, as opposed to the sad word (10%). In the placebo condition, the target appeared in the position of the neutral and sad words an equal amount of time (50%). Results of their trail indicated that for participants in the ABM condition, there was a significant reduction in depressive symptoms immediately following the 2-week training period, and that these reductions were maintained at a 3-month follow-up. Neither the placebo nor the assessment only conditions exhibited significant reductions in depression symptoms at either time point. Further, at 7-month follow up, ABM participants remained asymptomatic compared to participants in the placebo and assessment only conditions.

The previous literature on cognitive models of depression and the role of attention bias in depression vulnerability provide strong evidence of the relationship between depression symptoms and attention for dysphoric information. Though this evidence is now well-established in the literature, it remains unclear as to what additional factors may influence this relationship.

What accounts for attention bias in depression?

The previous literature demonstrates that attention bias is implicated in MDD. However, it is important to note that a mood congruent attention bias is not always observed in depression (e.g., Gotlib, McLachlan, & Katz, 1988; MacLeod, Mathews, & Tata, 1986; Mogg, Bradley, Williams, & Mathews, 1993). Thus, it is important to consider under what conditions a mood-congruent attention bias will be observed in depression. One model that may help explain when an attention bias in will be observed in depression is Beevers' (2005) dual process model. This model borrows from more general cognitive models that articulate two basic types of cognitive processes: associative and reflective processing. Associative processing refers to automatic, effortless processing, which often occurs outside of conscious awareness, but is dependent on previously encoded memories. For example, if a student is called into a professor's office, using associative processing, the student may think they did something wrong or may be getting kicked out of school. Conversely, reflective processing involves effortful, sequential, processing which often requires thoughtfulness and planning and takes place within conscious awareness. If a student were called into a professor's office, they may use reflective processing to think about past experiences of meeting with the professor, and may come to the conclusion that previous meetings had gone well, and the professor liked the student. Research has also suggested that associative processing is often employed first, but that associative processing can be overridden and corrected in certain situations by reflective processing (Beevers, 2005).

Beevers' dual process model posits that depressed, and depression vulnerable, individuals have developed negatively-biased associative processing. Though, under many conditions these individuals are able to "correct" their biased associative processing through reflective processing. For example, a depression-vulnerable individual may initially orient and be predisposed to dwell on depression-relevant information in the environment, but they are able to reflectively disengage and reorient their attention through the use of available cognitive resources. However, if the individual's cognitive resources are taxed, the individual will not be able to engage in reflective processing and the biased associative processing will prevail. Thus, situations or characteristics that reduce the ability to engage in reflective processing should increase associative processing and the likelihood of observing mood congruent biased attention in depression.

Research has found that depression symptoms can, in fact, deplete the cognitive resources necessary to engage in reflective processing (Wegner, Erber, & Zanakos, 1993). In one study, researchers induced mood states on college-aged study participants in order to examine the effects of mood state on reading comprehension and the ability to identify contradictions in reading passages (Ellis, Ottaway, Varner, Becker, & Moore, 1997). The authors found that individuals who were induced into a depressed mood state showed impaired comprehension, and failed to identify contradictions in the passages, as compared to those in a neutral mood induction. This suggests that cognitive resources may have been occupied by negative, dysphoric thoughts, and were unable to be employed in comprehension.

Additional research has shown that depressed and dysphoric individuals show broad cognitive deficits (Austin, Mitchell, & Goodwin, 2001). A recent meta-analysis found moderate cognitive deficits in attention, memory, and executive functioning of individuals with MDD (Rock, Roiser, Riedel, & Blackwell, 2014), and another meta-analysis found deficits in depressed individuals across tasks utilizing executive functions including inhibition, shifting, and working memory (Snyder, 2013). Executive function deficits have been implicated repeatedly in depressed individuals. These executive function deficits maybe related to cognitive deficits and biases for individuals with MDD in attention, memory, and problem-solving (Levin, Heller, Mohanty, Herrington, & Miller, 2007; Nitschke, Heller, Imig, McDonald & Miller, 2001). Further, executive function deficits have been associated with both structural and functional irregularities in the prefrontal cortex (PFC). In depressed individuals specifically, there are documented deficits in several areas of the prefrontal cortex including the dorsolateral PFC (DLPFC), ventrolateral PFC (VLPFC) and the anterior cingulate cortex (ACC) (Fitzgerald, Laird, Maller, & Daskalakis, 2008). Notably, these areas of the brain have been implicated specifically in working memory. As such, it may be particularly fruitful to examine working memory as a cognitive process that may be impaired in depression and could help account for biased attention.

