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Facilitating Visual Selective Attention via Monetary Reward: the Influence of Feedback, Hedonic Capacity, and Lifetime Major Depressive Disorder

Lauren Elizabeth Taubitz
University of Wisconsin-Milwaukee

FACILITATING VISUAL SELECTIVE ATTENTION VIA MONETARY REWARD: THE INFLUENCE OF FEEDBACK, HEDONIC CAPACITY, AND LIFETIME MAJOR DEPRESSIVE DISORDER

by

Lauren E. Taubitz

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ABSTRACT

FACILITATING VISUAL SELECTIVE ATTENTION VIA MONETARY REWARD: THE INFLUENCE OF FEEDBACK, HEDONIC CAPACITY, AND LIFETIME MAJOR DEPRESSIVE DISORDER

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Lauren E. Taubitz

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Recently, several researchers have demonstrated that reward enhances visual selective attention; however, no one has evaluated how individual differences in reward sensitivity or psychopathology involving disturbances in hedonic capacity (e.g., Major Depressive Disorder (MDD)) affect this process. In this investigation, a novel incentivized visual search task was developed to unite the literatures on reward facilitation of attention with the studies of individual differences in hedonic capacity and remitted MDD (rMDD). 161 undergraduates responded to self-report measures and completed standard and incentivized visual search tasks. In the standard task, subjects had to indicate if a letter F (target) was present or absent in a group of E's. The incentivized visual search task was the same as the standard task, but subjects could earn money if they responded both correctly and quickly, and they received performance feedback. Participants were randomly assigned to either receive feedback only if they earned the monetary reward (positive feedback group) or if they failed to earn the monetary reward (negative feedback group). A subsample of 126 participants completed the MINI International Neuropsychiatric Interview (55 never-depressed, 47 remitted MDD). Overall, monetary reward robustly enhanced visual search efficiency. In addition, greater SPSRQ Sensitivity to Reward was associated with enhanced incentivized search efficiency in the presence of positive, but not negative, feedback. On the contrary, the rMDD group exhibited less efficient search in the presence of positive, but not negative, feedback relative to the never-depressed group. Finally, there was a double dissociation between depressive affect and feedback. Increased MASQ General Distress – Depression (negative affective symptoms of depression) was associated with enhanced incentivized search in the presence of negative, but not positive, feedback whereas Anhedonic Depression was associated with decreased efficiency in the presence of positive, but not negative, feedback. Overall, these results provide a cohesive account of the relationship between motivation and attention as it relates to both basic cognitive and affective science and the study of psychopathology

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Introduction

There is a long history of psychological inquiry surrounding the principle that reward facilitates learning and behavior (i.e., O'Doherty et al., 2004; Skinner, 1963; Thorndike, 1898). However, reward processing does not occur at an equal rate or to an equal degree for all people (e.g., Gold, Waltz, Prentice, Morris, & Heerey, 2008; Kumar et al., 2008; Liu et al., 2011; Pechtel, Dutra, Goetz, & Pizzagalli, 2013; Pizzagalli, Goetz, Ostacher, Iosifescu, & Perlis, 2008; Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2009; Robinson, Cools, Carlisi, Sahakian, & Drevets, 2012), suggesting that there is variability in the capacity for which reward can improve learning and thus change behavior that may vary systematically with psychopathology. There is a growing body of literature indicating that reward can enhance cognitive processes such as visual selective attention (Della Libera & Chelazzi, 2006, 2009; Della Libera, Perlato, & Chelazzi, 2011; Kanske & Kotz, 2011; Krebs, Boehler, & Woldorff, 2010; Krebs, Boehler, Egner, & Woldorff, 2011; Ross, Lanyon, Viswanathan, Manoach, & Barton, 2011); however, few researchers have reported on how individual differences in reward sensitivity affect the magnitude by which reward facilitates attention, and there are no studies connecting psychopathology with this process. Thus, the purpose of this study is to unite the literatures on reward facilitation of attention with the study of individual differences and psychopathology, chiefly anhedonia and Major Depressive Disorder.

