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Abnormal Reward Processing and Visual Selective Attention: an Event-related Potential Investigation with Remitted Depressed Adults

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ABNORMAL REWARD PROCESSING AND VISUAL SELECTIVE ATTENTION: AN EVENT-RELATED POTENTIAL INVESTIGATION WITH REMITTED DEPRESSED ADULTS

by

Kevin Haworth

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ABSTRACT

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Under the Supervision of Professor Christine L. Larson, PhD

Feedback, rewarding and non-rewarding, received from the environment can facilitate learning, influence motivation and shape behavior (Skinner, 1963; Thorndike, 1898). Recent research has indicated that reward can also enhance cognitive processes such as visual selective attention (Anderson, Laurent, & Yantis, 2011a; Anderson, Laurent, & Yantis, 2011b; Della Libera, Perlato, & Chelazzi, 2011; Krebs, Boehler, Egner, & Woldorff, 2011). Depression is one of the most common, debilitating, and costly forms of mental illness (Katon, 1996; Kessler et al., 2005; Mathers, Fat, & Boerma, 2008) and has been characterized by reduced responsiveness to reward (Henriques, Glowacki, & Davidson, 1994; Henriques & Davidson, 2000). The current study aimed to investigate the connection between abnormal reward processing and visual selective attention in currently euthymic adults with a history of Major Depressive Disorder (rMDD). Indeed, deficits in reward processing may be a trait-like marker for depression, present even in the absence of significant symptoms. To this end, we measured reward processing capabilities, as captured by the feedback-related negativity (FRN), a medial frontal electrocortical event-related potential component, and visual search performance in both remitted and never-depressed individuals. We found that reward enhanced visual search performance, but failed to replicate the group differences and reward sensitivity findings of a similar previous study (Taubitz, Haworth,

& Larson, 2015). We also found no evidence for any relationship between FRN amplitude, depression history, reward sensitivity, anhedonic symptomology and incentivized search performance. We did, however, find that participants in the rMDD group had greater search efficiency than controls on Target Present trials during the Incentivized task as well as higher rates of behavioral avoidance – tentatively suggesting that the improved search efficiency in the rMDD group may be a result of a motivation to avoid negative feedback.

To my beloved wife, Sarah, and our beautiful daughter, Maya. Your enduring support, patience and love made this process possible.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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INTRODUCTION

Major depressive disorder (MDD) is one of the most common, debilitating, and costly forms of mental illness (Creed et al., 2002; Gaynes, Burns, Tweed, & Erickson, 2002; Sobocki et al., 2007; Strine et al., 2015). Lifetime prevalence of MDD in the United States is 16.6 % (Kessler et al., 2005) and the economic burden of this disorder is estimated to be $210 billion a year (Greenberg, Fournier, Sisitsky, Pike, & Kessler, 2015). The World Health Organization recently ranked MDD as the third most burdensome disease in the world, only behind heart disease and AIDS/HIV (Mathers et al., 2008). MDD is associated with a host of negative health consequences, including amplifying somatic symptoms (e.g., chronic pain), increasing adverse health behaviors (e.g., obesity, smoking), decreasing medication adherence and self-care (Katon, 1996) as well as impaired social functioning (Hirschfeld et al., 2000). Thus, characterizing the mechanisms that lead to this devastating disorder is critical (aan het Rot, Mathew, & Charney, 2009; Disner, Beevers, Haigh, & Beck, 2011; Pizzagalli, Jahn, & O'Shea, 2005).

Anhedonia - loss of pleasure or decreased reactivity to hedonic stimuli - is a core psychopathological feature of MDD (American Psychiatric Association, 2013). Anhedonia is associated with increased severity and poor response to treatment (Kasch, Rottenberg, Arnow, & Gotlib, 2002; Spijker, Bijl, De Graaf, & Nolen, 2001; Vrieze et al., 2013). Research has also suggested that anhedonia is correlated with abnormal reward based decision-making, impairments in goal-directed behavior, reduced reward sensitivity ('liking'), disruption in approach-related behavior ('wanting'), and dysfunction in reward learning (Davidson, 2003; Treadway & Zald, 2011). Anhedonia has also been considered to be a potential trait marker of vulnerability for developing MDD (Klein, 1987; Loas, 1996; Meehl, 1975; Willner, 1993). Of clinical relevance, these hedonic deficits might lead to decreased engagement in pleasurable

activities and blunted responsiveness to natural reinforcers in the environment resulting in the generation, maintenance and exacerbation of depressive symptoms (Hundt, Nelson-Gray, Kimbrel, Mitchell, & Kwapil, 2007; Kasch et al., 2002; Kimbrel, Nelson-Gray, & Mitchell, 2007; Lewinsohn, 1974; McFarland, Shankman, Tenke, Bruder, & Klein, 2006). Therefore, anhedonia is a key component of depression and clarifying its role in the pathophysiology of this detrimental disorder is important for understanding the development and perpetuation of depression and for optimizing treatments (Hasler, Drevets, Manji, & Charney, 2004; Nestler et al., 2002; Pizzagalli, 2014; Russo & Nestler, 2013).

Dysfunctional Reward Processing and Anhedonia

Recent evidence has suggested that impaired reward learning is linked to the onset and maintenance of depression (Treadway & Zald, 2011; Vrieze et al., 2013). Reward can be found throughout the natural environment (e.g., positive social interactions, monetary gains, sexual gratification, food consumption) and has the capability to influence goal-directed behavior, enhance motivation and facilitate reinforcement learning (Eshel & Roiser, 2010). Dysfunctional reward processing in depression can disrupt an individual's antidepressant behavior by removing the impact of positive reinforcers in their life, causing them to engage less and less in their previously rewarding environment – further exacerbating the depressive cycle (Admon & Pizzagalli, 2015; Lewinsohn, 1974; Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2008). This concept is crucial to understanding the theorized development of anhedonia in depressed individuals. Investigating the behavioral and neurological aspects of dysfunctional reward processing may provide a more thorough understanding of the underlying mechanisms of anhedonia.

Pizzagalli and colleagues (2008) found blunted hedonic capacity and impaired reward learning in participants with MDD compared to healthy controls. Individuals with a history of MDD had a lower response bias toward high reward stimuli, suggesting that MDD might be characterized by an impaired ability to integrate reinforcement learning to modulate behavior. Similar results have been found in multiple behavioral studies examining the effects of reward responsiveness on reward learning in individuals with MDD (Henriques & Davidson, 2000; Pechtel, Dutra, Goetz, & Pizzagalli, 2013; Pizzagalli et al., 2009). Other work has shown that impairments in reward learning are specifically associated with increased anhedonic symptoms (X. Liu, Hairston, Schrier, & Fan, 2011; Vrieze et al., 2013).

Neuroimaging studies have indicated that individuals with MDD exhibit reduced or impaired functioning in key reward-related brain regions (Treadway & Zald, 2011). In a study utilizing a monetary incentivized delay task, Pizzagalli and colleagues (2009) found that MDD participants had weaker neurological responses to rewarding stimuli (monetary gains) in the caudate and left nucleus accumbens compared to controls. Using this same task this group recently found that participants with MDD, compared to controls, had decreased connectivity between the caudate and dorsal anterior cingulate cortex (dACC) in response to positive feedback (monetary reward) and increased connectivity between the caudate and a more rostral subregion of the dACC in response to negative feedback (Admon et al., 2015). Investigators suggested that this reduction in the synchronicity between the caudate and dACC in response to positive feedback may reflect a diminished integration of positive feedback in the circuitry - potentially reducing the saliency of the positive feedback resulting in a disrupted reinforcement learning process (Admon et al., 2015).

Several researchers have also suggested a potential link between striatal abnormalities and anterior cingulate cortex (ACC) activation irregularities in response to reward and anhedonia (Forbes et al., 2006; Forbes et al., 2009; Keedwell, Andrew, Williams, Brammer, & Phillips, 2005a; Keedwell, Andrew, Williams, Brammer, & Phillips, 2005b; Knutson, Bhanji, Cooney, Atlas, & Gotlib, 2008; Kumari et al., 2003; Mitterschiffthaler et al., 2003; Schaefer, Putnam, Benca, & Davidson, 2006; Smoski et al., 2009; Steele, Kumar, & Ebmeier, 2007; Vrieze et al., 2013; Wacker, Dillon, & Pizzagalli, 2009). For example, Knutson and colleagues (2008) found that, compared to healthy controls, ACC activity was reduced in unmedicated participants with MDD during anticipation of increasing gains compared to ACC activity during anticipation of increasing losses. Likewise, reduced ACC activity during anticipation of reward as well as reduced response time post reward acquisition has been found in MDD participants (Steele et al., 2007). These findings indicate a potential dysfunction in the ACC, a structure proposed to influence reward-based decision-making, response selection, error detection and novelty detection (Bush et a., 2002; Williams et al., 2004), for individuals with MDD.

Similar dysfunctions in ACC and striatum activity linked to impaired reward processing have also been observed in electroencephalogram (EEG) studies involving depressed participants (Carlson, Foti, Mujica-Parodi, Harmon-Jones, & Hajcak, 2011; Gehring & Willoughby, 2002; Hajcak, Moser, Holroyd, & Simons, 2007; Holroyd & Coles, 2002; Martin, Potts, Burton, & Montague, 2009; Nieuwenhuis, Yeung, Holroyd, Schurger, & Cohen, 2004; Potts, Martin, Burton, & Montague, 2006). Relevant to the proposed study, investigations utilizing event related potential (ERP) methodology suggest that the feedback-related negativity (FRN) component may be a useful marker for capturing abnormalities in reward processing found in MDD (Foti & Hajcak, 2009; Santesso et al., 2008; Walsh & Anderson, 2012). The FRN is a

medial frontal negative deflection ERP component that peaks around 250 ms post feedback and is largest in response to negative outcomes, such as monetary losses or errors (Bress & Hajcak, 2013; Carlson et al., 2011; Foti, Weinberg, Dien, & Hajcak, 2011; Gehring & Willoughby, 2002; Hajcak, Holroyd, Moser, & Simons, 2005; Hajcak, Moser, Holroyd, & Simons, 2006; Holroyd & Coles, 2002; Holroyd, Hajcak, & Larsen, 2006; Nieuwenhuis, Holroyd, Mol, & Coles, 2004; Yeung & Sanfey, 2004). The prevailing theory, proposed by Holroyd and Coles (2002), suggests that FRN reflects phasic midbrain dopamine responses in the ACC that represent activity in the reinforcement learning system. According to this theory, the amplitude of feedback negativity is greater when feedback is unexpectedly negative compared to unexpectedly positive. The result of the processing of feedback is integrated into the reinforcement learning system, generating a potential adjustment in the organism's behavior or cognitive processing in order to promote a favorable outcome or remove an unfavorable outcome (Holroyd & Coles, 2002).

To date, only a few researchers have used the FRN component to investigate reward processing deficits and consequential reinforcement learning impairments in individuals with depressive symptomology (Bress & Hajcak, 2013; Foti & Hajcak, 2009; Foti, Carlson, Sauder, & Proudfit, 2014; Li et al., 2015; X. Liu et al., 2011; Santesso et al., 2008). Using a standard gambling task, researchers found that FRN amplitude was inversely related to depression and stress scores (Foti & Hajcak, 2009). The authors concluded that the results of this study are congruent with research linking depression with reduced reward sensitivity (Henriques et al., 1994; Henriques & Davidson, 2000), positive affect (Clark & Watson, 1991; Watson, Weber et al., 1995; Watson, Clark et al., 1995) and an underactive approach system (Davidson, 1992; Davidson, 1998) and suggest the FRN could be a useful measurement of reward/non-reward processing (Foti & Hajcak, 2009). Foti and colleagues (2014) further demonstrated that

participants with high-levels of anhedonia had blunted FRN amplitude as well as reduced BOLD activity in the ventral striatum, a key structure that, along with structures like the ACC, contribute to the reward system (Foti et al., 2014; Haber, 2011). Though still a newly researched ERP component, FRN appears to be a useful method for measuring reward processing in individuals with MDD.

Trait Aspect of Reward Processing Deficits

Understanding vulnerability factors and trait aspects of mood disorders has been an important focus of recent research (e.g.,Weinberg, Liu, Hajcak, & Shankman, 2015; Whitton et al., 2016, for review: Pizzagalli, 2014). Anhedonia has long been considered to be a possible trait marker of MDD (Meehl, 1975) and related symptom profiles maybe associated with an increased vulnerability for developing MDD (Pechtel et al., 2013; Pizzagalli, 2014). Evidence for the heritability of anhedonia has been found in never-depressed first-degree relatives of individuals with MDD (deficits in establishing a reward bias toward more frequently rewarded stimuli, W. Liu et al., 2016) as well as never-depressed 10 to 14 year old girls of depressed mothers (abnormal activation in reward-related areas of the brain during anticipation of reward, Gotlib et al., 2010). Also, the predictive influence of reward processing abnormalities have been found in never-depressed adolescent girls where blunted FRN amplitude during reward/non-reward feedback at baseline predicted major depressive episodes 2 years later (Bress & Hajcak, 2013) and adolescents of depressed parents where low reward seeking predicted onset of depression 1 year later (Rawal, Collishaw, Thapar, & Rice, 2013).

To our knowledge, only one study has used FRN to examine response to feedback in adults with remitted depression (rMDD). Santesso and colleagues (2008) found increased FRN amplitude in response to negative feedback in rMDD compared to controls. These findings

appear to be opposite of those found by Bress et al. (2013); however, Santesso et al. (2008) compared only FRN responses to negative feedback instead of examining the difference between reward/non-reward activity used by Bress et al. (2013), which is the preferred technique of FRN evaluation (Hauser et al., 2014). Overall, the literature suggests that anhedonia may be a trait feature of depression, however, there is a need for further research investigating the potential trait aspects of anhedonia in adults with rMDD.

Summary of Anhedonia and Reward

The past several decades have provided a substantial amount of research on depression, yet the etiology and pathophysiology of this debilitating disorder remains largely unknown (Pizzagalli, 2014; Strine et al., 2015). Anhedonia, or reduced reactivity to reward, is a potential trait-like feature of depression that has been associated with aberrant reward processing as indicated by dysfunctional reward learning, disrupted approach-related behavior and impaired reward sensitivity found in anhedonic populations (Davidson, 2003; Meehl, 1975; Treadway & Zald, 2011). Reward processing impairments in depressed participants have been measured using FRN (Bress & Hajcak, 2013; Foti & Hajcak, 2009; Foti et al., 2014; W. Liu et al., 2014), an ERP component purported to capture phasic midbrain dopamine activity in the ACC (Holroyd & Coles, 2002). Utilizing the FRN component to characterize abnormal reward processing in rMDD provides a promising method of explicating the function of anhedonic symptoms.

Impaired Reward Processing and Visual Selective Attention

Reward has also been found to influence other cognitive processes, such as visual selective attention (Anderson et al., 2011a; Anderson & Yantis, 2013; Anderson et al., 2011b; Della Libera & Chelazzi, 2006; Della Libera & Chelazzi, 2009; Hickey, Chelazzi, & Theeuwes, 2010; Raymond & O'Brien, 2009). Visual selective attention facilitates the privileged processing

of relevant stimuli and inhibits processing of distracting/irrelevant stimuli (Allport, 1989; Duncan, 1993; Egeth & Yantis, 1997; Pashler & Sutherland, 1998; Treisman, 1969). This selection process is thought to be driven by an interplay between the "bottom-up" saliency of the stimuli and "top-down" goals/motivations of the individual (Armstrong, Chang, & Moore, 2009; Buschman & Miller, 2007; Gregoriou, Gotts, Zhou, & Desimone, 2009; Kincade, Abrams, Astafiev, Shulman, & Corbetta, 2005). Visual selective attention can be evaluated in a laboratory setting through the use of a visual search task and measurement of search efficiency (e.g., (Wolfe, 1998; Wolfe, 2007). Search efficiency is usually determined by the search slope, which is the slope of the linear line of best fit connecting each mean reaction time by the set size – measured as the number of milliseconds (ms) it takes the participant to search through an array (e.g., Treisman & Gelade, 1980; Wolfe, 1998; Wolfe, 2007). Search efficiency can be affected by the features of the target and the context of the distractor (bottom-up) as well as the characteristics of the participant (e.g., emotional valence) and the demands of the search task (top-down) (Gerritsen, Frischen, Blake, Smilek, & Eastwood, 2008; Kristjánsson, Sigurjónsdóttir, & Driver, 2010; Treisman & Gelade, 1980, for review, see: Frischen, Eastwood, & Smilek, 2008; Pourtois, Schettino, & Vuilleumier, 2013; Wolfe, 2003; Wolfe, 2007). The visual search task is also thought to mimic everyday circumstances such as trying to find (top-down) your bright orange car (bottom-up) at the market parking lot.

Researchers have found that reward can influence visual selective attention by heightening the saliency of a target and strengthen the inhibitory faculties of an individual (Della Libera et al., 2011; Della Libera & Chelazzi, 2006; Della Libera & Chelazzi, 2009), resulting in a reward learning process that has been shown to continue to guide visual selective attention for several days after the initial study sessions (Della Libera & Chelazzi, 2009). The effects of

reward learning on visual selective attention have also been shown to remain intact even when previously learned association rules change (Anderson et al., 2011a). In addition, researchers have found that the introduction of reward during a visual search task enhances the "pop-out" feature of target stimuli (Kiss, Driver, & Eimer, 2009; Kristjánsson et al., 2010) regardless of object complexity (Donohue et al., 2016) or perceptual awareness of rewarding stimuli (Harris et al., 2016). Lee and Shomstein (2014) found that reward enhanced the "pop-out" effect carried over into a task that no longer provided reward based on performance.