Working Memory in Depression

The National Institute of Mental Health held a workshop in 2010 in order to define and discuss working memory as it relates to the Research Domain Criteria. The taskforce present at this meeting defined working memory as “the active maintenance and flexible updating of goal/task relevant information (items, goals, strategies, etc.) in a form that has limited capacity and resists interference” (National Institute of Mental Health, 2010). In other words, working memory is a system in which simple information is stored and manipulated. It can be posited that working memory is an essential component of reflective processing, as seen in the dual process model. For example, reflective processing requires planning and effortful thought, which appears to be highly related to processes within working memory. As such, examining working memory as a marker of reflective processing may help to elucidate the relationship of biased attention and depression.

Several theories of working memory have been proposed, though the current research employs a model of working memory as originally described by Baddeley and Hitch (1974). In their original model, working memory is comprised as three components of an attentional control system: the visuospatial sketchpad (visual information), the phonological loop (auditory information), and the central executive (assumed to be comprised of the phonological loop and the visuospatial sketchpad). Later models of working memory also include the episodic buffer which serves to help integrate the three components of working memory previously outlined, and integrate it with long term memory (Baddeley, 2007; Baddeley, 2012). Baddeley's model has been supported across a variety of disorders including ADHD and depression (e.g., Rapport et al., 2008; Alderson et al., 2015; Christopher & MacDonald, 2005; Baddeley, 2013). For example, one study examined deficits in specific components of Baddeley's working memory model (Christopher & MacDonald, 2005). In the study, depressed, anxious, and healthy participants completed a number tasks designed to assess working memory. Depressed participants showed impairments compared to healthy controls and anxious participants in the phonological loop and the visuospatial sketchpad. The depressed and anxious groups showed impairment compared to the control group on specific measures of executive function.

Additional research has demonstrated deficits in working memory in depression. For example, one study used an *N*-back task to compare working memory in individuals with and without MDD (Rose & Ebmeier, 2006). The research demonstrated that depressed individuals were slower to respond and were less accurate in their responses. Further, the study also indicated that depressed individuals showed deficits in working memory across all levels of the n-back task (1-3), as opposed to healthy controls, whom showed deficits only as the load increased. This suggests that individuals with MDD have broad deficits in working memory.

Another study examined differences in cognitive function and working memory in a sample of individuals with obsessive compulsive disorder, schizophrenia, depression, and healthy controls (Moritz et al., 2002). In the study, 145 participants (25 depressed, 25 OCD, 25 schizophrenic, and 70 healthy controls) completed a battery of cognitive tasks including the Wisconsin Card Sorting Task, Stroop Task, Trial-Making Tests A and B, Digit Span, and Verbal Fluency. Results suggested that individuals with schizophrenia and depression did not differ from each other on any of the tasks. However, both depressed and schizophrenic participants showed deficits on all tasks compared to healthy controls. This suggests that while depressed individuals do exhibit deficits in cognitive function and working memory, the deficits may not be specific to their disorder.

Overall, previous research on the relationship between working memory and depression has found both broad and specific deficits (e.g., Christopher & MacDonald, 2005; Rose & Ebmeier, 2006; Moritz et al., 2002). Further, these deficits have been associated with brain regions implicated in working memory (e.g., Fitzgerald et al., 2008). Thus, it is clear that there is a relationship between working memory deficits and depression. However, the relationship between working memory deficits and attention bias in depression remains unexamined.

Current Study

As summarized above, previous literature has suggested that attention bias for dysphoric information is important in the onset and maintenance of depression, and further, that it may play a causal role in the maintenance of depression (e.g., Wells & Beevers, 2010; Beevers & Carver, 2003; Gotlib et al., 2004). Additionally, it is important to examine factors that may impair reflective processing (Beevers, 2005), which would make it more difficult for depressed individuals to utilize reflective processing in order to correct negatively biased associative processing. One such factor to examine in its contribution to impaired reflective processing is working memory. Working memory, the system employed to remember and manipulate relatively simple information, is impaired in depressed individuals (Christopher & MacDonald, 2005). As previously noted, the construct of working memory appears to be very closely related to that of reflective processing, and therefore it is logical to assume that working memory may play an important role in the relationship between depression and attention for dysphoric stimuli. As such, the current study aimed to integrate these literatures to specifically examine the relationships between depression symptoms, working memory, and attention for dysphoric stimuli.