Visual Selective Attention

Visual selective attention (VSA) is the cognitive mechanism by which we resolve competition between visual stimuli and select relevant information to process more fully so that it may reach a level of conscious awareness and ultimately guide behavior (Treisman, 1969). Visual selective attention is controlled via the integration of two mechanisms - cognitive "top-down" and stimulus-driven "bottom-up" processing of visual input – each of which are driven by different underlying neural mechanisms (Kincade, Abrams, Astafiev, Shulman, & Corbetta, 2005; Posner, Snyder, & Davidson, 1980; Posner, Walker, Friedrich, & Rafal, 1984; Treisman & Gelade, 1980; for a review, see Corbetta & Shulman, 2002). The system involving goal-directed attentional control, or "top-down" selection of stimuli (Corbetta & Shulman, 2002; Hopfinger, Buonocore, & Mangun, 2000; Kastner, Pinsk, De Weerd, Desimone, & Ungerleider, 1999; Kincade et al., 2005), is engaged, for example, while looking for your suitcase at an airport baggage claim. To find your suitcase, you would employ some sort of cognitive strategy to find your particular bag such as prioritizing bags with pink luggage tags (if that was a feature of your bag) and ignoring bags without such tags. The second system is specialized for "bottom-up" selection or feature-driven attentional capture. It is used for detecting behaviorally-relevant stimuli, particularly when they are salient and unexpected (Corbetta & Shulman, 2002). This system would become engaged if, while working quietly at your desk, a fire alarm suddenly went off, and your attention was diverted from your work so you could evacuate the building. While these processes are often viewed as distinct, there is also evidence that some brain regions may be involved in integrating stimulus-driven attention with top-down goals and thus represent more intermediate areas of visual processing (Kastner et al., 1999; Ruff et al., 2008).

Visual Search

The visual search task is widely used in the laboratory to study both bottom-up attentional capture and top-down attentional control mechanisms affecting visual selective attention. A visual search task mimics everyday situations we encounter in which we must find a target stimulus amongst a sea of distracters, as in the aforementioned airport baggage claim example. In the laboratory, subjects are generally given the task of finding and/or identifying a target as quickly as possible among varying numbers of distracting stimuli (e.g., Garritsen, Frischen, Blake, Smilek, & Eastwood, 2008; Kristjánsson, Sigurjónsdóttir, & Driver, 2010;

Treisman & Gelade, 1980; Wolfe, Cave, & Franzel, 1989; Wolfe, 1998; for reviews see Treisman & Gormican, 1988; Wolfe, 2003; 2007). Reaction times and accuracy rates are used to evaluate the search efficiency of a particular target among a particular set of distractors. Search efficiency is measured by the search slope: the slope of the linear line-of-best-fit connecting mean reaction time by set size, indicating the number of milliseconds per item it takes, on average, to search through the array (e.g., Eastwood, Smilek, & Merikle, 2001; Treisman & Gelade, 1980; Wolfe, 1989; 1998; 2007). Search efficiency depends on characteristics of the target and distractor contexts as well as task demands and characteristics of the observer (Garritsen et al., 2008; Kristjánsson et al., 2010; Treisman & Gelade, 1980; Wolfe, 1989; for reviews, see Frischen, et al., 2008; Wolfe, 2003; 2007). Behavioral (Frischen et al., 2008; Treisman & Gelade, 1980; Wolfe, 2007), neuroimaging (Nobre, Couli, Walsh, & Frith, 2003; Wei, Müller, Pollmann, & Zhou, 2011), and psychophysiological research (Ossandon et al., 2012) all provide evidence that both bottom-up and top-down processes influence visual search efficiency.

Reward Facilitation of Visual Selective Attention

Recently, several researchers have demonstrated that reward can facilitate visual selective attention (Anderson, Laurent, & Yantis, 2011a,b; Anderson & Yantis, 2013; Della Libera & Chelazzi, 2006, 2009; Della Libera, Perlato, & Chelazzi, 2011; Hickey, Hickey, Chelazzi, & Theeuwes, 2010; Lee & Shomstein, 2014; Ross, Lanyon, Viswanathan, Manoach, & Barton, 2011; Theeuwes & Belopolsky, 2012) and other cognitive processes (Kanske & Kotz, 2011; Krebs, Boehler, & Woldorff, 2010; Krebs, Boehler, Egner, & Woldorff, 2011; Savine & Braver, 2010). For example, in a same/different judgment task, Della Libera and colleagues (Della Libera & Chelazzi, 2006; 2009; Della Libera et al., 2011) found that targets whose selection led to a reward became easier to select in the future, and distracting stimuli that were rewarded when successfully ignored were more easily discarded in the future. Moreover, these authors found that this is accomplished via two mechanisms (Della Libera et al., 2011): one requiring active monitoring of performance and outcome (i.e., If I *do* something, I will get a reward), and one detecting a relationship between objects in the environment and the more-or-less rewarding events that accompany them (i.e., If I *see* something, I will get a reward). Thus, reward facilitates visual selective attention both actively in a top-down manner (active modulation of task performance to attempt to earn a reward) and passively in a bottom-up fashion (associating reward or non-reward with objects) highlighting two mechanisms of action by which reward can influence attention.