It is clear that reward impacts visual selective attention, however, very few studies have examined the influence of reward on visual selective attention in populations with potential reward processing abnormalities such as depression. Anderson and colleagues (2014) investigated value-based attentional capture in individuals with current depressive symptomology. They found that, compared to controls, participants experiencing depressive symptoms did not develop an attentional bias toward rewarding stimuli. Suggesting that individuals with depressive symptomology have deficits in hedonic evaluation of rewarding stimuli that may influence how the attention system is shaped by reward (Anderson et al., 2014). Similar results were found in a recent study that examined the impact of depression history on the influence of reward on visual search performance. Taubitz, Haworth, and Larson (2015) found that search efficiency was enhanced with the introduction of reward (presented as positive feedback and monetary gains); however, reward had less effect on the search efficiency for participants with remitted depression compared to participants with no history of depression. The researchers also found that reward sensitivity was inversely related to search efficiency – the greater sensitivity to reward the more efficient visual search. These results suggest that blunted

reward sensitivity is a possible trait-like feature of MDD that continues to influence reward-based attention without the presence of active depressive symptoms.

Current Study

It is clear that reward impacts visual selective attention (Anderson et al., 2011a; Anderson & Yantis, 2013; Anderson et al., 2011b; Della Libera & Chelazzi, 2006; Della Libera & Chelazzi, 2009; Hickey et al., 2010; Raymond & O'Brien, 2009) and abnormal reward processing has been linked to MDD (X. Liu et al., 2011; Pizzagalli et al., 2008; Pizzagalli et al., 2009; Vrieze et al., 2013) and rMDD (Meehl, 1975). However, little is known as to what neurological mechanism is being disrupted so that reward information is not being encoded and used to assist in reinforcement learning to aid in the shaping of behavior (i.e., guiding attention). Coalescing knowledge gained from reward, anhedonia and visual selective attention literatures, our primary aim was to enhance the understanding of the association between abnormal reward processing and visual selective attention in remitted depressed individuals. To do so, we conducted an ERP study utilizing self-report measures (reward sensitivity and depression), a clinical interview and a two-part visual search task (Taubitz et al., 2015) to investigate the relationship between FRN amplitude, depression history, reward sensitivity, and search efficiency in a sample of undergraduate students. We first attempted to replicate findings from Taubitz et al. (2015) to establish the influence of reward on search efficiency in the broader participant population as well as between groups (rMDD and Never-Depressed) and in relation to individual differences in hedonic capacity. We hypothesized that reward would enhance search performance; however, the level of enhancement would depend on depression history and individual differences in reward sensitivity.

Next, we investigated the association between FRN amplitude and search efficiency in the greater participant population as well as between groups (rMDD and Never-Depressed) and in relation to individual differences in hedonic capacity. FRN was recorded in response to performance feedback provided after each trial. Since FRN is a putative index of reward processing, we hypothesized that FRN amplitude would be negatively correlated with search performance – increased FRN amplitude would result in more efficient visual search. Since MDD is marked by aberrant reward processing (Whitton, Treadway, & Pizzagalli, 2015) and that these effects are maintained when depression is in remission (Pechtel et al., 2013; Ubl et al., 2015), we also hypothesized that rMDD participants would have lower FRN amplitude and reduced search efficiency compared to Never-Depressed controls, which we would expect to have higher FRN amplitude and increased search efficiency. Lastly, because of the trait nature of hedonic capacity (Baskin-Sommers & Foti, 2015; Pechtel et al., 2013; Pizzagalli, 2014) and the proposed core role in reward processing (Berridge & Robinson, 1998; Berridge, 2003; Berridge & Kringelbach, 2008) it is possible that variations in hedonic capacity across the study population may differentially influence search efficiency. Thus, we hypothesized that participants with higher levels of reward sensitivity would have increased FRN amplitude and more efficient search performance than participants with lower levels of reward sensitivity.

METHOD

Participants

Recruited Population. A total of 79 University of Wisconsin-Milwaukee undergraduate students were recruited to participate in the study. Participants meeting criteria were compensated with course extra credit and monetary reward based on visual task performance. All

study procedures were approved by the University of Wisconsin-Milwaukee's Institutional Review Board.

Inclusion Criteria. (1) right-handed, (2) 18 to 55 years old, and (3) normal or corrected vision.

Exclusion Criteria. (1) underlying neurological condition (i.e., history of stroke, epilepsy), (2) current Major Depressive Disorder, (3) meeting criteria for current or lifetime diagnosis of Bipolar I or II Disorder, Alcohol and/or Substance Dependence or Abuse, or Schizophrenia.

Final Study Population. Data from 53 participants were used in the final analyses after removing participants for meeting criteria for bipolar (n = 2), current depression (n = 3); having unusable EEG data (n = 10) and for having scores in the outlier range for self-report (n = 2), behavioral data (n = 7) or FRN site-specific amplitude (n = 2). A Tukey outlier test (Tukey, 1977) was used to determine the outlier ranges for self-report, behavioral and FRN amplitude data. EEG data was deemed unusable if during manual cleaning of the data more than 25% of the trials were eliminated due to distorted segments of the EEG data (i.e., participant coughs or shifts dramatically resulting in unusable data).

Diagnostic Interview

All participants completed the Mini International Neuropsychiatric Interview (MINI) version 6.0 with a trained clinical graduate student. The MINI interview was used to evaluate diagnostic criteria for MDD (current and remitted), Bipolar (I and II), and Alcohol and Substance Dependence or Abuse. The MINI is highly correlated with the Structured Clinical Interview for DSM-IV (SCID) for a diagnosis of MDD (kappa = 0.84, sensitivity = 0.96, specificity = 0.88, Sheehan et al., 1998) and current/ lifetime mania (kappa = 0.67/0.73, sensitivity = 0.82/0.81,

specificity = 0.95/0.94, Sheehan et al., 1998), which is used in combination with diagnosis of MDD to inform Bipolar I and II diagnosis. Diagnostic questions for Alcohol and Substance Dependence or Abuse on the MINI match the DSM-IV criteria exactly; therefore, no validity or reliability information was necessary to support diagnostic accuracy of the MINI.

Self-Report Measures

Participants also completed a set of self-report surveys that assessed depression, sensitivity to reward and punishment, anxiety and trait indices of anhedonia.

Depression. To provide an additional assessment of current depression we used the Beck Depression Inventory (BDI-II: Beck, Steer, & Brown, 1996). Though participants with current depression were identified during the MINI interview, it is still expected that participants meeting criteria for rMDD will have higher rates of depressive symptoms (Keller, 2003). Therefore, the BDI-II was used to control for current levels of depressive symptoms during analyses comparing rMDD and Never-Depressed controls. The BDI-II is a 21-item measure that demonstrates good reliability and validity in college student populations seeking treatment services (Sprinkle et al., 2002) as well as a general college student population (Storch, Roberti, & Roth, 2004).

Punishment and Reward Sensitivity. We used the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia, Avila, Moltó, & Caseras, 2001) to measure sensitivity to reward and sensitivity to punishment. The SPSRQ is a 20-item measure that consists of two subscales, Sensitivity to Punishment and Sensitivity to Reward. The SPSRQ also has good reliability and construct validity (Avila & Parcet, 2000; Avila & Parcet, 2001; Caseras, Avila, & Torrubia, 2003).

Anhedonia. The Snaith–Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995) was used to evaluate the anhedonic characteristics of the study population. Anhedonia is marked by a loss in and/or blunted experience of reward. Reduction in the sensitivity to reward, as captured by SPSRQ, reflects an aspect of anhedonia, however, it is unclear as to the degree reward sensitivity represents the entirety of anhedonia. To this end, we have also decided to broaden the scope of anhedonic evaluation with the SHAPS. The SHAPS is a 14-item measure that has been found to have good validity and reliability in participants with MDD (Nakonezny, Carmody, Morris, Kurian, & Trivedi, 2010; Snaith et al., 1995) and in the general population (Snaith et al., 1995).

Anxiety. The Beck Anxiety Inventory (BAI) was used to measure current, self-report experience of anxiety. The BAI is a 21-item inventory that captures common symptoms of anxiety experienced during the past week. The BAI has good psychometric properties (Beck, Epstein, Brown, & Steer, 1988; Dent & Salkovskis, 1986; Fydrich, Dowdall, & Chambless, 1992).

Behavioral Inhibition (Avoidance). The Behavioral Inhibition System (BIS) subscale of the BIS/BAS scale was used to evaluate motivation to avoid adverse outcomes (Carver, & White, 1994). The BIS subscale consists of a 7-item self-report measure and has been demonstrated to have strong construct validity, good reliability and accurately predicts neuroticism, anxiety and negative affect (Campbell-Sills, Liverant, & Brown, 2004; Carver & White, 1994).

Behavioral Approach. The Behavioral Approach System (BAS) is measured as three separate subscales (Drive, Fun Seeking and Reward Responsiveness) of the BIS/BAS measure and is used to evaluate approach motivation (Carver, & White, 1994). All three subscales consist of 4 self-report items. The BAS subscales also have strong construct validity and reasonable reliability (Campbell-Sills, Liverant, & Brown, 2004; Carver & White, 1994).

Visual Search Task

The visual search task used for this study is a slightly modified version of the task used in Taubitz et al. (2015). Modifications were made to the task to accommodate ERP assessment. All participants completed 2 versions of the visual search task: Standard Version and Incentivized Version. The Standard Version search task contained 480 trials and was used to determine baseline visual search performance. Each trial consisted of a 1000ms – 2000ms fixation cross (mean 1500ms) followed by a search array of 4, 8, or 12 letters (see **Figure 1**). This initial fixation cross also acted as a brief delay period between trials. Half of the trials contained the target stimuli (Target Present) in which there was a blue (or green) E in an array of blue (or green) F's and green (or blue) E's and F's. The other half of the trials did not contain a target stimulus (Target Absent) in which all of the letters were blue (or green) F's and green (or blue) E's and F's. The letter array remained on the screen until a response was made or 3000ms (for 4 and 8 letter set sizes) or 4000ms (for 12 letter set size) had elapsed. The participant was instructed to determine whether or not a target stimulus was present or absent in the presented array of letters and was asked to respond as quickly and accurately as possible during each trial. The participants' mean reaction time (RT), minus 1.5 standard deviations of the standard search RT, was used as the threshold for rewarded responses during the Monetary Incentivized Reward Version of the task.

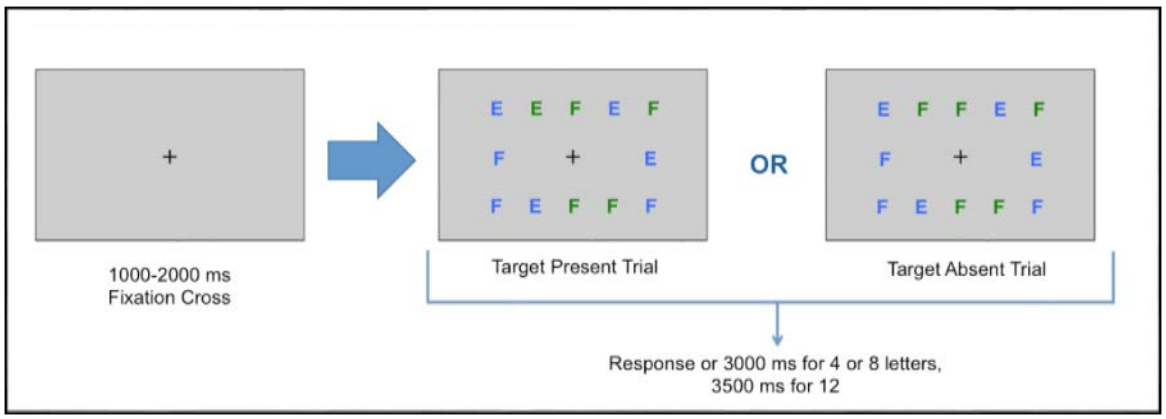

Figure 1. Part 1 – Standard Search Task. In this part of the task the participants do not receive feedback or monetary incentives in response to performance.

Next, the participants completed the Incentivized Version of the visual search task. The task was the same as the Standard Version; however, the participants received feedback and had the opportunity to earn money based on their performance (see **Figure 2**). The feedback participants received was either "Correct and Fast" (indicating a correct response made in less than 1.5 SD from Standard Version mean RT), "Correct and Slow" (indicating a correct response made in more than 1.5 SD from Standard Version mean RT), "Incorrect and Fast" (indicating an incorrect response made in less than 1.5 SD from Standard Version mean RT) or "Incorrect and Slow" (indicating an incorrect response made in more than 1.5 SD from Standard Version mean RT). Participants also had the opportunity to earn up to $14.00 (5 cents for every correct response completed under the threshold time). Trials exceeding 3 standard deviations below or above the mean response time were removed (mean number of trials removed: 7%). Participant behavioral data would have been excluded from further analysis if trial removal exceeded 25% or accuracy fell below 70%, however, no participant data was excluded from further analysis due to high rates of trial removal or impaired accuracy.

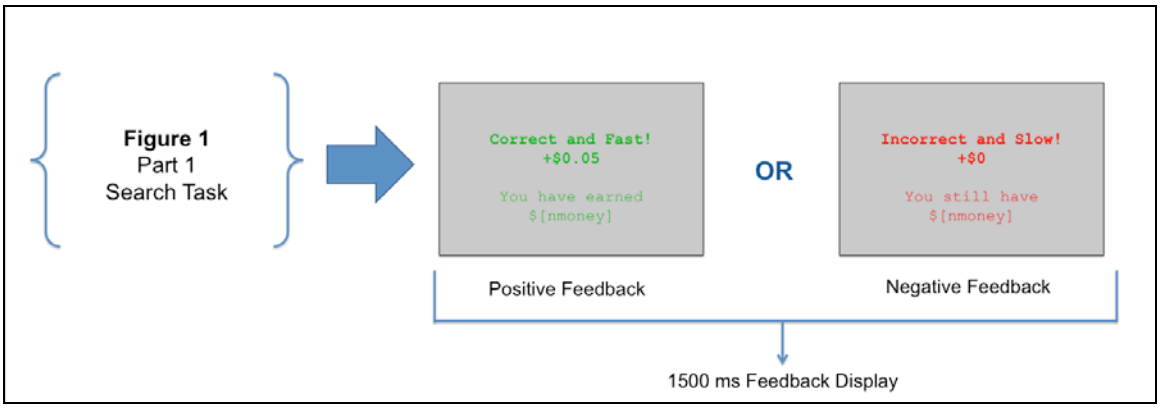

Figure 2. Part 2 – Incentivized Visual Search Task. In this part of the task the participants receive positive (including monetary incentives) and negative feedback in response to performance.

Electroencephalogram Data Acquisition and Preprocessing

Electroencephalogram (EEG) data were recorded using a DC amplifier and a 32-channel cap with shielded leads (Advanced Neuro Technology B.V., Netherlands). During collection, data were referenced to the left mastoid, sampled at 512 Hz and subjected to anti-aliasing low-pass filter (~138 Hz). Impedances for each electrode were less than 15 kΩ. Once collected, data were manually cleaned (removal of large shifts and compromised data sections), filtered (Butterworth band-pass, .05-30 Hz) and processed through an independent components analysis (as implemented by EEGLab v.12) in order to identify and remove artifacts due to eye blinks and eye movement. Next, data were re-referenced to mean mastoid, epoched using the first 2 seconds of the feedback slide, and baseline corrected using 200 ms prior to feedback slide as the new onset baseline. Trials with voltage change greater than 100 μV were removed and participants missing more than 25% of trials were considered to have poor EEG data and removed from further analysis. To capture medial frontal activity we focused on the Fz electrode site (Hajcak et al., 2007; Moser & Simons, 2009; Santesso et al., 2008). Average waveforms of activity at Fz for each feedback type (Correct and Fast, Correct and Slow, Incorrect and Fast, Incorrect and Slow) for each participant were created. Next, we created an average wave for the negative feedback conditions (Correct and Slow + Incorrect and Fast + Incorrect and Slow / 3) and a negative

minus positive feedback difference wave (negative – Correct and Fast) for each participant was used as the measure of FRN (Foti & Hajcak, 2009; Moser & Simons, 2009; Walsh & Anderson, 2012). A grand average waveform was then created for each group (rMMD, Never-Depressed controls) for each feedback type at Fz. The most often used method for determining the FRN window is to examine the grand average waveform for controls and visually determine a 100ms window of negativity around 300ms following feedback (Moser & Simons, 2009). After review of the grand average waveform for Fz, we determined that the best window for representing the FRN component was between 225ms and 325ms post feedback (**Figure 3)**.

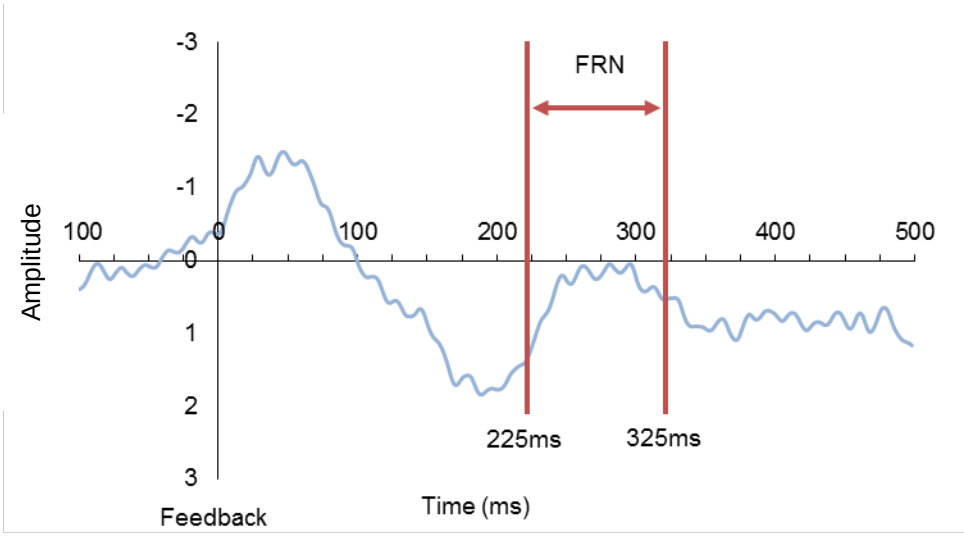

Figure 3. Grand Average for Controls: FRN at Fz. The FRN window (225ms to 325ms) was determined by examining the grand average FRN waveform at Fz post feedback for controls only. FRN is a difference wave created by subtracting activity post positive feedback from neural activity post negative feedback.