APPENDIX B

TABLES

Table 1. *Study conditions*

Condition	First Eye Tracking Run	Second Eye Tracking Run
1	A with load	B without load
2	A without load	B with load
3	B with load	A without load
4	B without load	A with load

Table 2. *Zero-order correlations between the variables.*

Measure	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**
1. PHQ-9	-								
2. GAD-7	.701***	-							
3. PH	**-.075**	-.086	-						
4. VS	**.101**	.159	.313**	-					
5. TVD_Sad	**.322****	.304**	-.017	.036	-				
6. TVD_Ang	.117	.029	.014	-.182	-.063	-			
7. TVD_Dis	.076	-.124	-.064	-.164	.092	.600***	-		
8. TVD_Hap	-.265**	-.117	.010	.069	-.378***	-.479***	-.597***	-	
9. TVD_Neu	-.045	-.108	-.021	.073	-.309**	-.257**	-.212*	-.288**	-

Note. *** = p < .001; ** = p < .01; * = p < .05; PHQ-9 = Patient Health Questionnaire-9; GAD-7 = Generalized Anxiety Disorder Scale – 7; PH = Phonological working memory composite score; VS = Visuospatial working memory composite score; TVD_Sad = Total visit duration for sad faces; TVD_Ang = Total visit duration for angry faces; TVD_Dis = Total visit duration for disgust faces; TVD_Hap = Total visit duration for happy faces; TVD_Neu = Total visit duration for neutral faces. Bolded values represent hypothesized effects.

Table 3. *Means, standard deviations, and t-statistics*

	No Load	Load		
	M(SD)	M(SD)	*t*-statistic	*p* value
TVD Angry	49.27 (13.58)	47.43 (17.00)	.775	.440
TVD Disgust	47.45 (12.23)	43.29 (14.61)	2.65	.009
TVD Happy	70.14 (29.75)	62.26 (35.65)	2.52	.013
TVD Neutral	63.6 (21.19)	52.53 (22.3)	4.58	< .001
TVD Sad	53.86 (20.12)	45.44 (15.47)	3.83	< .001

Note: TVD = Total Visit Duration.

APPENDIX C

FIGURES

Figure 1. An example trial used in the eye tracking tasks. Top Left = happy, Top Right = sad, Center = angry, Bottom Left = disgust, Bottom Right = neutral.

APPENDIX D

MEASURES

Demographic Information

To start with, we would like to get some background information from you.

1. What is your age? _______ 2. What is your sex? _______

3. Please indicate your level of physical/sexual attraction to women and men:

1 = Only attracted to women

2 = Primarily attracted to women, and slightly attracted to men

3 = Mostly attracted to women, and moderately attracted to men

4 = Equally attracted to women and men

5 = Mostly attracted to men, and moderately attracted to women

6 = Primarily attracted to men, and slightly attracted to women

7 = Only attracted to men

4. What is your current marital situation (please check one)?

_____ Married _____ Separated _____ Never married/Single

_____ Common law marriage _____ Divorced _____ Widowed

5. Do you consider yourself to be Hispanic or Latino (see definition below)? ☐Yes ☐No

Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.

6. What is your race? (please check one)

☐	American Indian or Alaska Native	A person having origins in any of the original peoples of North, Central, or South America, and who maintains tribal affiliations or community attachment.
☐	Asian	A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.