Using behavioral and eye-tracking methodologies, others have shown that the learned reward value of a stimulus increases bottom-up attentional capture above and beyond attention captured by the stimulus' physical salience alone (Anderson et al., 2011a; 2011b; Anderson & Yantis, 2013; Hickey et al., 2010; Lee & Shomstein, 2014; Theeuwes & Belopolsky, 2012). This effect is strong and persists across time. For example, Anderson and Yantis (2013) showed that previously rewarded stimuli continued to capture attention 6 months later even without any new reward learning during that time. Moreover, Hickey and colleagues (2010) showed that attentional capture of reward-related stimuli was strengthened in individuals reporting greater BAS: Drive – a scale designed to measure how persistent one is in pursuing desired goals (Carver & White, 1994). Thus, it is well-established that reward learning enhances visual selective attention in a bottom-up manner, and there is some evidence that this may be related to individual differences in drive to pursue rewards (i.e., "wanting").

Reward and Visual Search

Recently, researchers have started examining the impact of reward on visual search efficiency (e.g.; Kiss, Driver, & Eimer, 2009; Kristjánsson et al., 2010; Lee & Shomstein, 2014). These researchers have shown that reward can enhance the efficiency of "pop out" visual search and that this increase in efficiency is enhanced by increasing reward magnitude (Kiss et al., 2009; Kristjánsson et al., 2010; Lee & Shomstein, 2014). Kiss et al. (2009) also showed that the N2pc event-related potential (ERP) component, a neural indicator of target selection in visual search (Luck & Hillyard, 1994), occurred earlier and was larger in amplitude for high- than for low-reward targets in pop-out search. This indicates that reward value can enhance very early target selection processes (within 200 ms post-stimulus onset). Additionally, the sustained posterior contralateral negativity (SPCN) ERP component, which is thought to reflect sustained stimulus processing and maintenance in visual short term memory (Vogel & Machizawa, 2004), was enhanced for high-reward relative to low-reward targets, indicating that reward value may also enhance post-stimulus selection processing. Finally, Lee and Shomstein (2014) recently demonstrated that stimulus features associated with reward in a "pop-out" search task (e.g., line orientation) can be transferred to a subsequent conjunction search task involving greater top-down demands on attention, even though the reward contingency was no longer relevant. These findings further demonstrate that reward influences search efficiency by both enhancing target salience and changing distractor filtering.

Visual Selective Attention and Reward Summary

In summary, an abundance of behavioral, psychophysiological, and neuroimaging research has mapped out top-down and bottom-up attentional networks and how reward may guide visual selective attention via these two mechanisms. Krebs and colleagues (2011) suggest that one possible underlying neural mechanism by which reward may enhance visual selective attention is via frontal-striatal connections. Individuals with current or past MDD exhibit decreased function of the dopaminergic midbrain and ventral striatum (McCabe et al., 2009; Nestler et al., 2002; Nestler & Carlezon, 2006; Russo & Nestler, 2013; Smoski et al., 2009) as well as abnormal effective connectivity across visual attention networks (Desseilles et al., 2011).

However, there is no research, to the best of our knowledge, evaluating the influence of psychopathology on reward facilitation of visual selective attention, and there is only one investigation that has linked individual differences related to reward sensitivity with this process. Thus, an important next step in this line of research is to apply basic experimental models of reward and attention to understanding how the ability to use reward to facilitate attention or other cognitive processes is related to individual differences in reward sensitivity as well as psychopathology such as MDD.