Statistical Analysis Approach

Assessing the effect of reward on search performance. We first conducted analyses to replicate the behavioral findings of Taubitz et al. (2015). Taubitz and colleagues (2015) found that reward enhanced visual search efficiency across all participants. We conducted a 3 (Set Size: 4, 8 or 12) X 2 (Target Type: Absent or Present) X 2 (Task Version: Standard or Incentivized) repeated measures ANOVA, with reaction time (RT) as the dependent variable. A Set Size X

Task Version interaction was examined to determine if the introduction of reward enhanced search efficiency. If the introduction of reward improves search performance, then we would expect the search slopes for each of the three Set Sizes to be greater for the Standard Version compared to the Incentivized Version of the task.

A main effect of Set Size would indicate that there is a linear increase as set size increases. As expected our results indicated a main effect for set size (see results below), thus we calculated a linear slope of Reaction Time X Set Size for Target Absent and Target Present for both versions of the task using an ordinary least squares (OLS) method. This provides a standard measure of search efficiency (SMSE) across all Set Size trials based upon RT. Search slope was calculated with the following equation:

$$\hat{\beta} = \frac{n \sum x_i y_i - \sum x_i \sum y_i}{n \sum x_i^2 - (\sum x_i)^2}$$

History of Depression and Search Efficiency. Taubitz et al. (2015) also found that participants with a history of MDD exhibited less efficient search in the presence of reward. To replicate these findings we conducted two MANCOVAs with Group (rMDD or Never-Depressed) as the predicting variable and SMSE for Target Present and Target Absent for the Incentivized Version as the dependent variables. Current depression symptoms (BDI-II) and baseline search performance (Standard) were covaried. A main effect of Group would indicate that there is a significant difference in search efficiency between rMDD and Never-Depressed participants. We predicted that rMDD participants in general would have weaker search performance than Never-Depressed controls on both Target Present and Target Absent trials; however, based on the results presented by Taubitz and colleagues (2015), we only expected a significant difference in search efficiency for Target Present trials.

Sensitivity to Reward and Search Efficiency. For Target Present trials, Taubitz and colleagues (2015) found that the Sensitivity to Reward (SR) subscale of the SRSPQ predicted search efficiency during the Incentivized Task. To replicate these findings we conducted a multiple linear regression with Target Present SMSE during Incentivized Task as the dependent variable, SR as the predictor variable and Target Present SMSE on the Standard Task as the controlled variable. We expected a strong association between SR and Target Present SMSE (Incentivized Task), the greater the SR the more efficient the visual search.

Analyses used to Evaluate FRN Amplitude and Search Performance

FRN, Reward and Search Efficiency. To evaluate the relationship between FRN, reward and search efficiency we calculated two linear regressions on SMSE during the Incentivized Task, one with Target Present SMSE as the dependent variable and the other with Target Absent SMSE as the dependent variable. Both regressions included FRN amplitude as the predictor variable and controlled for current depression symptoms (BDI-II) and Standard Task SMSE. We expected that FRN amplitude would be inversely related to SMSE for Target Present and Target Absent trials; the greater the FRN amplitude, the more efficient the visual search.

History of MDD, Reward and FRN Amplitude. To understand the difference in FRN amplitude between rMDD and Never-Depressed controls we conducted a between groups (rMDD, Never-Depressed) ANCOVA on FRN amplitude during the Incentivized Task, controlling for current depression symptoms (BDI-II). We predicted that there would be a significant difference between groups – significantly lower FRN amplitude for rMDD compared to Never-Depressed controls.

FRN, Reward, History of MDD and Search Efficiency. Next, we examined the relationship between FRN activity and depression history on visual search efficiency during the

Incentivized Task. To do so, we used the MODPROBE (Hayes & Matthes, 2009) SPSS procedure to conduct two multiple linear regressions on SMSE for Target Present and Target Absent trials, controlling for current depression symptoms and Standard Task search performance. History of depression served as the moderator, FRN amplitude as predictor and history of depression X FRN amplitude as the interaction term. A significant interaction between history of depression and FRN amplitude would indicate that the slope of the regression line was significantly different between rMDD and Never-Depressed controls. For the rMDD group, we predicted that the slope of the regression line would remain relatively flat, indicating that there was not a strong relationship between FRN and search efficiency. For the Never-Depressed group, we predicted a negative slope for the regression line – the larger the FRN amplitude, the more efficient the search.

FRN, Reward, Reward Sensitivity and Search Efficiency. To better understand the relationship between deficits in reward sensitivity, FRN amplitude and search performance we again used the MODPROBE (Hayes & Matthes, 2009) SPSS procedure to conduct two multiple linear regressions with these predictors: reward sensitivity (moderator), FRN amplitude (focal predictor) and reward sensitivity X FRN amplitude interaction variable, controlling for current depression symptoms and Standard Task search performance. SMSE for Target Present and SMSE for Target Absent during the Incentivized Task served as dependent variables for each of the regressions. A significant interaction between reward sensitivity and FRN amplitude would indicate that effect of reward sensitivity on SMSE varies based on FRN amplitude. We expected that low rates of reward sensitivity would be associated with lower FRN amplitude and inefficient search. Conversely, we expected that greater reward sensitivity would be associated with lower FRN amplitude and more efficient search.

FRN, Reward, Anhedonia and Search Efficiency. Finally, we sought to evaluate the relationship between anhedonic symptoms (measured by SHAPS), FRN amplitude and search efficiency once reward had been introduced. To do so, we used the MODPROBE (Hayes & Matthes, 2009) SPSS procedure to conduct two multiple linear regression analyses on SMSE for Target Present and SMSE for Target Absent during the Incentivized Task. Predicting variables in this analysis were the SHAPS (focal predictor), FRN amplitude (moderator) and a SHAPS X FRN amplitude interaction term. A significant SHAPS X FRN amplitude interaction would indicate that the impact of anhedonic symptoms on SMSE varies at different levels of FRN amplitude. We expected that greater anhedonic symptoms would be related to lower FRN amplitude and inefficient search.

RESULTS

Demographic, Psychometric, and Diagnostic Characteristics

Demographic Information. Participant demographic information can be found in **Table 1**. There were no significant gender differences for remitted depressed and control groups, x^2 (1) = 2.237, p = .135. Additionally, there were significantly more remitted depressed participants than control taking psychotropic medications, x^2 (1) = 8.254, p = 0.04.

Table 1

Participant Demographics

	Control (n = 25)	rMDD (n = 28)	Total (N = 53)
Age *Mean (SD)*	20.96 (3.372)	22.25 (5.648)	21.64 (4.715)
Gender			
Female	16 (64%)	23 (82%)	39 (73.6%)
Male	9 (36%)	5 (17.9%)	14 (26.4%)
Transgender	0 (0%)	0 (0%)	0 (0%)
Ethnicity			
Asian or Pacific Islander	7 (28%)	2 (7.1%)	9 (17%)
African American/Black	0	2 (7.1%)	2 (3.8%)
Latino/Hispanic	5 (20%)	4 (14.3%)	9 (17%)
White, not of Hispanic Origin	11 (44%)	20 (71.4%)	31 (58.5%)
Middle Eastern	1 (4%)	0 (0%)	1 (1.9%)
Biracial/Multiracial	1 (4%)	0 (0%)	1 (1.9%)
Psych Med	0 (0%)*	8 (28.6%)*	8 (15.1%)

Differences between Control and rMDD subjects are denoted as follows: †p < 0.10, *p < 0.05, **p < 0.01, ***p < 0.001.

Self-Report Results. Means and standard deviations for self-report measures can be found in **Table 2**. There was no significant group difference on BDI-II scores, however, results were approaching a statistically significant difference between groups, $t(52) = -1.956$, $p = .056$, Cohen's $d = -.55$. The average BDI-II score for both groups fell below the cutoff of 16 for the presence of depressed mood in a college student population (Sprinkle et al., 2002). There were also no significant group differences for SPSRQ (sensitivity to reward), $t(52) = .378$, $p = .71$, Cohen's $d = .11$, and SHAPS scores, $t(52) = -.548$, $p = .586$, Cohen's $d = -.15$. Thus, the groups did not differ in self-reported reward sensitivity or anhedonia.

To further understand the characteristics of the participant population we collected measures of anxiety (BAI), behavioral avoidance (BIS), behavioral approach (BAS), and sensitivity to punishment. Means and standard deviations for these measures can also be found in **Table 2.** The remitted depressed group scored significantly higher than controls on anxiety, $t(52)$

= -2.685, p = .010, Cohen's d = .749, and behavioral avoidance (BIS), $t(52)$ = -3.147, p = .003, Cohen's d = .75. There was also a nearly significant group difference on sensitivity to punishment, $t(52)$ = -1.982, p = .053, Cohen's d = .53. There were no significant BAS total, $t(51)$ = 1.240, p = .271, Cohen's d = .42; BAS Fun Seeking, $t(51)$ = 1.373, p = .176, Cohen's d = .38; BAS Drive, $t(51)$ = 1.83, p = .073, Cohen's d = .51; BAS Reward Responsiveness, $t(51)$ = .172, p = .864, Cohen's d = .044.

Table 2

Study Sample Self-Report Measures

	Control *M(SD)*	**rMDD** *M(SD)*	**Total** *M(SD)*
BDI-II	7.32 (3.69)†	9.82 (5.35)†	8.64 (4.77)
SPSRQ (reward)	5.32 (2.43)	5.07 (2.36)	5.19 (2.37)
SHAPS	19.08 (4.48)	19.79 (4.86)	19.45 (4.65)
BAI	6.04 (4.35)**	10.36 (6.90)**	8.32 (6.18)
BIS	20.40 (3.65)**	22.89 (2.95)**	21.54 (3.57)
BAS Fun Seeking	12.88 (1.67)	12.14 (2.17)	12.49 (1.76)
BAS Drive	11.36 (2.23)	10.11 (2.70)	10.70 (2.55)
BAS Reward Responsiveness	18.12 (1.72)	18.04 (1.84)	18.08 (1.76)
SPSRQ (punishment)	3.96 (3.21)†	5.64 (2.97)†	4.85 (3.17)

Note: BDI-II = Beck Depression Inventory; SPSRQ = Sensitivity to Punishment/Sensitivity to Reward Questionnaire; SHAPS = Snaith–Hamilton Pleasure Scale; BAI = Beck's Anxiety Inventory; BIS = Behavioral Inhibition System and BAS = Behavioral Approach System. Differences between Control and rMDD subjects are denoted as follows: †p < 0.10, *p < 0.05, **p < 0.01, ***p < 0.001.

DSM-5 Diagnoses. Diagnostic information for the participant population can be found in **Table 3.** There were no significant between group differences on the diagnostic characteristics of the participant populations (other than the history of major depressive disorder).

Table 3

Diagnostic Characteristics of Study Population

	Control	rMDD	Total
Major Depressive Disorder			
Never Depressed	25 (100%)	0 (0%)	25 (47%)
Remitted MDD	0 (0%)	28 (100%)	28 (53%)
Anxiety Disorders			
Any Current DSM-5 Anxiety Disorder	6 (24%)	5 (17.9%)	11 (20.1%)
Past Panic Disorder	3 (12%)	4 (14.3%)	7 (13.2%)
Current Panic Disorder	0 (0%)	0 (0%)	0 (0%)
Agoraphobia	1 (4%)	5 (17.9%)	6 (11.3%)
Social Phobia	3 (12%)	2 (7.1%)	5 (9.4%)
Generalized Anxiety Disorder (GAD)	0 (0%)	3 (10.7%)	3 (5.7%)
Posttraumatic Stress Disorder (PTSD)	0 (0%)	0 (0%)	0 (0%)
Obsessive-Compulsive Disorder (OCD)	0 (0%)	0 (0%)	0 (0%)
Substance Use Disorders			
Any Current Substance Use Disorder	0 (0%)	3 (10.7%)	3 (5.7%)
Alcohol Dependence	0 (0%)†	3 (10.7%)†	3 (5.7%)
Substance Dependence	0 (0%)	0 (0%)	0 (0%)
Eating Disorders			
Any Current Eating Disorder	0 (0%)	0 (0%)	0 (0%)
Bulimia Nervosa	0 (0%)	0 (0%)	0 (0%)
Unspecified Eating Disorder	0 (0%)	0 (0%)	0 (0%)
Psychosis			
Schizoaffective Disorder, Bipolar Type	0 (0%)	0 (0%)	0 (0%)
Current MDD w/ past Mood-Congruent Hallucinations	0 (0%)	0 (0%)	0 (0%)

Participants may have multiple diagnoses. Differences between Control and rMDD participants denoted as follows: †$p < 0.10$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Replicating Previous Findings of Blunted Incentivized Search Efficiency in rMDD Reward and Search Efficiency

Standard Task Visual Search Data. To better understand potential between group variations on baseline (Standard task) search performance we conducted a 3 (Set Size: 4, 8 or 12) X 2 (Target Type: Absent or Present) X 2 (Group: rMDD or Controls) repeated measures ANOVA, with reaction time (RT) as the dependent variable. The ANOVA results did not indicate a significant interaction between Set Size and Group, $F(2, 50) = 2.46$, $p = .096$, or Target Type X Group, $F(2, 50) = 1.019$, $p = .318$. There was a main effect of Group, $F(1, 51) =$

8.11, p = .006, indicating that participants in the rMDD group (M = 899.56, SD = 176.39) were more efficiency at visual search on the Standard task than Controls (M = 1000.45, SD = 195.26). All following statistically analyses will control for Standard task search performance. Means and standard errors for RT for each set size and target type can be found in **Figure 4**.

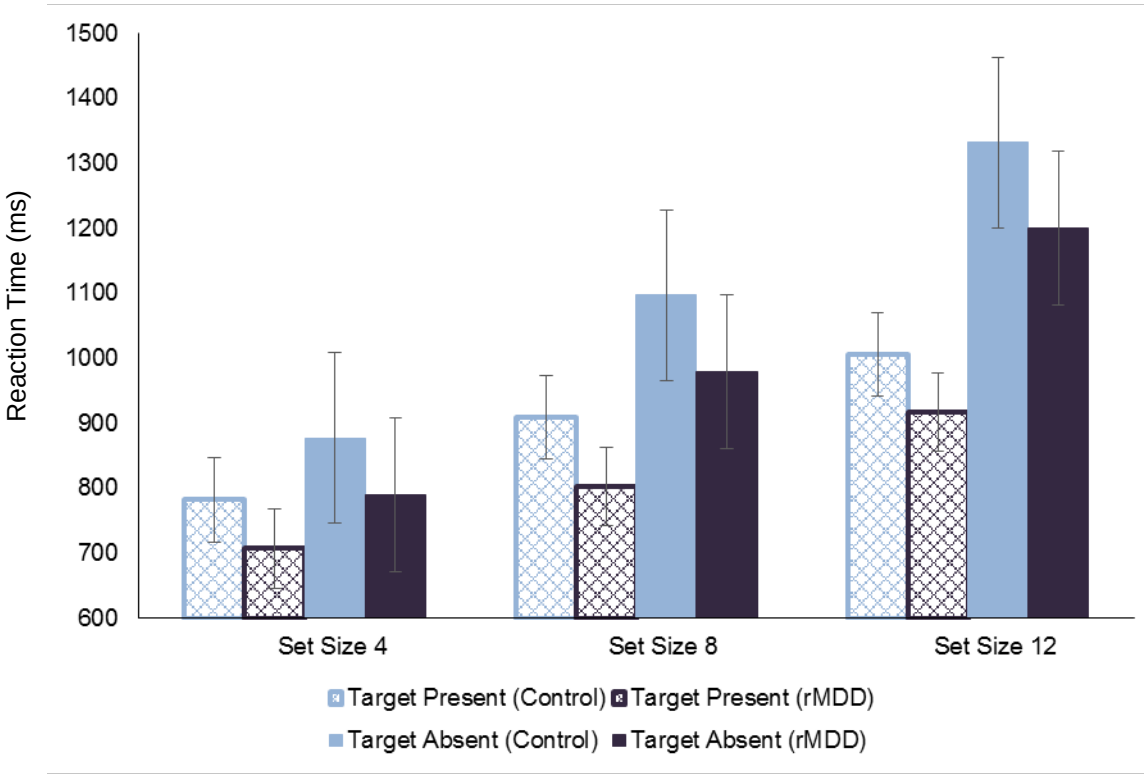

Figure 4. rMDD participants are more efficient at visual search on the Standard task than Controls.

To further investigate potential between group variations on visual search accuracy we conducted a 3 (Set Size: 4, 8 or 12) X 2 (Target Type: Absent or Present) X 2 (Task Version: Standard or Incentivized) X 2 (Group: rMDD or Controls) repeated measures ANOVA, with visual search accuracy as the dependent variable. The ANOVA results did not indicate a significant main effect of Group, $F(1, 51) = .737$, $p = .395$, suggesting that participants in the rMDD group (M = 63.58, SD = 7.09) and Control group (M = 62.64, SD = 7.82) had similar rates of accuracy during the visual search tasks. Accuracy data for each task version, target type and set size can be found in **Table 4**.