☐	Black or African American	A person having origins in any of the black racial groups of Africa.
☐	Native Hawaiian or Other Pacific Islander	A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
☐	White	A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.
☐	Multiple races	
☐	None of the above	

7. What is the highest grade in school you have completed (please check one)?

_____ Less than High School (**record actual grade**)   _____ A.A. or other degree that is not a B.A. or B.S.

_____ High School   _____ 4 years of college with degree

_____ 1 year of college or technical school   _____ Postgraduate, M.D., Ph.D.

_____ 2 or more years of college but did not graduate

8. How many people do you live with (not including yourself)?

_____ Number of children   _____ Number of adults

9. During the past year, what was your total family income? $

____

10. Do you ***currently*** take medication for emotional problems (e.g., anxiety, depression)? ☐No   ☐Yes

If yes, please list below (if you need additional room, please continue on the back of this page):

Date Prescribed	Medication name	Dosage	Reason for medication

11. ***In the past,*** did you take any medication for emotional problems (e.g., anxiety, depress.)? ☐No ☐Yes

If yes, please list below (if you need additional room, please continue on the back of this page):

Duration	Medication name	Dosage	Reason for medication
From to			
From to			
From to			
From to			

12. Have you ever been in therapy or counseling for emotional problems? ☐No ☐Yes If yes, please list below (if you need additional room, please continue on the back of this page):

Duration	Type of provider (PhD, MD, priest, social worker)	# of sessions	Reason for therapy
From to			
From to			
From to			

13. Have you ever been hospitalized for emotional problems (e.g., anxiety, depression, drugs)? ☐No ☐Yes

If yes, please list below (if you need additional room, please continue on the back of this page):

Duration	Length of stay	Reason for hospitalization

From to		
From to		
From to		

14. Please list any family history of psychological/psychiatric illnesses (e.g., depression, anxiety, alcohol, drug)

Person's Relationship to you (e.g., mother, paternal aunt, etc.)	Diagnosis/Problem(s) or Symptom(s)	Treatment Received? (Y/N)	Type of Treatment

15. Please list any personal current medical illnesses/concerns

Diagnosis/Problem(s) or Symptom(s)	Onset?	Treatment Received? (Y/N)	Type of Treatment

PHQ-9

Over the last 2 weeks, how often have you been bothered by the following problems?

	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself-or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed? Or the opposite—being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3

If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people? Circle one:

Not difficult at all   Somewhat difficult   Very difficult   Extremely difficult

GAD-7

Over the last 2 weeks, how often have you been bothered by the following problems?

	Not at all	Several days	More than half the days	Nearly every day
1. Feeling nervous, anxious or on edge	0	1	2	3
2. Not being able to stop or control worrying	0	1	2	3
3. Worrying too much about different things	0	1	2	3
4. Trouble relaxing	0	1	2	3
5. Being so restless that it is hard to sit still	0	1	2	3
6. Becoming easily annoyed or irritable	0	1	2	3
7. Feeling afraid as if something awful might happen	0	1	2	3

If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people? Circle one:

Not difficult at all   Somewhat difficult   Very difficult   Extremely difficult

APPENDIX E

IRB APPROVAL

Oklahoma State University Institutional Review Board

Date:	Tuesday, March 21, 2017
IRB Application No	AS1718
Proposal Title:	Attention, Working Memory, and Depression
Reviewed and Processed as:	Expedited

Status Recommended by Reviewer(s): Approved   Protocol Expires: 3/20/2018

Principal Investigator(s):

Morganne A. Kraines
116 N Murray
Stillwater, OK 74078

Tony Wells
116 N Murray
Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of the research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Scott Hall (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Hugh Crethar, Chair
Institutional Review Board

VITA

Morganne Ashley Kraines

Candidate for the Degree of

Doctor of Philosophy

Dissertation: THE INFLUENCE OF WORKING MEMORY ON THE RELATIONTHIP BETWEEN DEPRESSIVE SYMPTOMS AND ATTENTION FOR DYSPHORIC STIMULI

Major Field: Psychology

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Psychology at Oklahoma State University, Stillwater, Oklahoma in July, 2019.

Completed the requirements for the Master of Science in Psychology at Oklahoma State University, Stillwater, Oklahoma in 2015.

Completed the requirements for the Bachelor of Arts in Psychology at Colby College, Waterville, Maine in 2011.

Experience:

- Clinical residency at the Alpert Medical School of Brown University, Providence, Rhode Island
- 17 publications in peer-reviewed journals
- $\geq$ 50 papers or posters presented at conferences
- Various research laboratory experience (2010 – 2018)
- Various clinical practica (2013 – 2018)
- Various teaching assignments (2014 – 2016)

Professional Memberships:

- Association for Behavioral and Cognitive Therapies (2012 – present)
- Anxiety and Depression Association of America (2015 – present)