Anhedonia and Major Depressive Disorder

Anhedonia, generally defined as a loss of interest or pleasure, is considered to be a core feature of Major Depressive Disorder (MDD; American Psychiatric Association, 2013; Brown, Chorpita, & Barlow, 1998; Clark, Watson, & Mineka, 1994; Watson et al., 1995a; 1995b). It has long been hypothesized to be a risk factor for depression (Meehl, 1975), and more recent experimental research indicates that poorer behavioral and neural responses to rewards predict future onset of MDD (Bress et al., 2013; Rawal, Collishaw, Thapar, & Rice, 2013). In the context of current MDD, prospective longitudinal studies indicate that anhedonia and reduced reward processing are associated with persistence of MDD and poorer treatment outcome (Spijker et al., 2001; Vrieze et al.,2013; Vrieze et al., 2014). Finally, anhedonia and poor reward processing remain prominent features after remission of a major depressive episode (Clark et al., 1994; McCabe et al., 2009; Pechtel et al., 2013; c.f. McFarland & Klein, 2009). Consequently, anhedonia is regarded as a “trait-like” rather than “state-like” feature of depression.

Reward Processing and MDD

Researchers have identified several distinct reward processing constructs including, but not limited to, the hedonic response to rewards (i.e., “liking”), incentive salience or motivation to seek out rewards (i.e., “wanting”), anticipation of reward, post-reward attainment (i.e., consummatory reward response), and learning predictive associations of reward (i.e., “learning”; Berridge & Robinson, 1998; 2003; Berridge et al., 2009; Knutson, Adams, Fong, & Hommer, 2001; Rangel, Camerer, & Montague, 2008; Salamone, Correa, Farrar, & Mingote, 2007; Treadway & Zald, 2013). There is a robust literature suggesting that both current and remitted MDD are associated with deficits across all of these areas of reward processing (Kumar et al., 2008; McCabe et al., 2009; McFarland & Klein, 2009; Pizzagalli et al., 2009; Robinson et al., 2012; Smoski et al., 2009; Treadway et al., 2012), particularly in the presence of anhedonic symptoms (Chase, et al., 2010; Liu et al., 2011; Pizzagalli et al., 2009; Shankman, Sarapas, & Klein, 2011; Vrieze et al., 2013). There is considerable evidence from both behavioral and neuroimaging investigations supporting the idea that both currently (Kumar et al., 2008; Liu et al., 2011; Pizzagalli et al., 2009; Robinson et al., 2012; Vrieze et al., 2013) and remitted (Pechtel et al., 2013) depressed individuals exhibit an impaired tendency to modulate behavior as a function of prior reinforcements (i.e., poorer reward learning) especially in the presence of increased anhedonia (Liu et al., 2011; Pizzagalli et al., 2009; Vrieze et al., 2013). McCabe and colleagues (2009) found that individuals with remitted MDD (rMDD) exhibited decreased activation in the ventral striatum during visual and gustatory presentation of pleasurable stimuli indicating decreased “liking” of rewards. Similarly, Dichter and colleagues (2012) showed that subjects with rMDD exhibited decreased activation of other reward network regions relative to never-depressed controls during the reward outcome phase of a monetary incentive delay task, indicating decreased consummatory pleasure. Finally, Treadway and colleagues (2012) have provided evidence that individuals with current MDD are less willing to expend effort for rewards than controls, indicating decreased “wanting” of rewards.

The Present Study

Previous studies on the effect of reward on visual selective attention have had several limitations that the present study seeks to address. First, in all studies combining visual search tasks and reward, stimulus properties such as color have been used to signify reward value (e.g., Kiss et al., 2009; Kristjánsson et al., 2010; Lee & Shomstein, 2014), consistent with Della Libera and colleagues' (2011) passive reward facilitation of attention or Berridge and colleagues' (2009) concept of reward "learning". No one has examined active, "top-down" reward-facilitation of attention in the context of visual search. Thus, the first purpose of this investigation is to determine if purely motivational, top-down reward mechanisms can enhance visual search efficiency. It is hypothesized that visual search will be much more efficient when subjects can earn money for faster search versus when they cannot.

Second, many studies of reward processing involve displaying positive and negative feedback after each trial indicating a win, loss, or failure to win (e.g., Chase et al., 2010; Lee & Shomstein, 2014; Treadway et al., 2009; 2012). Because both types of feedback were displayed to all people, it is unclear if enhancement of attention is being driven more by positive or negative feedback across time. Thus, another purpose of this study is to evaluate how the emotional valence of feedback affects reward facilitation of cognition tasks by randomly assigning subjects to receive only positive or negative feedback. Because of a large body of research on negativity biases (for a review, see Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001), it is hypothesized that subjects in the negative feedback group will be more efficient than subjects in the positive feedback group overall; however, it also expected that the effect of feedback will depend on individual differences in hedonic capacity.