Table 4

Accuracy Data for Trial Type, Set Size and Task Version

Standard Visual Search Task						
	Target Absent			Target Present		
	4	*8*	*12*	*4*	*8*	*12*
rMDD	98%	98%	97%	97%	96%	95%
Controls	98%	98%	97%	97%	96%	94%

Incentivized Visual Search Task						
	Target Absent			Target Present		
	4	*8*	*12*	*4*	*8*	*12*
rMDD	58%	66%	62%	57%	56%	60%
Controls	63%	70%	69%	58%	58%	57%

Reward Enhances Visual Search Efficiency. To replicate Taubitz et al. (2015) findings, we first conducted a 3 (Set Size: 4, 8 or 12) X 2 (Target Type: Absent or Present) X 2 (Task Version: Standard or Incentivized) repeated measures ANOVA, with reaction time (RT) as the dependent variable, to assess the impact of reward on search efficiency. The ANOVA results indicated a significant interaction between Set Size and Task Version on reaction time, $F(2, 52) = 388.210$, $p < .001$. Post hoc analyses indicated that search efficiency significantly increased for Set Size 4, $t(52) = 17.43$, $p < .001$; 8, $t(52) = 23.61$, $p < .001$; and 12, $t(52) = 27.92$, $p < .001$, once reward was introduced, see **Figure 5**. There were also significant main effects for Set Size, $F(2, 52) = 462.744$, $p < .001$; Target Type, $F(2, 52) = 329.386$, $p < .001$; and Task Version, $F(2, 52) = 625.240$, $p < .001$, such that search was faster for smaller set sizes, Target Present trials, and the Incentivized search task.

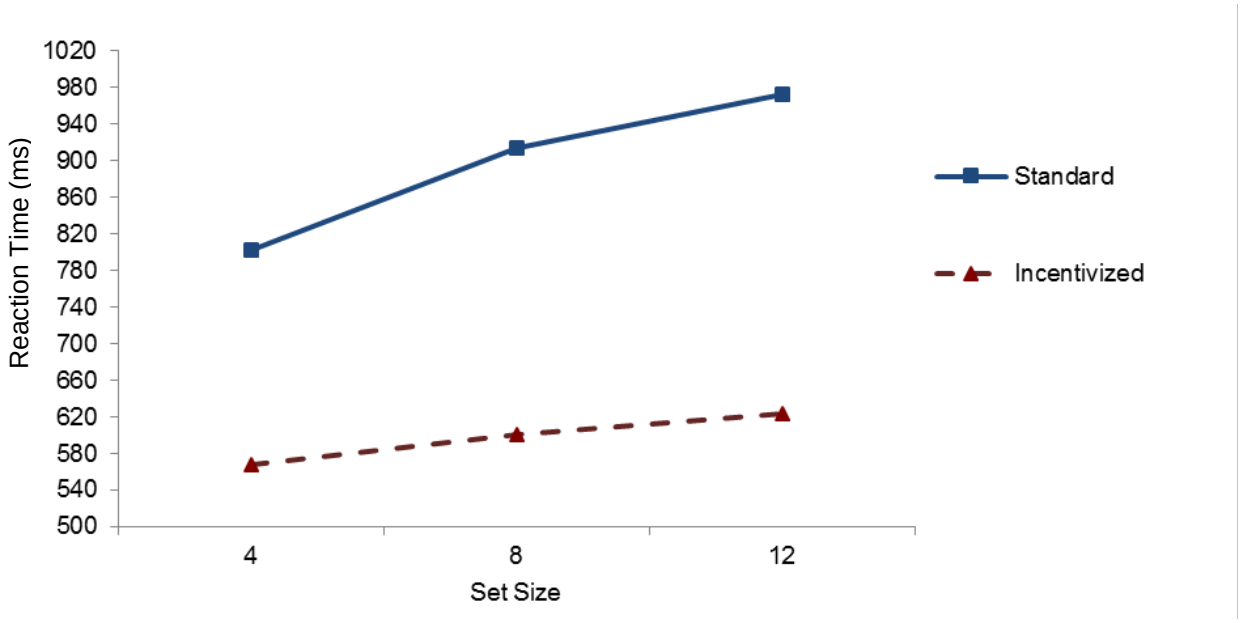

Figure 5. Search efficiency for each set size increases with the introduction of reward.

We also found a significant interaction between Target Type and Task Version, $F(1, 52) = 119.39$, $p < .001$. We used one-sample *t*-tests to follow-up these results and found that RT between the Standard and Incentivized Task were significantly different for both Target Absent and Target Present trials (**Figure 6**) (Target Absent: $M_{diff} = 404.979$ ms, $t(52) = 24.41$, $p < .001$, 95% $C.I._{diff} = 371.681\text{-}438.276$; Target Present: $M_{diff} = 285.387$ ms, $t(52) = 22.171$, $p < .001$, 95% $C.I._{diff} = 259.558\text{-}311.217$). These results suggest that search efficiency increases with the introduction of reward for both Target Absent and Present Trials. However, we also found that the introduction of reward did appear to influence Target Absent more than Target Present trials, Target Absent $M = 50.62$ ms/item, Target Present $M = 35.67$ ms/item; $t(52) = 10.92$, $p = 0.08$, 95% $C.I. = 12.20 - 17.69$.

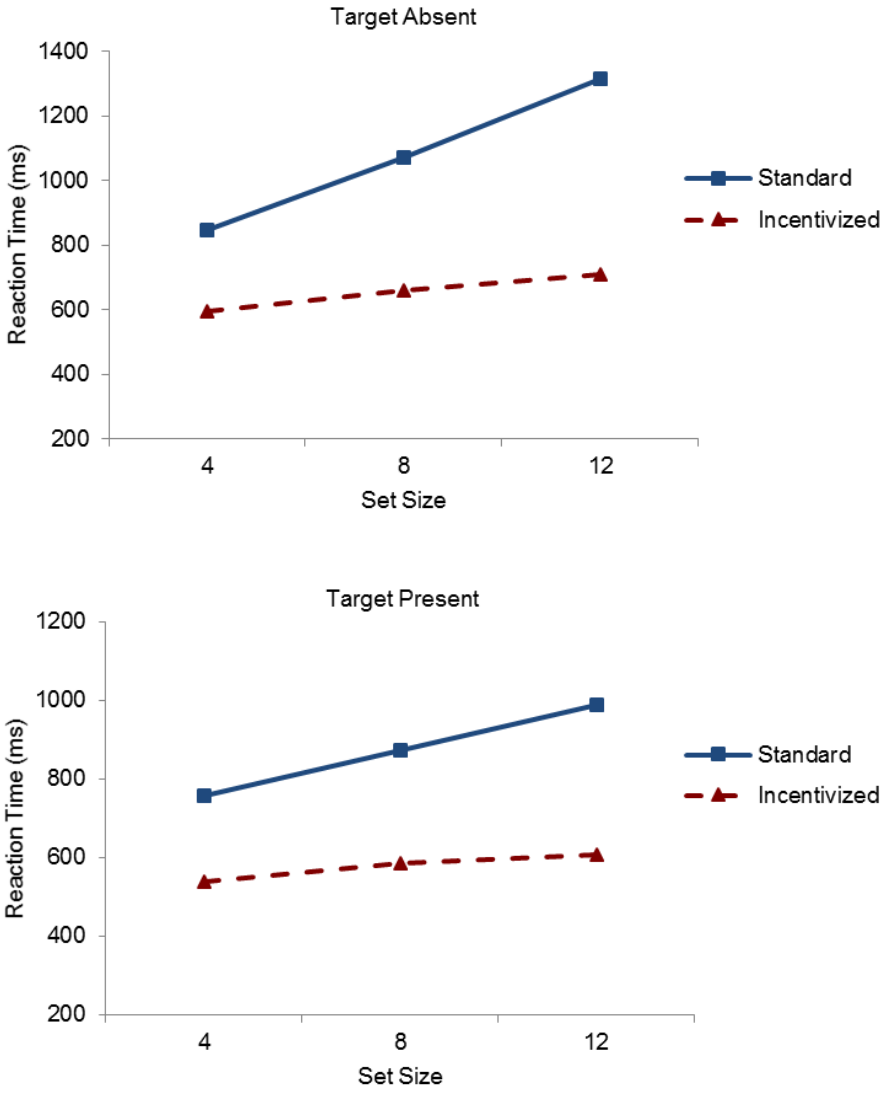

Figure 6. Introduction of reward influences search efficiency for both trial types. Search efficiency significantly improves from the Standardized Visual Search task to the Incentivized Visual Search task for both Target Absent and Target Present trials.

Results from the ANOVA also indicated that there was a significant Set Size X Target Type X Task Version interaction, $F(2, 52) = 131.509$, $p < .001$. For Target Absent, we found a significant interaction between Set Size and Task Version, $F(2, 52) = 405.284$, $p < .001$. Follow up analyses indicated significant simple effects of Set Size by Task Version for Set Size 4, $F(1, 52) = 274.197$, $p < .001$; Set Size 8, $F(1, 52) = 518.645$, $p < .001$; and Set Size 12; $F(1, 52) =$

740.268, p < .001. These results indicate that reward enhanced search efficiency for all Set Sizes on Target Absent trials. For Target Present, we found a significant interaction between Set Size and Task Version, $F(2, 52) = 162.872$, p < .001. Follow up analyses indicated significant simple effects of Set Size by Task Version for Set Size 4, $F(1, 52) = 269.630$, p < .001; Set Size 8, $F(1, 52) = 437.170$, p < .001; and Set Size 12; $F(1, 52) = 575.190$, p < .001. These results indicate that reward enhanced search efficiency for all Set Sizes on Target Present trials.

Linear Increase as Set Size Increases. To simplify subsequent analyses we sought to create a single dependent variable that provided a standard measure of search efficiency for each subject. A significant main effect of Set Size was found, $F(2, 52) = 462.744$, $p < .001$. In light of this finding, we used an ordinary least squares (OLS) method to calculate a linear slope for Reaction Time X Set Size for Target Absent and Target Present trials. This method provided a standard measure of search efficiency (SMSE) across all Set Size trials based upon RT.

History of Depression and Search Efficiency in the Incentivized Task. We conducted two MANCOVAs with Group (rMDD or Never-Depressed) as the predicting variable and SMSE for Target Present and Target Absent for the Incentivized Version as the dependent variables. The MANCOVA model controlled for both Standard search performance and BDI-II scores. Results from the MANCOVAs revealed a significant main effect of Group on search efficiency for Target Present trials, $F(1, 49) = 5.456$, $p = .024$. There was no significant main effect for Group on search efficiency for Target Absent trials, $F(1, 49) = 4.22$, $p = .724$. Participants in the remitted depressed group (M = 5.26, SD = 4.96) were more efficient at visual search on Target Present trials than controls (M = 9.18, SD = 6.05) during the incentivized search task (**Figure 7)**. Though we found a significant between group difference, we failed to replicate Taubitz et al. (2015) findings. Our results indicated the opposite effect – participants in the rMDD group had

greater search efficiency than those in the control group for Target Present trials during incentivized search.

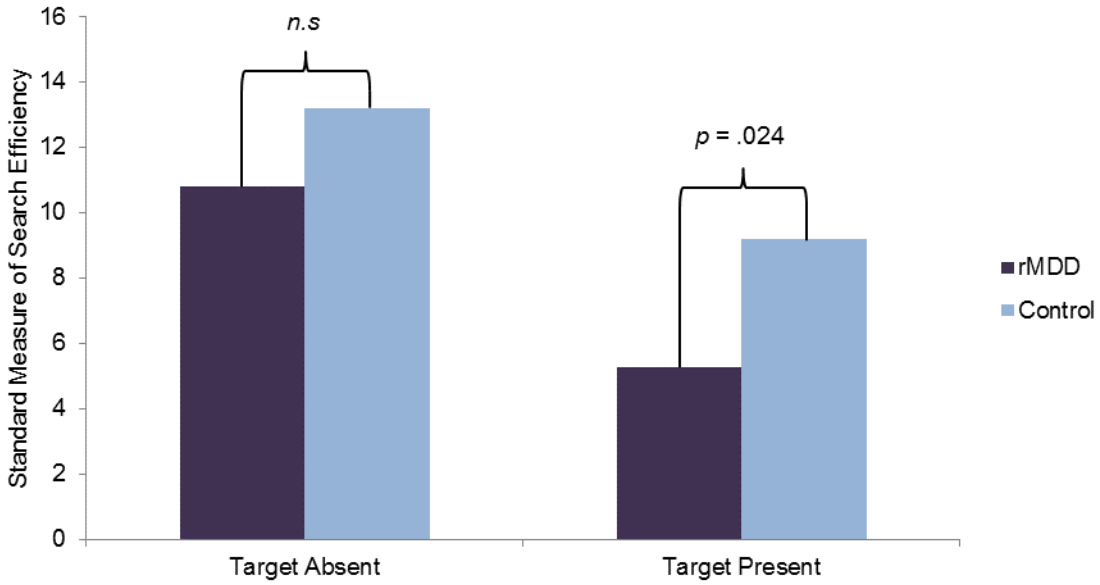

Figure 7. Remitted Depressed More Efficient at Visual Search than Controls on Target Present trials during the incentivized task. Search efficiency was not significantly different between rMDD and controls for the Target Absent trials.

Sensitivity to Reward and Search Efficiency. Results from the multiple linear regression also did not replicate the findings of Taubitz and colleagues (2015). Controlling for Standard Task performance, sensitivity to reward did not predict search efficiency on Target Present trials during the Incentivized Task, (B = -0.207, $S.E.$ = 0.315, p = 0.513). Sensitivity to reward also did not predict search efficiency on Target Absent trials, (B = -0.166, $S.E.$ = 0.342, p = 0.630).

FRN Analyses

Investigating FRN Amplitude and Search Efficiency in the Incentivized Task. We conducted two linear regressions on SMSE during the Incentivized Task (one for Target Present and one for Target Absent trials) to investigate the relationship between FRN search efficiency during the Incentivized task. FRN amplitude was used as the predictor variable and we

controlled for current depression symptoms (BDI-II) and Standard Task SMSE. Results did not demonstrate any significant relationships between FRN incentivized search efficiency on Target Absent trials, $B = 0.042$, $S.E. = 0.330$, $p = 0.900$; or Target Present trials, $B = 0.214$, $S.E. = 0.307$, $p = 0.490$. Our results indicated that there was no relationship between FRN on incentivized visual search efficiency.

History of MDD and FRN Amplitude. To investigate the potential differences in FRN amplitude between rMDD and Never-Depressed controls we conducted a between groups (rMDD, Never-Depressed) ANCOVA on FRN amplitude during the Incentivized Task, controlling for current depression symptoms (BDI-II). There were no significant group differences on FRN amplitude, $F(1, 50) = .656$, $p = .422$, refer to **Figure 8**. These results indicated that remitted depressed participants did not differ in FRN amplitude from controls.

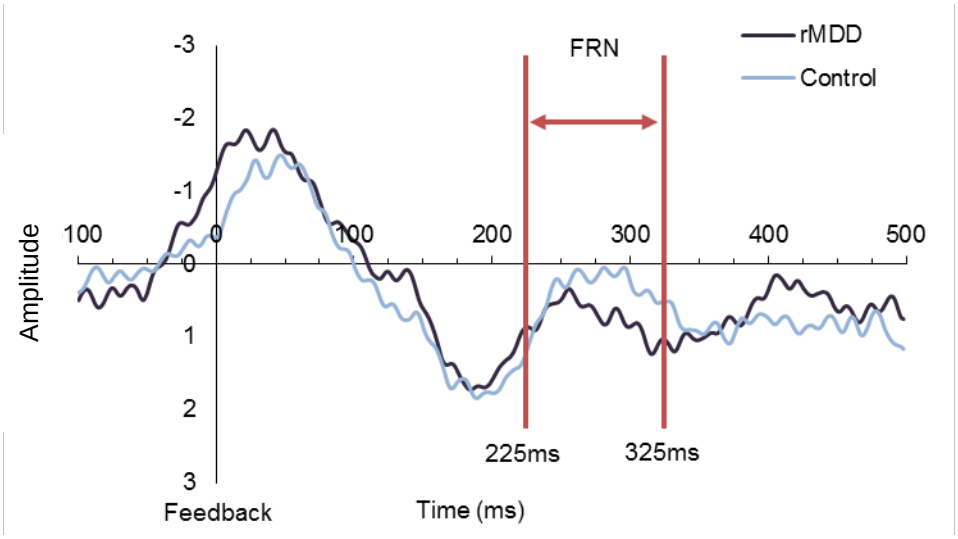

Figure 8. FRN activity at site Fz for both the remitted depressed and control groups. There was no difference between groups on FRN amplitudes.

Since the FRN component is comprised of neurological activity after both positive and negative feedback (by subtracting activity post positive feedback from activity post negative feedback), we decided to examine each aspect of this FRN difference score separately in order to

understand what may be driving FRN results. We did not find any group differences in Fz amplitude in the FRN window following either positive feedback, $F(1, 52) = .109$, $p = .742$; or negative feedback, $F(1, 52) = .583$, $p = .449$. **Figure 9** presents grand average waveforms for rMDD and control participants.