One of the major aims of this investigation is to evaluate how individual differences in hedonic capacity influence the effect of monetary rewards on visual search efficiency, and if the effect of individual differences differs based on the presence positive versus negative feedback.

To the best of our knowledge, Hickey and colleagues (2010) are the only researchers to have reported on how individual differences in hedonic capacity affects reward facilitation of attention. Based on their research, and research on other aspects of reward processing, it is expected that individuals who are more sensitive to reward will be more efficient at using monetary incentives to enhance visual search, particularly in the presence of positive feedback. On the contrary, it is hypothesized that greater anhedonia will be associated with less efficient visual search when subjects could earn money, particularly in the presence of positive feedback.

Last, no one has reported on the relationship between psychopathology and reward facilitation of attention. Plus, most investigations of reward processing related to MDD have either relied on stimulus properties to signify reward, thus primarily examining bottom-up processes that influence reward learning (e.g., Kumar et al., 2008; Liu et al., 2011; Pizzagalli et al., 2009; Robinson et al., 2012; Vrieze et al., 2013), or they have evaluated top-down processes but outcome was not tied to the subjects' actual performance (i.e., feedback was predetermined; McFarland et al., 2009; c.f., Treadway et al., 2012). Thus, another aim of this study was to evaluate the effect of lifetime MDD on a top-down, effort-based reward task (i.e., tapping into the "wanting" construct of reward processing) to evaluate how motivation affects visual selective attention in individuals with a history of MDD. Remitted MDD was chosen because of the trait-like nature of reward processing deficits in depression and for recruitment convenience. Moreover, each subject's outcome and feedback will actually be tied to their performance. This simulates more "real-world" situations in which obtaining a desired outcome is dependent upon persistent effort and focus (e.g., to get an A in a class, or to get a good performance review at work) than tasks in which the outcome is arbitrarily predetermined, and it more closely taps into the motivational "wanting" aspect of reward processing. It is hypothesized that remitted depressed subjects will be less efficient than never-depressed subjects on the incentivized visual search task, particularly in the presence of positive feedback.

Method

Participants

Participants included 161 undergraduates at the University of Wisconsin – Milwaukee (UWM) who completed the study for course credit and a monetary reward based on their task performance. To ensure that an equal number of individuals were never-depressed and remitted-depressed, we prescreened individuals for history of depression. To identify individuals who may have experienced a lifetime major depressive episode, the following pre-screening question was asked during an online survey administered to all potential undergraduate research participants: "Have you ever been depressed or down most of the day nearly every day for at least 2 weeks?"

Diagnostic Interview

To assess lifetime diagnosis of Major Depressive Disorder and other psychopathology, subjects completed the Mini International Neuropsychiatric Interview (MINI) version 6.0. The MINI is a short structured diagnostic interview that was designed to assess *Diagnostic and Statistical Manual of Mental Disorders, 4th Edition (DSM-IV;* American Psychiatric Association, 1994) psychopathology. The MINI exhibits similar validity and reliability properties as other commonly used structured clinical interviews (e.g., the SCID or CIDI; Sheehan et al., 1998), and it is highly concordant with the SCID for a diagnosis of MDD (kappa = 0.84, sensitivity = 0.96, specificity = 0.88; Sheehan et al., 1998).

For any statistical analyses involving diagnostic group, individuals were included in the never-depressed group if they have never met criteria for a mood or psychotic disorder. Any other psychopathology was allowable, including anxiety and substance use disorders. Individuals were included in the remitted-depressed (rMDD) group if they experienced at least one Major Depressive Episode (MDE) in the past but did not currently meet criteria for an MDE. Exclusionary criteria for this group include presence of a current MDE, a bipolar-spectrum disorder, or a history of psychosis. Any other comorbid psychopathology was allowed. Individuals for which a *Diagnostic Statistical Manual of Mental Disorders, 5th Edition* (*DSM-5; American Psychiatric Association, 2013)* Other Specified mood disorder was warranted (e.g., subthreshold current MDD, or unclear if unipolar or bipolar depressive disorder) were not included in either the rMDD or never-depressed group.