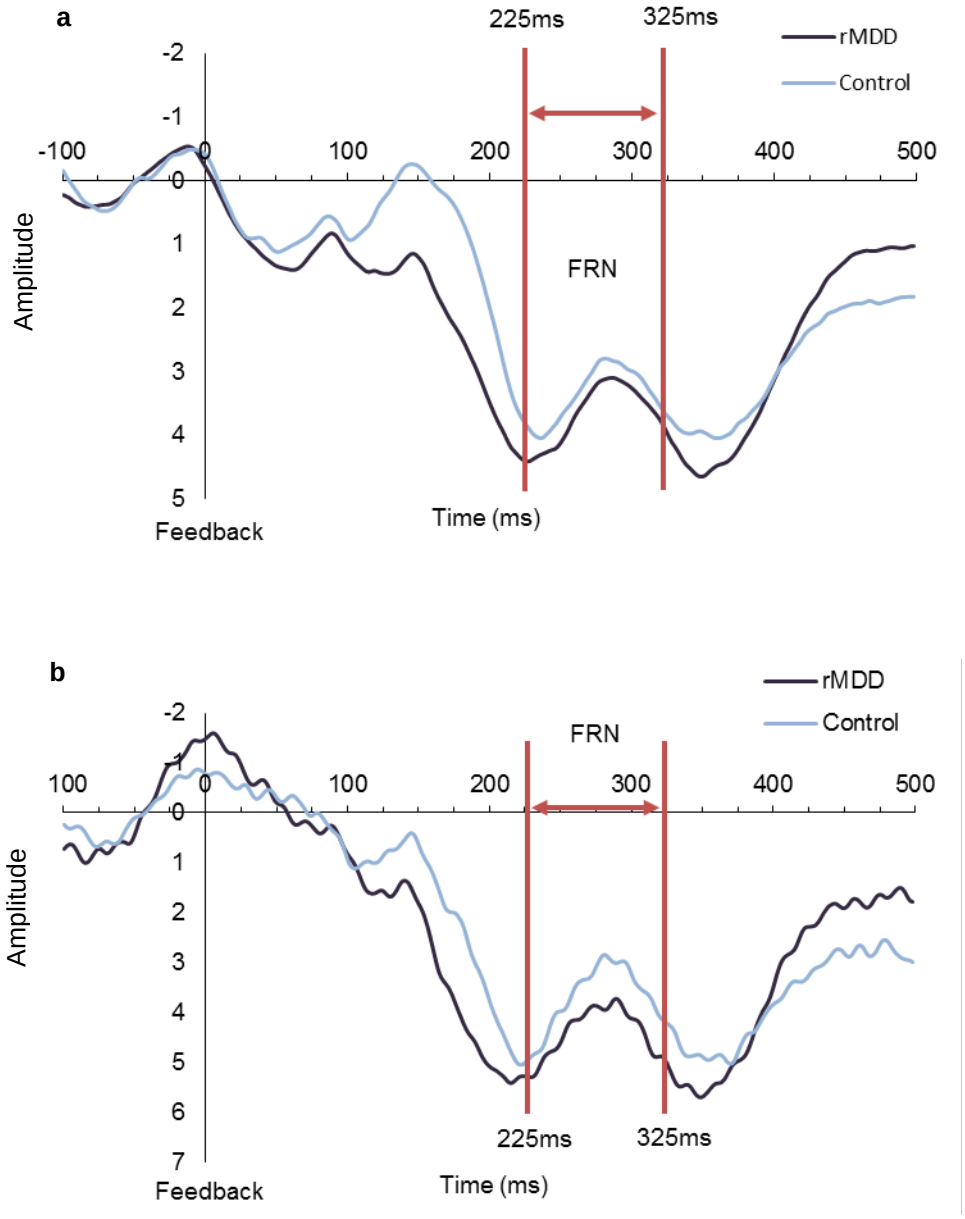

Figure 9. Grand average waveforms for FZ in FRN window for positive feedback trials (a) and negative feedback trials (b), separately for the remitted depressed and control groups. There were no group differences for either positive or negative feedback trials.

FRN, History of MDD and Search Efficiency in the Incentivized Task. To examine the relationship between FRN amplitude and depression history on visual search efficiency during the Incentivized Task we used a MODPROBE (Hayes & Matthes, 2009) SPSS procedure to conduct two multiple linear regressions on SMSE for Target Present and Target Absent trials, controlling for current depression symptoms and Standard Task search performance. History of depression was the moderator, FRN amplitude was the predictor and history of depression X FRN amplitude was the interaction term. The overall model provided by the MODPROBE procedure was significant for Target Absent, $F(5, 47) = 5.286$, $p < .001$, $R^2 = 0.380$, however the results did not indicate a significant interaction between history of depression and FRN amplitude for Target Absent trials, $B = -0.686$, $S.E. = 0.786$, $p = 0.387$. Also, the overall model for Target Present trials was significant, $F(5, 47) = 5.238$, $p < .001$, $R^2 = 0.281$. Similar to Target Absent trial results, there was no significant interaction between history of depression and FRN amplitude on Target Present trials ($B = 0.218$, $S.E. = 0.609$, $p = 0.722$), indicating that the slopes of the regression lines were not significantly different between participants with a history of depression and controls. These findings suggest that history of depression did not have an influence on the relationship between FRN amplitude and incentivized search efficiency for both Target Present and Target Absent trials. Somewhat in line with our prediction, the slope for FRN was negative for controls on Target Absent trials indicating that search efficiency increased as FRN amplitude increased, refer to **Figure 10.**

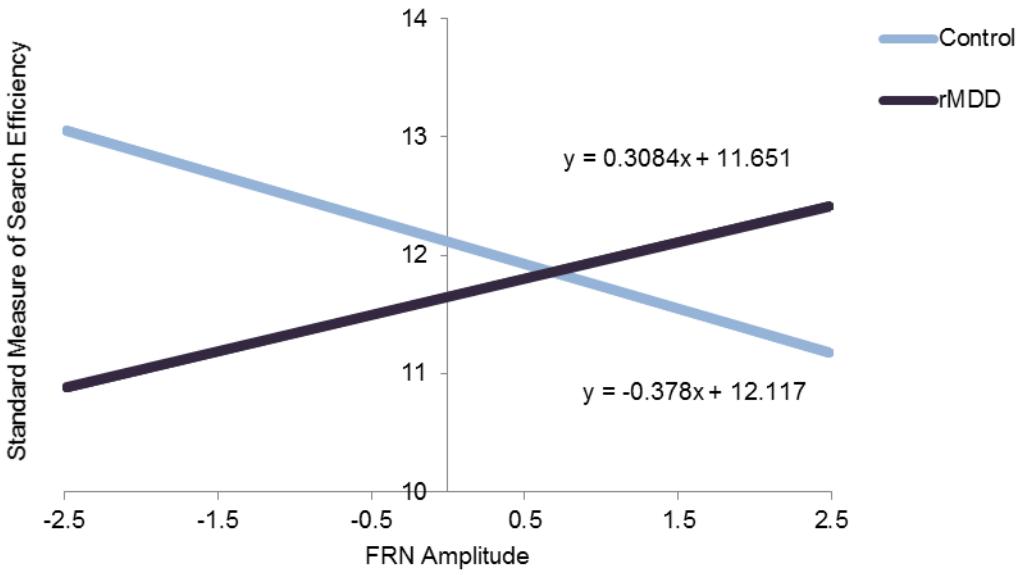

Figure 10. Relations between FRN and search efficiency moderated by group. The negative slope for controls suggests that search efficiency increases as FRN amplitude increases (although the group difference was not significant).

FRN, Reward Sensitivity and Search Efficiency in the Incentivized Task. In order to investigate the relationship between reward sensitivity, FRN amplitude and incentivized search efficiency we used the MODPROBE (Hayes & Matthes, 2009) SPSS procedure to conduct two multiple linear regressions. Predictors for the analyses were reward sensitivity (moderator), FRN amplitude (focal predictor) and reward sensitivity X FRN amplitude interaction variable, controlling for current depression symptoms and Standard Task search performance. SMSE for Target Present and SMSE for Target Absent during the Incentivized Task served as dependent variables for each of the regressions. The overall model for Target Absent and Target Present trial search efficiency results of the MODPROBE procedure were significant, $F(5, 47) = 7.173$, $p < .001$, $R^2 = 0.379$; $F(5, 47) = 4.001$, $p < .05$, $R^2 = 0.207$. There was not a significant interaction between reward sensitivity and FRN amplitude on Target Absent trials, $B = -0.236$, $S.E. = 0.151$, $p = 0.123$, or Target Present trials, $B = -0.128$, $S.E. = 0.120$, $p = 0.291$. These results suggest that

the degree of reward sensitivity did not moderate the relationship between FRN and search efficiency. Refer to **Figure 11** for a visual representation of the findings.

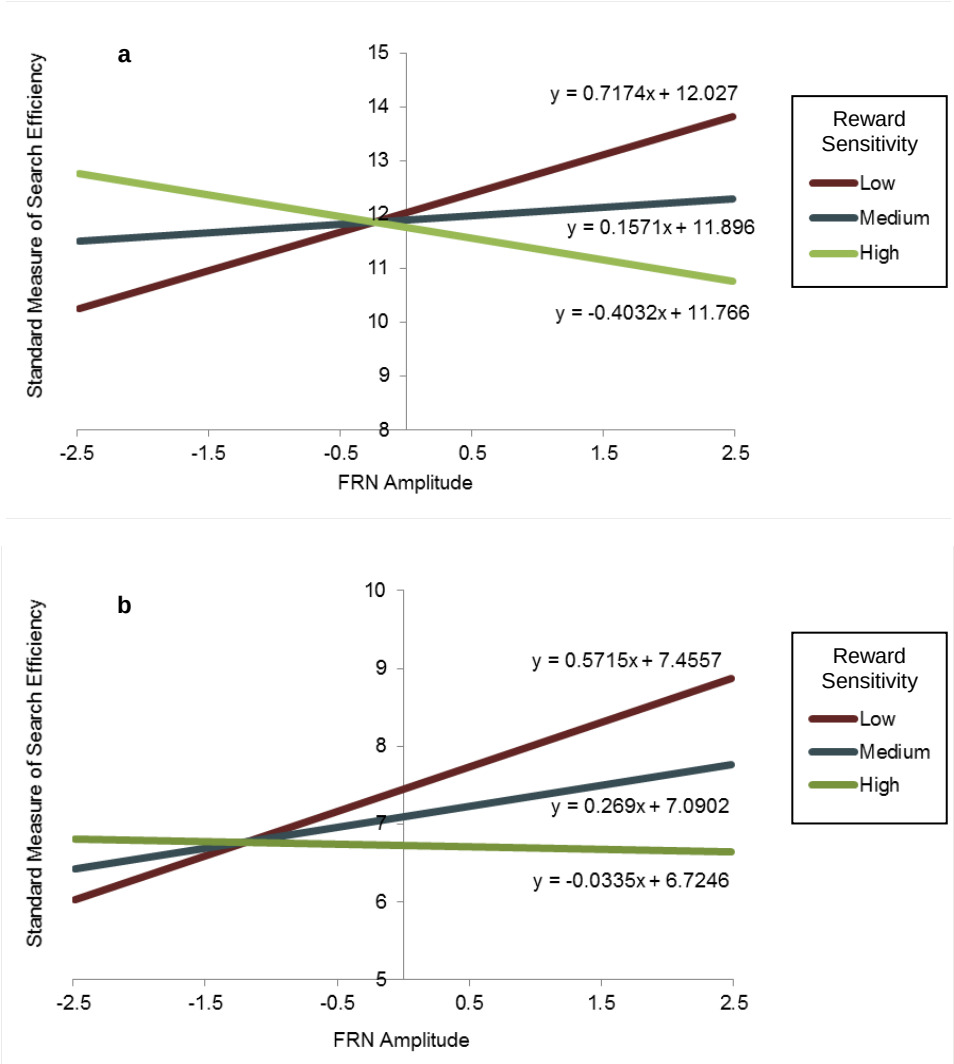

Figure 11. Non-significant moderation of reward sensitivity on the relationship between FRN amplitude and search efficiency for both target absent (a) and target present (b) trials.

FRN, Anhedonia and Search Efficiency in the Incentivized Task. Finally, we sought to examine the relationship between anhedonic symptoms (measured by SHAPS), FRN amplitude and search efficiency once reward was introduced. To do so, we used the identical MODPROBE (Hayes & Matthes, 2009) SPSS linear regression model, but used SHAPS as the moderator. The overall model for Target Absent trial search efficiency was significant, $F(5, 47)$

= 6.634, $p < 0.001$, $R^2 = 0.404$. However, there was not a significant interaction between SHAPS and FRN for Target Absent trials, $B = -0.105$, *S.E.* = 0.072, $p = 0.152$. The overall model for Target Present trial search efficiency was not significant, $F(5, 47) = 0.596$, $p = 0.668$, $R^2 = 0.060$; and there was also no significant interaction between SHAPS and FRN for Target Present trials, $B = -0.064$, *S.E.* = 0.099, $p = 0.521$. These findings suggest that anhedonia does not moderate the relationship between FRN amplitude and search performance. Counter to our prediction, individuals with low and medium levels of anhedonic symptoms were less efficient at visual search the greater the FRN amplitude (although, again, this interaction was not significant), refer to **Figure 12.**

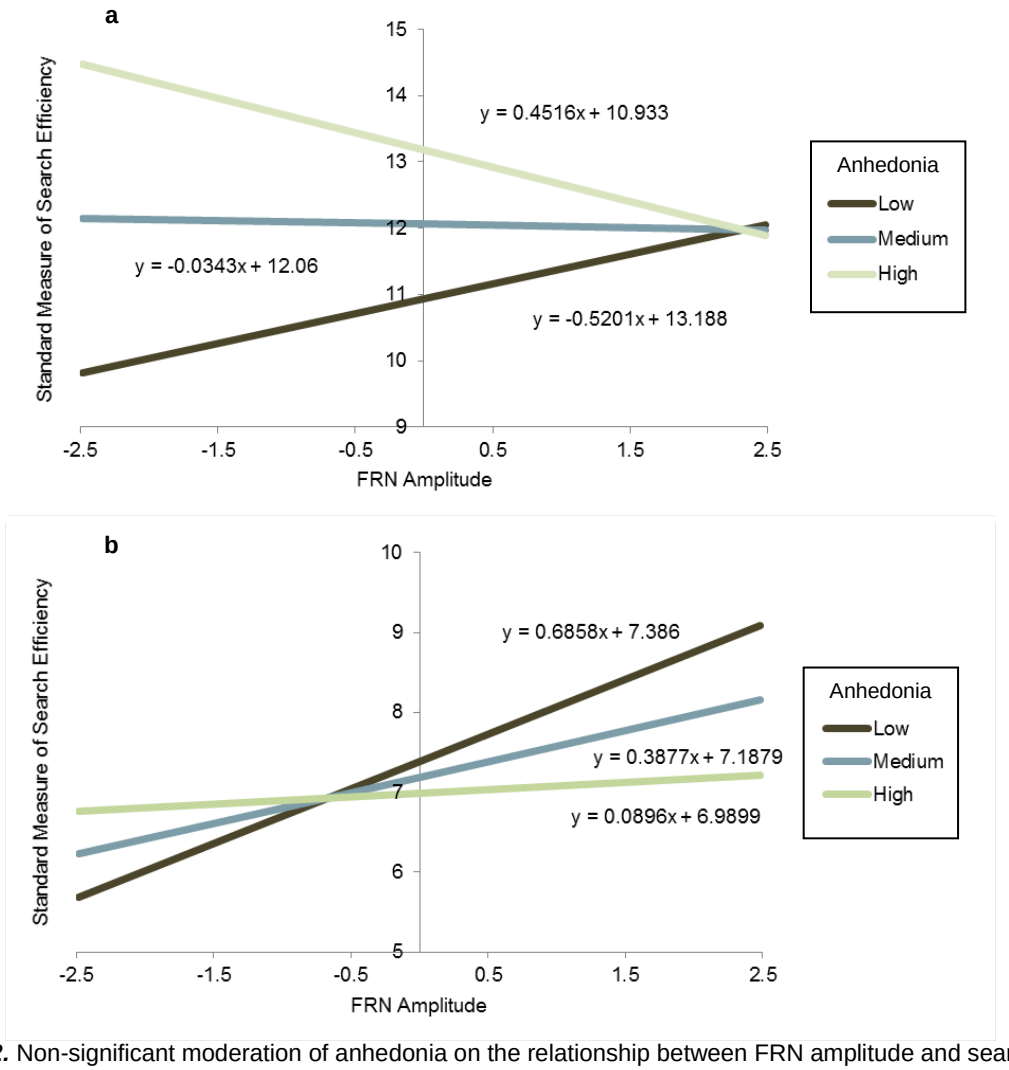

Figure 12. Non-significant moderation of anhedonia on the relationship between FRN amplitude and search efficiency on target absent (a) and present (b) trials.

Further Examination into Null Results

We found that participants with a history of depression significantly outperformed controls on visual search once reward was introduced. Despite being a very similar design (adapted to accommodate ERPs), this outcome was the opposite of the findings of Taubitz and colleagues (2015) and counter to what is expected from a remitted depressed population. Namely, reward should not have a greater impact on performance for participants with a history of depression (Henriques & Davidson, 2000; Pechtel, Dutra, Goetz, & Pizzagalli, 2013; Pizzagalli et al., 2009). To better understand our unexpected findings, we examined several characteristics of the group populations; specifically, state anxiety, sensitivity to punishment, approach and avoidance motivation.

Anxiety. We first examined anxiety rates in the study population due to the high comorbidity with MDD (Kessler et al., 2005) and its influence on motivation (Eysenck, Derakshan, Santos, & Calvo, 2007). According to Eysenck and Calvo's (1992) Processing Efficiency Theory, worry is a major component of anxiety that can increase motivation to avoid adverse state anxiety. Our results indicated that remitted depressed participants had a significantly greater level of anxiety than controls, $t(52) = -2.685$, $p = .010$, Cohen's $d = .749$ (refer to **Figure 13**). However, there was no predictive relationship between BAI scores and search efficiency (Target Absent or Present) for controls, $r(25) = -.269$, $p = .193$; $r(25) = -.194$, p .394, or rMDD, $r(28) = -.134$, $p = .498$; $r(28) = .273$, $p = .160$. Though there were no predictive relationships, it is possible that higher levels of anxiety in the rMDD group may have influenced task performance by motivating the participant to avoid the aversive, negative feedback. Unfortunately, due to the mixed feedback design of our task we were not able to directly examine any relationships between anxiety and negative feedback.