Self-Report Battery

Subjects completed a packet of questionnaires designed to measure reward sensitivity, anhedonia, depression, and other related traits. The primary measures of interest included the Snaith-Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995), the 20-item version of the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ-20; Aluja & Blanch, 2011; Torrubia, Ávila, Moltó, & Caseras, 2001), the 62-item version of the Mood and Anxiety Symptom Questionnaire (MASQ; Watson & Clark, 1991; Watson et al., 1995), the BIS/BAS Scales (Carver & White, 1994), and the Beck Depression Inventory, 2nd Edition (Beck et al., 1996). The SHAPS is a 14-item self-report questionnaire designed to assess symptoms of anhedonia (Snaith et al., 1995). It has good reliability and validity in the general population (Snaith et al., 1995), students unselected for psychopathology (Franken, Rassin, & Muris, 2007), and individuals with Major Depressive Disorder (Franken, et al., 2007; Nakonezny et al., 2010; Snaith et al., 1995) and other psychopathology involving hedonic disturbance (i.e., schizophrenia, substance use disorders; Franken et al., 2007; Silver & Shlomo, 2002). The SHAPS was chosen as a primary measure of anhedonia because it has been used in numerous other investigations of reward processing (e.g., Lempert & Pizzagalli, 2010; Pechtel et al., 2013; Treadway et al., 2009; Vrieze et al., 2013), and it has been suggested that the SHAPS is a more pure measure of anhedonia (i.e., the absence of pleasurable feelings) than other measures of anhedonia (Franken et al., 2007).

The SPSRQ assesses Sensitivity to Punishment, defined as worry or avoidance of situations involving the possibility of aversive consequences, and Sensitivity to Reward, which assesses reward-oriented behavior. The original 40-item SPSRQ has shown good reliability and validity properties (Torrubia, Avila, Molto, & Caseras, 2001), and it has shown to be a better measure of the reward interest aspect of behavioral approach that is germane to this investigation (rather than impulsivity) (Caseras, Ávila, & Torrubia, 2003). The SPSRQ-20 maintains the validity, orthogonality, and reliability of the original longer SPSRQ version with acceptable reliability and validity (Aluja & Blanch, 2011).

The Mood and Anxiety Symptom Questionnaire (MASQ) is a 62-item self-report measure of a range of depression and anxiety symptoms based on the tripartite model of depression and anxiety (Clark & Watson, 1991; Watson et al., 1995a; Watson et al., 1995b). It contains four subscales including two subscales that are unique to anxiety and depression (Anxious Arousal and Anhedonic Depression, respectively), and two General Distress subscales that contain items related to general anxious mood (General Distress – Anxiety) and general negative affective symptoms of depression (General Distress – Depression). The MASQ subscales show excellent convergent validity in students, community adults, and patients (Watson et al., 1995b). The Anxious Arousal and Anhedonic Depression subscales show the best discriminant validity while the General Distress subscales are less discriminant, though this fits with the tripartite theory (Watson et al., 1995b). The MASQ was chosen because it delineates anhedonic and negative affective symptoms of depression and because it has been used to study the relationship between anhedonia and reward learning in individuals with current MDD (Pizzagalli et al., 2009).

The BIS/BAS Scales (Carver & White, 1994) were included because they are the most commonly-used measure of behavioral inhibition and behavioral approach, and the three BAS subscales (Reward Responsiveness, Drive, and Fun Seeking) tap into three separate, though interrelated, areas of behavioral approach. The Reward Responsiveness subscale reflects the degree to which one experiences positive responses to rewarding experiences or to the anticipation of rewarding experiences. The Drive subscale is thought to measure how persistent one is in pursuing desired goals, and the Fun Seeking scale measures how much one desires new rewards and seeks out rewarding events on the spur of the moment (Carver & White, 1994).

The 21-item BDI-II (Beck et al., 1996) was chosen because it is one of the most commonly-used measures of depression severity. It was used to assess current symptoms of depression, including both positive and negative affective features, and to control for current symptoms of depression in analyses comparing never-depressed and rMDD subjects. The BDI-II exhibits good reliability and validity in college students unselected for psychopathology (Storch, Roberti, & Roth, 2004; Whisman, Judd, Whiteford, & Gelhorn, 2013) and seeking services from a university counseling center for depression (Sprinkle et al., 2002).

Finally, the following secondary measures-of-interest were added to ensure that none of these constructs related to reward sensitivity, anhedonia, and/or depression could better explain our findings: the Beck Anxiety Inventory (Beck & Steer, 1993), Barratt Impulsivity Scale (BIS-11), Zuckerman Sensation Seeking Scale, and the Toronto Alexithymia Scale (TAS-20). These scale were chosen because of the overlap between anxiety and depression, anhedonia and alexithymia, and reward sensitivity and impulsivity.