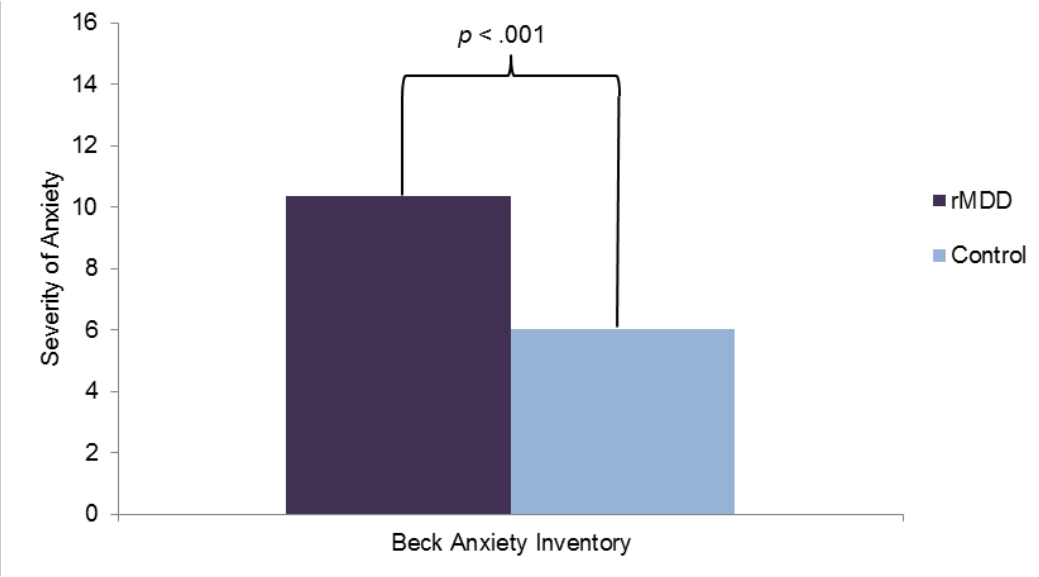

Figure 13. rMDD had greater levels of anxiety than controls.

Punishment. Next, we investigated sensitivity to punishment, which has been found to be elevated in currently depressed adults (Pizzagalli, Dillon, Bogdan, & Holmes, 2011), remains heighten in a remitted depressed state and is suggested to influence the saliency of aversive stimuli (Santesso et al., 2008). It is possible that heightened sensitivity to punishment may contribute to the aversive nature of negative stimuli - influencing search performance as a result of motivation to avoid aversive, negative feedback. The rMDD participants in our study population were also more sensitive to punishment than controls, though this effect was just shy of meeting statistical significance $t(52) = -1.982$, $p = .053$, Cohen's $d = .53$ (see **Figure 14**). However, we did not find a predictive relationship between sensitivity to punishment and search efficiency (target Absent or Present) for controls, $r(25) = -.137$, $p = .513$; $r(25) = -.343$, $p = .094$, or rMDD, $r(28) = -.031$, $p = .876$; $r(28) = .193$, $p = .326$.

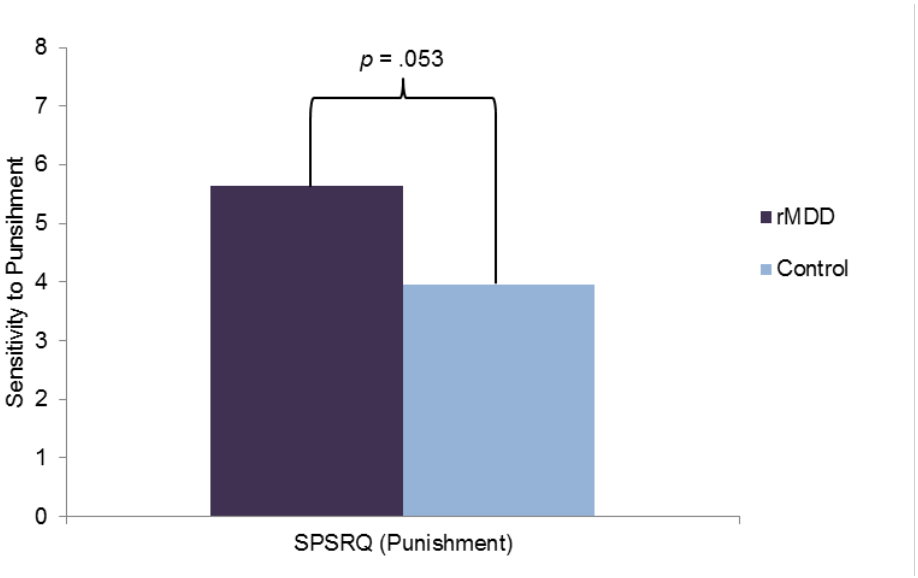

Figure 14. rMDD had greater sensitivity to punishment than controls.

Motivation to Avoid. Approach and avoidance motivation play a major role in human behavior (Elliot & Covington, 2001). In depressed samples, increased avoidance motivation has been demonstrated to limit access to positive reinforcers and influence negative information processing biases, potentially increasing vulnerability to the onset and reoccurrence of depression (Trew, 2011). In our study sample, participants in the rMDD group were significantly more motivated to avoid negative information (higher BIS scores) than controls, $t(51) = -3.147$, $p = .003$, Cohen's $d = .75$. The groups, however, did not differ on approach motivation: BAS total, $t(51) = 1.240$, $p = .271$, Cohen's $d = .42$; BAS Fun Seeking, $t(51) = 1.373$, $p = .176$, Cohen's $d = .38$; BAS Drive, $t(51) = 1.83$, $p = .073$, Cohen's $d = .51$; BAS Reward Responsiveness, $t(51) = .172$, $p = .864$, Cohen's $d = .044$. **Figure 15** depicts the means for measures of approach and avoidance motivation for the rMDD and controls.

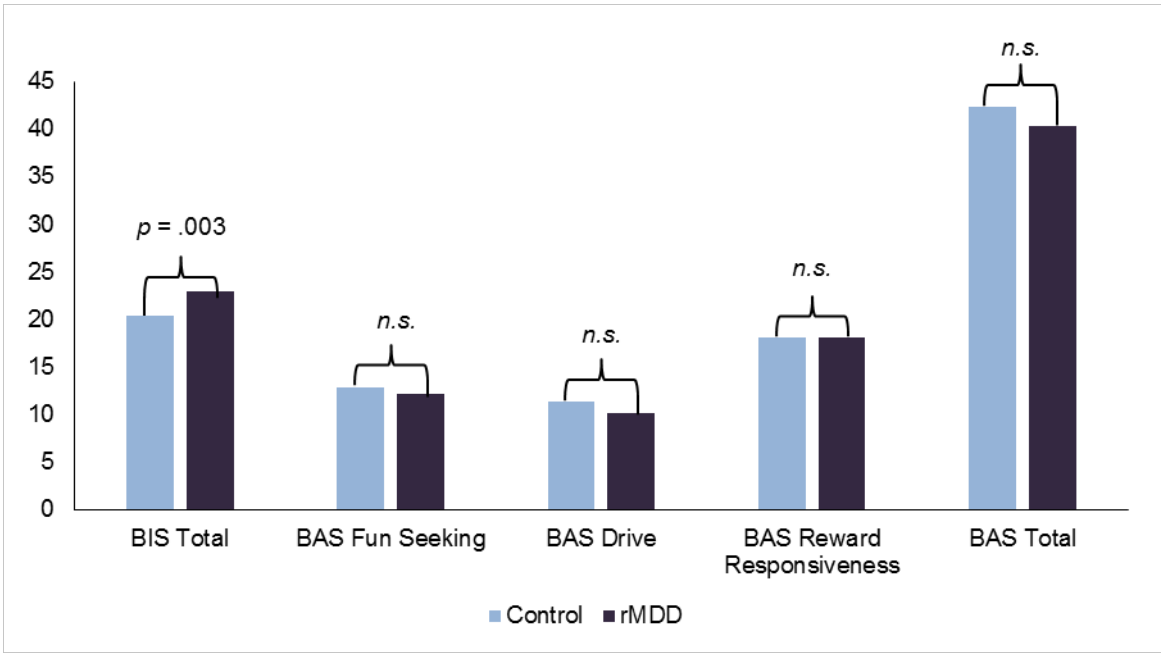

Figure 15. Group differences of approach and avoidance motivation.

We found a significant relationship between avoidance motivation (BIS scores) and Target Absent search efficiency for controls, $r(25) = -.465$, $p = .019$. We did not find a significant relationship between approach motivation (BAS total) and Target Absent, $r(25) = -.136$, $p = .516$, or Present search efficiency, $r(25) = .063$, $p = .776$. We also did not find a significant relationship between avoidance motivation and search performance (Target Absent or Present) for the rMDD group, $r(28) = .178$, $p = .366$; $r(28) = .251$, $p = .198$. We also did not find any relationship between approach motivation (BAS total) and search efficiency (Target Absent or Present) for the rMDD group, $r(28) = -.066$, $p = .738$; $r(28) = -.252$, $p = .198$. **Figure 16a and 16b** presents the correlational relationships between approach, avoidance motivation and visual search performance. These results suggest that rMDD participants might not be utilizing affective information (positive and negative feedback) to promote overall search performance.

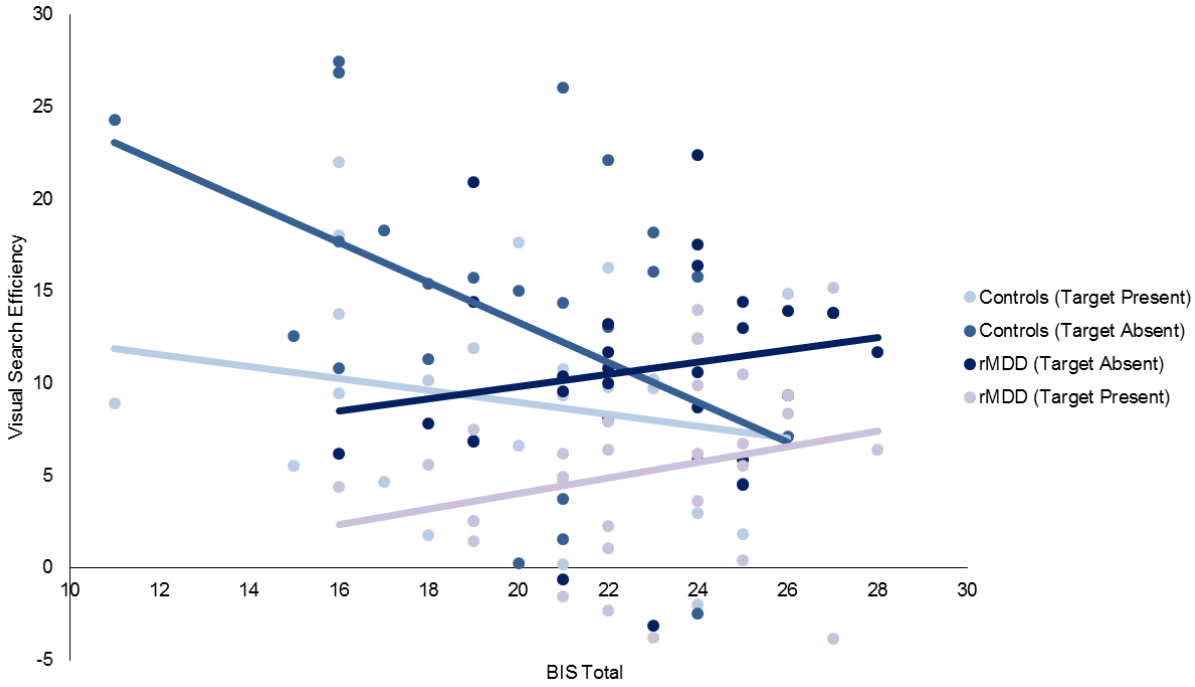

Figure 16a. Correlational relationships between BIS total (avoidance) and visual search performance. There was a significant relationship between BIS total and visual search performance on Target Absent trials for Controls. No other significant relationships were found.

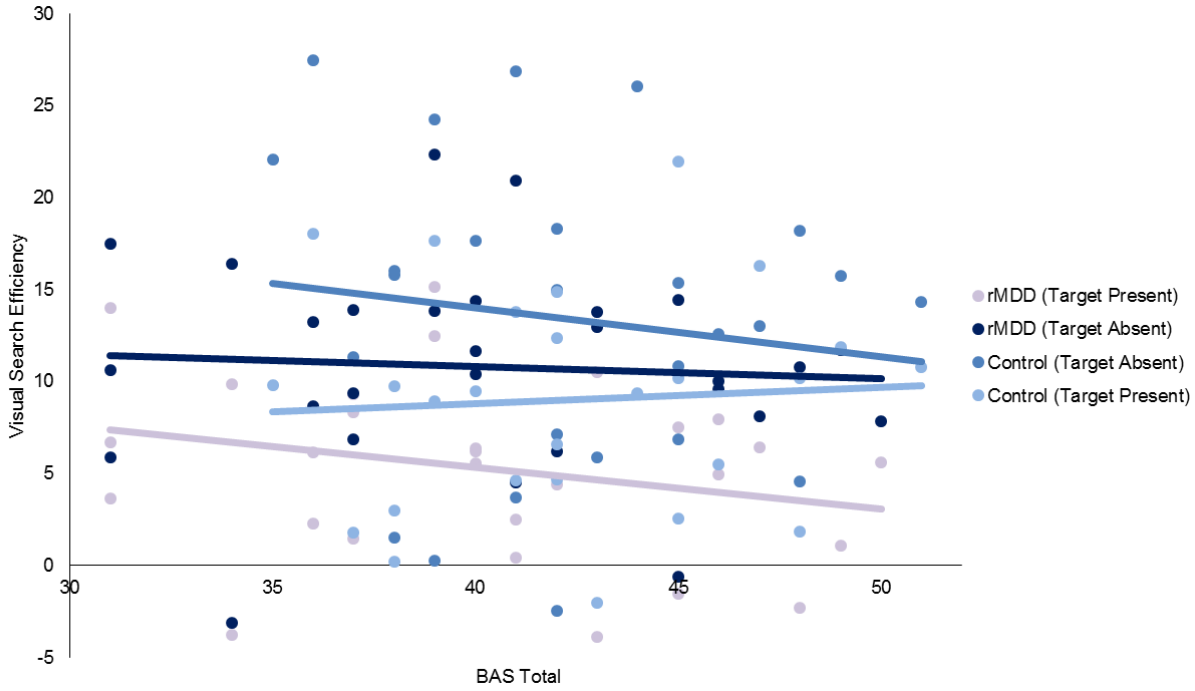

Figure 16b. Correlational relationships between BAS total (approach) and visual search performance. There were no significant relationships for either rMDD or Controls for BAS total scores and visual search efficiency.

DISCUSSION

Depression remains one of the most common, costly, and debilitating forms of mental illness (Creed et al., 2002; Gaynes et al., 2002; Sobocki et al., 2007; Strine et al., 2015). Anhedonia is a trait marker and cardinal feature of depression that has been linked to abnormal reward processing, resulting in sustained depressive states, disrupted goal-directed behavior and impaired reward learning (Davidson, 2003; Meehl, 1975; Treadway & Zald, 2011; Vrieze et al., 2013). The aim of the current study was to acquire a better understanding of the association between abnormal reward processing and visual selective attention in remitted depressed individuals; specifically, evaluating the connection between reward processing capabilities (as measured by FRN amplitude) and search efficiency, a proposed measure of visual selective attention (Steele et al., 2007; Wolfe, 2007). We demonstrated that reward did enhance search performance, as expected, but failed to replicate the finding that remitted depressed individuals showed blunted reward enhancement of search (Taubitz et al., 2015). We found, instead, that once reward was introduced individuals with remitted depression actually had a greater increase in search efficiency than controls for Target Present trials. We also did not find a relationship between sensitivity to reward and search efficiency. We discuss possible explanations for the divergent findings of the two studies below.

Our FRN study results were also not consistent with our predictions. We did not find a relationship between FRN and incentivized visual search performance. Lower FRN amplitude (greater response to positive feedback) was not related to increased search efficiency. We also did not find any group differences on FRN amplitude during the incentivized task – suggesting that remitted depressed participants responded to positive and negative feedback similarly to controls. Also counter to our predictions, we did not find a moderating effect of reward

sensitivity or anhedonic symptoms on the relationship between FRN amplitude and search efficiency. Since there have only been two studies examining FRN abnormalities in remitted depression (blunted FRN activity in adolescent females predicted onset of MDD 2 years later: Bress et al, 2013; decreased FRN in response to negative feedback in adults with rMDD: Santesso et al., 2008), the results from this investigation provide additional insight into FRN activity in adults with remitted depression. Below we discuss our findings in the context of previous work and suggest possible directions for future research.

Consideration of Discrepant Findings on the Effect of Reward on Visual Search in rMDD

We examined the population characteristics and task design of each study to better understand why we did not fully replicate the findings of the Taubitz and colleagues (2015) study. Though not statistically significant, $t(72) = 1.554$, $p = .125$, remitted depressed participants in our study had lower BDI-II scores ($M = 9.82$) than the Taubitz et al. (2015) study (M = 12.98). Other studies that demonstrate the effects of blunted response to reward have participant samples with much higher BDI-II scores (M=23.1: Henriques & Davidson, 2000; M=32.12: Pizzagalli et al., 2008). It is possible that our study sample had enough of a reduction in depressive symptomology that they were able to maintain a responsiveness to reward, resulting in enhanced search performance.

A notable difference in our study is the rate of participants taking some sort of antidepressant in the rMDD group. Twenty-eight percent of our rMDD participants were taking an antidepressant (SSRI = 24.5%, Other = 3.5%) compared to 15% of the Taubitz et al. (2015) study rMDD participants (SSRI = 12.27%, Other = 2.73%), although this difference was not statistically significant, $x^2(1) = 1.921$, $p = 0.166$. Though most antidepressants do not act directly on the dopaminergic (reward) system, burgeoning research has suggested that serotonin

contributes to the motivational, emotional and cognitive aspects of reward representation – resulting in a modulating effect on reward processing (Kranz, Kasper, & Lanzenberger, 2010). Therefore, it is possible that the antidepressants are addressing some of the reward processing deficits in the rMDD group. There is, however, a possibility that other factors are contributing to the improved visual search efficiency in our rMDD group as evidenced by the greater search efficiency found in the rMDD participants not taking SSRIs compared to rMDD taking SSRIs and Controls, though not a statistically significant (see **Figure 17**). Additionally, the potential effects of SSRIs on reward processing deficits may also partially account for the differences found in reward responsiveness between our study and Taubitz et al. (2015).

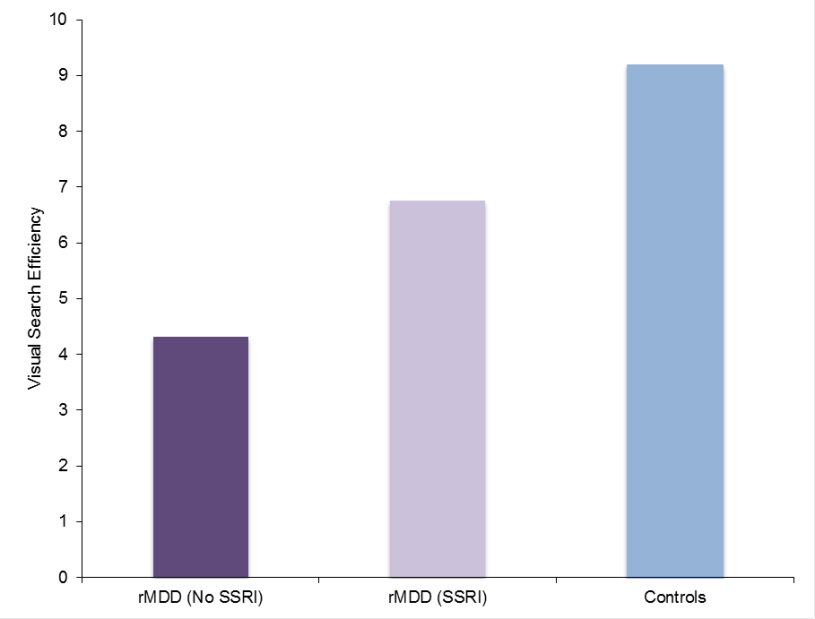

Figure 17. Visual search efficiency differences between rMDD (No SSRI), rMDD (SSRI) and Controls on Target Present Trials.

The variation between the visual search tasks used for each study may also provide insight into the differences in the results of the studies. For example, our visual search task was based off of the same task, but had a few important differences, including variations in the visual array (color and arrangement of stimuli), number of set size conditions (no 16 set size), and

presentation of both negative and positive feedback to all participants. In the Taubitz et al. (2015) study participants were randomly assigned to only receive either positive or negative feedback. This allowed the researchers to investigate the influence of positive and negative feedback separately. Due to recruitment restrictions, we were not able to include feedback valence as a between groups variable, and as a result it is difficult to parse the influence of positive and negative feedback on search performance. Additionally, since selective attention is biased toward negative information in adults with remitted depression (Joormann & Gotlib, 2007) and depressed individuals are more avoidant of negative information (Trew, 2011), it is possible that the influence of negative feedback maybe driving the difference between the results of the two studies. This concept is reviewed further below.

Alternative View on Null Results: Motivation to Avoid

Our results indicated that individuals with a history of depression are more sensitive to reward, showing enhanced search efficiency when reward is introduced (at least for Target Present trials). This is inconsistent with the vast majority of the extant literature on reward processing in depression (Henriques & Davidson, 2000; Pechtel et al., 2013; Pizzagalli et al., 2009). However, in addition to rewarding efficient search, the Incentivized version of the task also incorporated feedback on performance. Thus, it is possible that our findings are driven not primarily by performance incentiviation, but motivation to receive positive and avoid negative feedback.

Depression is marked by increased behavioral avoidance (Bijttebier et al., 2009). Behavioral avoidance motivates the individual to avoid negative outcomes (Carver, 2006) and/or engage in prevention of negative outcomes (Higgins, 1997). In this sense, avoidance provides an adaptive function that prompts the best results for the individual (i.e., not eating moldy food

keeps us from getting sick). In depression, avoidance can eventually become maladaptive, limiting access reward in the environment (i.e., solitude turning into isolation) – contributing to the onset and maintenance of depression (Lewinsohn, 1974; Jacobson et al., 2001; Martell et al., 2001). Over time, avoidance may move from adaptive to maladaptive as depression symptoms increase. In our our study, we may be seeing the adaptive function of avoidance influencing search performance since the participants in the rMDD group had higher levels of behavioral avoidance (BIS scores) than controls and outperformed controls on the Target Present trials of the Incentivized Task. Also, although we did not find a correlation between BIS scores and search efficiency on Target Present trials for the rMDD group, we did find that higher levels of BIS scores were related to increased visual search efficiency in the controls. Thus, in general participants in our study high on BIS were more efficient in their visual search performance. While we cannot isolate the separate effects of incentivization and feedback, it might be possible that the enhanced search efficiency of the rMDD was influenced by a motivation to avoid negative feedback.

Limitations and Future Directions

There are a few limitations to consider regarding our study design, recruited population and FRN data. As we have pointed out, the recruited rMDD group included a fairly large number of participants medicated with SSRIs, potentially contributing to alterations in reward processing. The participants in the rMDD group also had faster baseline visual search efficiency than Controls. Even though we controlled for baseline performance, it is possible that the rMDD were more efficient in general at visual search and were able to further improve visual search efficiency with the introduction of reward. Also, the combined feedback search task used in our study did not allow us to directly examine the influence of positive and negative feedback

separately on search efficiency. Finally, the Reward-Related Positivity (RewP), a newer ERP component, may be a more specific marker of reward processing than the FRN (Proudfit, 2015). Future work should consider using the RewP to more thoroughly investigate the trait-like features of reward processing abnormalities and visual selective attention in depression.

Conclusion

In sum, the results of our study failed to fully replicate Taubitz et al. (2015) and failed to provide evidence of the connection between FRN amplitude, reward and search efficiency. We did, however, find that participants in the rMDD group had greater search efficiency than controls on Target Present trials during the Incentivized task. Interpreted in the context of reward processing, these findings are inconsistent with previous studies of both depressed and remitted depressed individuals (Henriques & Davidson, 2000; Pechtel et al. 2013; Pizzagalli et al., 2009; Taubitz et al., 2015; Vrieze et al., 2013). We tentatively speculated that these findings suggest that the rMDD participants may have outperformed controls as a result of avoidance motivation. However, it is also possible that our rMDD group just happened to be particularly adept at visual search. Further research is warranted in order to more accurately understand the influences of reward and avoidance motivation on visual search efficiency in rMDD adults.

Our previous work was the first study to demonstrate reduced search efficiency in response to positive feedback in a rMDD population (Taubitz et al., 2015), however, as little is known as to the neurological mechanisms underlying this process we sought to investigate one likely marker, the FRN (Foti & Hajcak, 2009; Santesso et al., 2008; Walsh & Anderson, 2012). Unfortunately, the results of our study did not provide any evidence for a relationship between FRN and visual selective attention in remitted depressed adults. Future work is warranted to better understand the degree to which abnormal reward processing, as well as response to

negative feedback, are trait-like features of individuals prone to depression and how this impacts visual selective attention.

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Watson, D., Weber, K., Assenheimer, J. S., Clark, L. A., Strauss, M. E., & McCormick, R. A. (1995). Testing a tripartite model: I. evaluating the convergent and discriminant validity of anxiety and depression symptom scales. *Journal of Abnormal Psychology, 104*(1), 3.

Weinberg, A., Liu, H., Hajcak, G., & Shankman, S. A. (2015). Blunted neural response to rewards as a vulnerability factor for depression: Results from a family study. *Journal of Abnormal Psychology, 124*(4), 878.

Weinberg, A., Riesel, A., & Proudfit, G. H. (2014). Show me the money: The impact of actual rewards and losses on the feedback negativity. *Brain and cognition, 87*, 134-139.

Whitton, A. E., Kakani, P., Foti, D., Van't Veer, A., Haile, A., Crowley, D. J., & Pizzagalli, D. A. (2016). Blunted neural responses to reward in remitted major depression: A high-density event-related potential study. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging, 1*(1), 87-95.

Whitton, A. E., Treadway, M. T., & Pizzagalli, D. A. (2015). Reward processing dysfunction in major depression, bipolar disorder and schizophrenia. *Current Opinion in Psychiatry, 28*(1), 7-12. doi:10.1097/YCO.0000000000000122 [doi]

Willner, O. (1993). Anhedonia. In C. G. Costello (Ed.), *Symptoms of depression* (). NY: John Wiley & Sons, Inc.

Wolfe, J. M. (1998). What can 1 million trials tell us about visual search? *Psychological Science, 9*(1), 33-39.

Wolfe, J. M. (2003). Moving towards solutions to some enduring controversies in visual search. *Trends in Cognitive Sciences, 7*(2), 70-76.

Wolfe, J. M. (2007). Guided search 4.0. *Integrated Models of Cognitive Systems, ,* 99-119.

Yeung, N., & Sanfey, A. G. (2004). Independent coding of reward magnitude and valence in the human brain. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience, 24*(28), 6258-6264. doi:10.1523/JNEUROSCI.4537-03.2004 [doi]

Curriculum Vitae
(Last Revision: October 2016)

Kevin M. Haworth

EDUCATION

Graduate

2012 – present **University of Wisconsin – Milwaukee**
Anticipated Ph.D. in Clinical Psychology
Expected Graduation Date: May 2018
Dissertation: "Abnormal Reward Processing and Visual Selective Attention: An Event-Related Potential Investigation with Remitted Depressed Adults"
(Dissertation Adviser: Christine L. Larson, Ph.D.)

University of Wisconsin – Milwaukee
Master of Science in Psychology
Graduation Date: May 2014
Master's Thesis: "The Impact of Feedback in Response to Self-Disclosure on Social Connection: A Possible Analog Component Model of the Therapy Relationship"
(Thesis Advisers: Jonathan Kanter, Ph.D. & Christine L. Larson, Ph.D.)

Undergraduate

2000 – 2005 **University of Northern Colorado, Greeley, CO**
Bachelor of Arts in Psychology
Bachelor of Science in Business Administration; Emphasis: Finance
Graduation Date: May 2005

AWARDS, SCHOLARSHIPS & FELLOWSHIPS

2015 COGDOP Graduate Research Scholarship. American Psychological Foundation. Awarded: $1000 for research project costs.

2014 Department of Psychology Summer Research Fellowship. University of Wisconsin – Milwaukee. $3178 stipend for 12-week research support.

2012 – 2015 Graduate School Graduate Student Travel Support Program. University of Wisconsin – Milwaukee. Awarded $440 in 2012, $174 in 2013, $375 in 2014 and $100 in 2015 for conference travel.

2012, 2016 Association of Graduate Students in Psychology Conference Travel Award. University of Wisconsin – Milwaukee. Awarded $440 in 2012 and $485 in 2016 for conference travel.

2002 Arta Mae Johnson Memorial Scholarship. Arta Mae Johnson Foundation. Awarded: $1250 for educational costs.

CLINICAL EXPERIENCE

8/16 – present Practicum Student
Post-Deployment/PTSD Clinical Team, VA Medical Center
Clement J. Zablocki VA Medical Center, Milwaukee, WI
Primary Supervisor: M. Christina Hove, Ph.D.

Responsibilities: providing individual therapy (i.e., Cognitive Processing Therapy and Prolonged Exposure for PTSD, broad cognitive-behavioral techniques for coping with post-deployment life, managing PTSD symptoms, and general life stressors) co-leading group therapy (Seeking Safety and War Zone), conducting semi-structured psychodiagnostic interviews, writing psychodiagnostic reports and assisting with Compensation and Pension evaluations. I am currently developing and implementing a Mindfulness-Based Relapse Prevention group. Assessment battery includes: semi-structured clinical interview and MMPI.

5/15 – 6/16 Practicum Student
Comprehensive Dialectical Behavioral Therapy Program, Private Clinic
Center for Behavioral Medicine, Brookfield, WI
Primary Supervisors: Kim Skerven, Ph.D. & Neal Moglowsky, LPC

Responsibilities included: providing individual therapy, leading weekly DBT skills groups, conducting assessments, writing integrated reports, observing live individual DBT therapy sessions, providing skills coaching over the phone to clients, participating in weekly team consultation and assisting with the development of an Adolescent DBT program. Assessment battery includes: Structured Clinical Interview for the DSM-IV (SCID), Structured Clinical Interview for the DSM-IV Axis II Personality Disorders (SCID-II), Borderline Symptom List (BSL), Difficulties in Emotion Regulation Scale (DERS), DBT Ways of Coping Checklist, Self-Harm Inventory, and Montreal Cognitive Assessment (MoCA). Integrated reports completed for 2 adults.

5/14 – 6/16 Student Therapist
General Psychopathology Vertical Team (Therapy Practicum)
University of Wisconsin-Milwaukee Psychology Clinic
Primary Supervisor: Robyn Ridley, Ph.D.

Responsibilities included: providing broad evidenced-based and evidence-informed CBT treatments (i.e., Acceptance and Commitment Therapy, CBT for depression, Behavioral Activation for depression, and Mindfulness-Based Stress Reduction) in the format of individual therapy to adult clients with interpersonal difficulties, mood and/or anxiety disorders. Other responsibilities included observing live therapy, participating in weekly group and individual supervision. Assessment battery includes: BDI, BAI, PSWQ, DASS and MAAS.

5/14 – 8/15 Student Therapist
Behavioral Activation Vertical Team (Therapy Practicum)
University of Wisconsin-Milwaukee Psychology Clinic
Primary Supervisor: Christopher Martell, Ph.D., ABPP

Responsibilities included: delivering Behavioral Activation treatment for depression in the format of individual therapy, observing live therapy, participating in weekly group supervision, and participating in individual supervision. Assessment battery

includes: Quality of Behavioral Activation Scale (Q-BAS), HRSD, BDI and BAI.

1/14 – 5/14 Practicum Student
Practicum in Empirically Supported Interventions
University of Wisconsin-Milwaukee Psychology Clinic
Primary Supervisor: Shawn Cahill, Ph.D.

Responsibilities included: attending experiential learning course, as an adjunct to an Empirically Supported Interventions course for the purpose of receiving training in empirically supported treatments for DSM-IV diagnoses.

8/12 – 5/14 Practicum Student
Practicum in Psychodiagnostic Assessment
University of Wisconsin-Milwaukee Psychology Clinic
Primary Supervisors: Bonita Klein-Tasman, Ph.D. & Hanjoo Lee, Ph.D.

Responsibilities included: administering, scoring, and interpreting psychoeducational/psychodiagnostic assessments with adults and children, conducting clinical interviews, assessment scoring, integrative report writing, classroom observation (with an emphasis on cultural and ethnic diversity) and assisting supervisors with the development of an abbreviated assessment protocol. Assessment battery included: SCID-I, SCID-II, Woodcock-Johnson Tests of Cognitive and Achievement Abilities 3rd Edition (WJ-III), Wechsler Individual Achievement Test (WIAT-II), Wechsler Adult Intelligence Scale (WAIS-III), Wechsler Intelligence Scale for Children (WISC-IV), Minnesota Multiphasic Personality Inventory (MMPI-II), Stroop, Neuropsychology Assessment Battery (NAB), NEO-PI-R, Personality Assessment Inventory (PAI), Children's Memory Scale (CMS), Cognitive Assessment System (CAS), Behavioral Assessment System for Children – Second Edition (BASC-2), Cognitive Assessment System, Hamilton Rating Scale for Depression, California Verbal Learning Test – 2nd Edition, Stroop, Test of Word Reading Efficiency (TOWRE), Conners' Continuous Performance Test II (CPT-II), and Delis-Kaplan Executive Function System (DKEFS). Integrated reports completed using data collected from projective and objective assessments instruments for 3 adults and 2 children.

1/14 – 5/14 Practicum Student
Behavioral Activation Vertical Team
University of Wisconsin-Milwaukee Psychology Clinic
Primary Supervisor: Christopher Martell, Ph.D, ABPP

Responsibilities included: participating in live observation of student therapists providing Behavioral Activation, evaluating treatment protocol adherence, and attending weekly group supervision. Assessment battery includes: HRSD and Quality of Behavioral Activation Scale (Q-BAS).

8/13 – 12/13 Practicum Student
General Psychopathology Vertical Team
University of Wisconsin-Milwaukee Psychology Clinic
Primary Supervisor: Robyn Ridley, Ph.D.

Responsibilities included: attending weekly group supervision for student therapists providing a wide range of CBT interventions for mood and anxiety disorders (e.g., GAD, MDD) at a departmental clinic.

8/12 – 5/13 Practicum Student
Behavioral Activation Vertical Team
University of Wisconsin-Milwaukee Psychology Clinic
Primary Supervisor: Jonathan Kanter, Ph.D., Christopher Martell, Ph.D., ABPP

Responsibilities included: reading and discussing the Behavioral Activation treatment manual (*Behavioral Activation for Depression: A Clinician's Guide*) and related empirical literature, participating in live observation of student therapists providing Behavioral Activation, evaluating treatment protocol adherence and attending weekly group supervision. Assessment battery includes: Quality of Behavioral Activation Scale (Q-BAS).

9/09 – 9/10 Volunteer
Community Networks Program
Sound Mental Health, Seattle, WA
Primary Supervisor: Martin Knutson, M.A.

Responsibilities included: developing a weekly group program designed to support and increase peer interactions in adults with a dual diagnosis (mental illness and a developmental disability), conduct weekly group sessions and attend weekly individual supervision.

9/04 – 3/05 Undergraduate Intern
Individualized Education Program and Bully Prevention Program
Franklin Middle School, Greeley, CO
Primary Supervisor: Nichol Crawford, Ph.D.

Responsibilities included: supporting staff and school psychologist with educational tasks and emotional support for students that have been given an Individualized Education Program (IEP), helped facilitate student specific accommodations defined by IEP, attend IEP team meetings, and assist school psychologist with implementation of bullying prevention program.

PROVISION OF SUPERVISION

8/16 – present Peer Clinical Supervisor
General Psychopathology Vertical Team (Therapy Practicum)
University of Wisconsin-Milwaukee Psychology Clinic
Primary Supervisor: Robyn Ridley, Ph.D.

Responsibilities: co-supervising 3rd year Ph.D. students conducting CBT techniques for mood and anxiety disorders (e.g., Exposure Therapy for GAD and Social Anxiety, Mindfulness-Based Stress Reduction, ACT and BA) for adult outpatient clients at a departmental clinic, observing therapy conducted by 3rd year Ph.D. students, attending group supervision, providing one-on-one supervision to 3rd year Ph.D. students, receiving supervision on delivering supervision to 3rd year Ph.D. students.

ATTENDED WORKSHOPS AND SEMINAR TRAININGS

9/2015 *Dialectical Behavior Therapy for Substance Use Disorders (DBT-SUD) Training*
Workshop Presenter: Linda Dimeff, Ph.D., Practice Ground Learning Community
Content: Online training of delivery of DBT for a clinical population of individuals

with co-morbid Borderline Personality Disorder (BPD) and substance use disorders.
Time: 3 hours

5/2015 *Intensive Training In Delivery of Dialectical Behavior Therapy*
Workshop Presenters: Kim Skerven, Ph.D., Neal Moglowsky, LPC, Center for Behavioral Medicine, a DBT-Linehan Board of Certification, Certified Program
Content: Introductory training on the delivery of DBT for an adult population
Time: 20 hours

11/2013 *Cultural Competence in Cognitive-Behavioral Therapy: A Process, Skills-Based Model*
Workshop Presenters: Steve Lopez, Ph.D., Gaby Nagy, M.S., Maria Santos, Ph.D. and Jonathan Kanter, Ph.D.
Content: Introductory training in a cultural competence model for mental health professionals using CBT (Mini-workshop)
Time: 3 hours

8/2010 *Functional Analytic Psychotherapy, Level 1 Training*
Workshop Presenters: Mavis Tsai, Ph.D. and Robert J. Kohlenberg, Ph.D.
Content: Introductory training in Functional Analytic Psychotherapy
Time: 20 hours

RESEARCH EXPERIENCE

Affective Neuroscience Laboratory
Supervisor: Christine L. Larson, Ph.D.
Department of Psychology, University of Wisconsin-Milwaukee, Milwaukee, WI

Dissertation Project
Duration of project: 4/14 – present
Abnormal Reward Processing and Visual Selective Attention
Project Scope: to examine the connection between abnormal reward processing and visual selective attention in adults with a history of Major Depressive Disorder using event-related potentials. Specifically, measuring reward processing capabilities, as captured by the feedback-related negativity (FRN), a medial frontal electrocortical event-related potential component, and visual search performance in both remitted and never-depressed adults.
Responsibilities: design of study methodology, development of a behavioral task (using E-Prime software), training Research Assistants, oversight of research team, conducting Mini-International Neuropsychiatric Interview (M.I.N.I.) psychodiagnostic interviews, data collection/management/analysis (using SPSS, Matlab and EEGlab software) and manuscript preparation.

Principal Student Investigator
Duration of Project: 4/15 – present
Effects of Rumination on Working Memory: EEG Oscillation Investigation
Project Scope: the objective of this project is to investigate the neurobiological mechanisms of rumination by exploring changes in alpha-band EEG during attempted inhibition of task-irrelevant stimuli and gamma-band EEG activity post rumination induction, and how those changes are related to WM performance.
Responsibilities: development of study paradigm and methodology, creating and testing a behavioral task (using E-Prime software), training Research Assistants, oversight of research team, conducting Mini-International Neuropsychiatric Interview (M.I.N.I.) psychodiagnostic interviews and data

management.
Funded: COGDOP Graduate Research Scholarship, American Psychological Foundation - $1000

Graduate Research Assistant
Duration: 8/13 – present
- Conducted two independent behavioral studies examining (1) approach motivation and (2) gender differences reward processing in a remitted depressed adult population.
- Used E-Prime software to develop behavioral tasks
- Aided in preprocessing and analysis of neuroimaging (fMRI) data using AFNI software and SPSS for two research projects (1) examining resting state bed nucleus of the stria terminalis (BNST) and amygdala connectivity in adults while under threat of shock and (2) investigating activation changes in the dorsomedial prefrontal cortex and amygdala pre and post a computerized social anxiety treatment
- Data management/analysis using Qualtrics online survey system, Excel and SPSS software for three projects
- Conducted Mini-International Neuropsychiatric Interview (M.I.N.I.) psychodiagnostic interviews
- Oversight of research team and training of Research Assistants for three studies

Depression Treatment and Specialty Clinic
Supervisor: Jonathan Kanter, Ph.D.
Department of Psychology, University of Wisconsin-Milwaukee, Milwaukee, WI

Master's Thesis Project
Duration of Project: 8/12 – 9/14
Investigating the Impact of Feedback in Response to Self-Disclosure on Social Connection
*Project Scope: t*his project represents and aimed to examine the impact of delivering feedback in response to statements of self-disclosure provided by a participant and how that feedback could increase the sense of social connection between the participant and the Research Assistant.
Responsibilities: design of study paradigm and methodology, coordinating research efforts with a research team at the University of Washington, training Research Assistants, oversight of research teams, data collection/management/analysis (using SPSS) and manuscript preparation.

Graduate Research Assistant
Duration: 8/12 – 8/13
- Assisted with the development and evaluation of a theoretically driven prejudice reduction workshop
- Aided in the development and evaluation of the feasibility of a web-based therapist training platform for Functional Analytic Psychotherapy
- Oversight of research teams, data management and analysis for two projects
- Coordinated project resources with graduate students at Sao Paulo University in Sao Paulo, Brazil to help develop a Portuguese version of the training program

Center for the Science of Social Connection
Department of Psychology, University of Washington, Seattle, WA
Supervisors: Robert Kohlenberg, Ph.D. Gareth Holman, Ph.D., Sarah Bowen, Ph.D. & Mavis Tsai, Ph.D.

Research Coordinator
Duration: 12/08 – 11/12
- Assisted in the development of study paradigms and methodologies for two project examining

methods to enhance interpersonal connection: (1) brief mindfulness intervention and (2) behavioral-based treatment protocol
- Aided in the development of the a mindfulness intervention protocol
- Completed human subjects/IRB applications, recruited and coordinated participants, oversight of research team, trained and managed Research Assistants for five projects
- Evaluated treatment sessions for protocol adherence (achieved criterion coder status)
- Data management and analysis using SPSS, WebQ online survey software and Excel
- NIMH R34 grant application preparation
- Prepared and presented three conference posters
- Manuscript preparation for three studies

Other Research Experiences

Graduate Research Assistant
Behavior Therapy and Research Lab, University of Wisconsin-Milwaukee, Milwaukee, WI
(NIMH Grant [RO1] R01MH080966). Direct Costs: $ 1,127,980.
Supervisor: Douglas Woods, Ph.D.
Duration of Work: 8/12 – 8/13
Project Scope: to evaluate the efficacy and effectiveness of an Acceptance Enhanced Behavioral Therapy for the treatment of Trichotillomania.
Responsibilities: assisting with oversight of data transfer (hardcopy to digital) and database management.

Research Assistant
Evidence-Based Practice Institute, LLC, Seattle, WA
Supervisors: Gareth Holman, Ph.D. and Kelly Koerner, Ph.D.
Duration of Work: 4/10 – 6/11
Project Scope: to evaluate the functional interface and feasibility of an online psychotherapy training platform.
Responsibilities: conducting preliminary usability testing of the website, creating a comparison to evaluate similar websites, data management and analysis and assisting with SBIR Phase 1 NIH grant application.

Research Assistant
University of Nevada, Reno
Supervisor: Mike Worrall, Ph.D.
Duration of Work: 9/11 – 12/11
Project Scope: to evaluate the functionality of a web-based training system for Dialectical Behavioral Therapy.
Responsibilities: conducting usability testing of the web-based system and providing extensive usability assessment reports to research coordinator.

Undergraduate Research Assistant
University of Northern Colorado, Greeley, CO
Supervisor: Molly Geil, Ph.D.
Duration of Work: 10/04 – 5/05
Responsibilities: attending weekly meetings with Principle Investigator and conducting literature reviews.

ORIGINAL PUBLICATIONS IN PEER REVIEWED JOURNALS

Haworth, K., Kanter, J., Tsai, M. Kuczynski, A.M., Rae, J. R., & Kohlenberg, R. J (2015). Reinforcement Matters: A Laboratory-Based Component-Process Analysis of Functional Analytic Psychotherapy's Model of Social Connection. *Journal of Contextual Behavioral Science, 4*(4), 281-291.

Bowen, S., **Haworth, K.,** Grow, J., Tsai, M., & Kohlenberg, R. J. (2012). FAP informed brief interpersonal mindfulness intervention: Background and pilot study findings. *International Journal of Behavioral Consultation and Therapy*, *7*(2), 9-15.

Holman, G. I., Kohlenberg, R. J., Tsai, M., **Haworth, K.,** Jacobson, E., & Liu, S. (2012). Functional Analytic Psychotherapy is a framework for implementing evidence-based practices: The example of integrated smoking cessation and depression treatment. *International Journal of Behavioral Consultation and Therapy*, *7*(2), 58-62.

MANUSCRIPTS UNDER REVIEW

Taubitz, L.E., **Haworth, K.,** & Larson C.L. (Under Review). Facilitating Visual Selective Attention via Reward: The Influence of Feedback, Hedonic Capacity, and Lifetime Major Depressive Disorder. Submitted in July, 2016.

MANUSCRIPTS IN PROGRESS

Haworth, K., Taubtiz, L. E., & Larson C. L. (In Preparation). Abnormal Reward Processing and Visual Selective Attention: An Event-Related Potential Investigation with Remitted Depressed Adults.

Pedersen, W. S., **Haworth K.**, Larson C. L. (In Preparation). Resting state connectivity of the bed nucleus of the stria terminalis while under threat of unpredictable shock and while safe: a high resolution 7T fMRI study.

Liverant, G., Orsillo S., Gollan J., **Haworth, K.,** Martell, C.R. (In Preparation). The Neuroscience of Behavioral Activation: Connecting Preclinical Research to Clinical Treatment.

SYMPOSIUM

Martell, C.R. (Discussant), **Haworth, K. (Discussant)**. Presenters: Gollan, J., Liverant, G., Weinstock, L. (2015, November). *Identifying Mechanisms of Change in Behavioral Activation Treatment for Mood Disorders.* Symposium presented at the Association for Behavioral and Cognitive Therapies 49th Annual Convention, Chicago, Illinois.

PROFESSIONAL PRESENTATIONS

Haworth, K., Taubitz, L. E., Larson C. L. (2016, October). *Impact of Reward on Visual Search Performance: An Event-Related Potential Investigation.* Poster will be presented at the Association for Behavioral and Cognitive Therapies 50th Annual Convention, New York, New York.

Davine, T., **Haworth, K.,** Fritz, J., Yadlosky, L., Johnson, B., Skerven, K. (2016, October). *Examining the Effect of Dialectical Behavior Therapy on Emotion Regulation and Effective Coping: A Preliminary Uncontrolled* Trial. Poster presented at the International Society for the Improvement and Teaching of Dialectical Behavior Therapy 21st Annual Conference, New York City, New York.

Boeh, H. A., Nimphius, M.C., LeMaire, K. L., **Haworth, K.,** Takamine, P.M., Skerven, K. (2015, November). *Symptom Differences Between DBT Clients With and Without PTSD*. Poster presented at the International Society for the Improvement and Teaching of Dialectical Behavior Therapy 20th Annual Conference, Chicago, Illinois.

Haworth, K., Burdick, B., Gast, D., Velazquez, A., Gruneberg, M., Kanter, J. (2014, November). *The Effectiveness of Feedback on Interpersonal Connection – An Analog Study of the Therapeutic Relationship.* Poster presented at the Association for Behavioral and Cognitive Therapies 48th Annual Convention, Philadelphia, Pennsylvania.

Haworth, K., Taubitz, L. E., Larson C. L. (2014, September). *Gender Differences on Visual Search Task Performance Emerge after Reward is Introduced*. Poster presented at the Society for Research in Psychopathology 29th Annual Meeting, Evanston, Illinois.

Haworth, K., Taubitz, L. E., Larson C. L. (2014, April). *Gender Differences in Reward Sensitivity*. Poster presented at The Society of Affective Science Inaugural Conference, Bethesda, Maryland.

Haworth, K., Velazquez, A., Burdick, B., Canido, K., Murphy, J., Kanter, J. (2013, November). *Improving Interpersonal Connection - Exploring the Effects of Reinforcement on Interpersonal Connectedness.* Poster presented at the Association for Behavioral and Cognitive Therapies 47th Annual Convention, Nashville, Tennessee.

Haworth, K., Tsai, M., Holman, G. I., Koerner, K., Murphy, J., Kanter, J. (2013, November). *Maximizing the Power and Potential of the Therapeutic Relationship Through a Web-Based Training Program.* Poster presented at the Association for Behavioral and Cognitive Therapies 47th Annual Convention, Nashville, Tennessee.

Haworth, K., Bowen, S., Kohlenberg, R. J., & Tsai, M. (2012, November). *Differences between Asian American and Caucasian participants in state mindfulness following a brief intervention.* Poster presented at the Association for Behavioral and Cognitive Therapies 46th Annual Convention, National Harbor, Maryland.

Murphy, J., Crowe, A., Kanter, J., Tsai, M., Holman, G. I., Koerner K., & **Haworth, K.** (2012, November). *A randomized pilot study of web-based Functional Analytic Psychotherapy therapist training*. Poster presented at the Association for Behavioral and Cognitive Therapies 46th Annual Convention, National Harbor, Maryland.

Haworth, K., Liu, S., Kohlenberg, R. J., Holman, G. I., & Tsai, M. (2011, November). *A discussion of FAP coding systems; CRIVI vs. FAPRS.* Poster presented at the Association for Behavioral and Cognitive Therapies 45th Annual Convention, Toronto, Canada.

Haworth, K., Bowen, S., Kohlenberg, R. J., & Tsai, M. (2011, November). *A study of brief interpersonal mindfulness training.* Poster presented at the Association for Behavioral and Cognitive Therapies 45th Annual Convention, Toronto, Canada.

Haworth, K., Holman, G. I., Jacobson, E., Kohlenberg, R. J., & Dimidjian, S. (2010, November). *Which items on the Hamilton Rating Scale of Depression change after treatment? A comparison of antidepressant medication and psychotherapy.* Poster presented at the Association for Behavioral and Cognitive Therapies 44th Annual Convention, San Francisco, CA.

Jacobson, E., Holman, G. I., **Haworth, K.,** Kohlenberg, R. J., & Dimidjian, S. (2010, November). *Remission of anxiety disorders following treatment for depression.* Poster presented at the Association for Behavioral and Cognitive Therapies 44th Annual Convention, San Francisco, CA.

Holman, G. I., **Haworth, K.**, Liu, S., Tsai, M., & Kohlenberg, R. J. (2010, May). *Development of a FAP analogue protocol: Brief relationship enhancement.* Poster presented at the Association of Behavior Analysis International, 34th Annual Convention, San Antonio, TX.

Liu, S., Holman, G. I., **Haworth, K.,** Plummer, M., Tsai, M., & Kohlenberg, R. J. (2010, May). *FAP therapist training: A behavioral rationale and preliminary data.* Poster presented at the Association of Behavior Analysis International, 34th Annual Convention, San Antonio, TX.

AD HOC STUDENT REVIEWER

Psychology of Addictive Behaviors
Psychiatric Research

TEACHING EXPERIENCE

Fall 2016	Teaching Assistant. Psychology 407, Theories of Personality. University of Wisconsin – Milwaukee. Department of Psychology. Primary Supervisor: Robyn Ridley, Ph.D.
Spring 2016	Teaching Assistant. Psychology 407, Theories of Personality. University of Wisconsin – Milwaukee. Department of Psychology. Primary Supervisor: Robyn Ridley, Ph.D.
Fall 2015	Teaching Assistant. Psychology 407, Theories of Personality. University of Wisconsin – Milwaukee. Department of Psychology. Primary Supervisor: Robyn Ridley, Ph.D.
Spring 2015	Teaching Assistant. Psychology 325, Research Methods. University of Wisconsin – Milwaukee. Department of Psychology. Primary Supervisor: Marcellus Merritt, Ph.D.
Fall 2014	Teaching Assistant. Psychology 407, Theories of Personality. University of Wisconsin – Milwaukee. Department of Psychology. Primary Supervisor: Robyn Ridley, Ph.D.
Spring 2014	Teaching Assistant. Psychology 325, Research Methods. University of Wisconsin – Milwaukee. Department of Psychology. Primary Supervisor: Marcellus Merritt, Ph.D.
Fall 2013	Teaching Assistant. Psychology 325, Research Methods. University of Wisconsin – Milwaukee. Department of Psychology. Primary Supervisor: Susan Lima, Ph.D.

CO-MENTORING EXPERIENCE (Undergraduate Research Assistants)

2015 – 2016	Hannah Sallmann (Support for Undergraduate Research Fellows awardee, Honors Thesis)
2014 – 2015	Brian Danzyger (Support for Undergraduate Research Fellows awardee, Honors Thesis)

PROFESSIONAL DEVELOPMENT

11/2014 *Analysis of Functional Neuro-Imaging (AFNI) Bootcamp*
National Institutes of Health 40 hour training seminar for AFNI software

PROFESSIONAL AFFILIATIONS

2014 – present Student Affiliate. American Psychological Association
2014 – present Associate Member. Sigma Xi
2014 – present Student Member. Association of Psychological Science
2013 – present Student Member. Society for Affective Sciences
2010 – present Student Member. Association for Behavioral and Cognitive Therapies
Special Interest Group: Mindfulness

REFERENCES

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