Visual Search Task

All subjects completed two versions of a visual search task: a standard visual search task and an incentivized visual search task. All subjects completed the standard visual search task first to get a baseline measure of search efficiency on the task. At the start of the task, participants were told that their goal was to determine as quickly and accurately as possible if there was an F present on the screen or if there were only E's. Participants were not told before starting the standard visual search task that the speed they needed to go to earn monetary rewards on the incentivized search task would be based on their reaction time from this part of the experiment. This was done so that participants would not intentionally go slower on the standard visual search task in order to maximize the amount of money they could earn on the incentivized visual search task.

After the instructions, subjects completed 20 practice trials followed by 240 experimental trials consisting of a 1000-2000 ms fixation cross (mean 1500 ms) and then a search array containing 4, 8, 12, or 16 letters (see Figure 1). Participants indicated if a target was present or absent by pressing the left or right arrow keys respectively. Half of the trials (120 trials) were Target Present trials in which there was an F present among the group of E's, and half of the trials (120 trials) were Target Absent trials in which all of the letters were E's. The letters appeared on the screen until a response was made or 3000 ms has elapsed for 4 or 8 letter arrays or 3500 ms has elapsed for 12 or 16 letter arrays. These time frames were chosen to allow participants ample time to respond while eliminating potential outlying reaction times (RTs). Each participant's standard visual search task mean reaction time minus one standard deviation was calculated and used as a variable in the incentivized search task to set the threshold for how fast each participant needed to respond to earn the monetary reward in the incentivized search task. Consequently, monetary rewards in the incentivized visual search task were based on each individual's own motor speed so that differences in motor reaction time that covary individual differences of interest to this investigation could not account for incentivized search findings.

After completing the standard visual search task, subjects completed the incentivized visual search task. In this part of the experiment, the instructions for the visual search task were the same as in the standard version except that participants were told that they could also earn money on all trials based on their performance (see Figure 2). Participants were told in the instructions that the speed they needed to go to earn the monetary reward was based on their reaction time from the first part of the experiment, and that their goal on this task was to win as much money as possible. Because it was unclear from previous research how performance is affected by receiving positive or negative feedback after each trial, subjects were randomly assigned to one of two feedback versions: positive and negative. Subjects in the positive feedback group only received feedback after a trial if they responded both correctly and one standard deviation faster than they did on average on the standard visual search task. They did not receive any feedback if they responded incorrectly and/or too slowly. If they responded incorrectly and/or too slowly, they moved on to the next trial instead of receiving feedback. The feedback display stated “Correct and fast! You have won $0.05. You have earned $x.xx,” where $x.xx is the running total of the amount of money the participant has earned thus far (see Figure 2 for an example). Subjects in the negative feedback group only received feedback if they responded incorrectly and/or too slowly. There were three possible feedback displays for this group: “Incorrect! You have won $0. You still have $x.xx,” “Too slow! You have won $0. You still have $x.xx,” and “Incorrect and too slow! You have won $0. You still have $x.xx,” where $x.xx is the running total of the amount of money the participant has earned thus far (see Figure 2). If they responded correctly and at least one standard deviation faster than they did on the standard visual search task (i.e., if they earned the monetary reward), they simply moved on to the next trial. Participants were informed of the type of feedback they would receive on the task in the instructions for the task.

As in the standard visual search task, subjects completed 20 practice trials and 240 experimental trials consisting of a 1000-2000 ms fixation cross (mean 1500 ms) followed by a search array containing 4, 8, 12, or 16 letters in the incentivized visual search task (see Figure 2). Half of the trials (120 trials) were Target Present trials in which there was an F present among the group of E's, and half of the trials (120 trials) were Target Absent trials in which all of the letters displayed were E's. The letters appeared on the screen until a response was made or 3000 ms has elapsed for 4 or 8 letter arrays or 3500 ms has elapsed for 12 or 16 letter arrays. At the end of the experiment, subjects were told how much money they had earned on the task, and they were paid that amount in cash in addition to receiving course credit for participation. Credit was equivalent for all subjects and was not based on task performance.

Statistical Analysis

To answer the first two question as to whether active top-down reward mechanisms enhance visual search and if this is affected by the type of performance feedback that participants receive (positive versus negative), we conducted a 4 (Set Size: 4, 8, 12, or 16 letters) x 2 (Target: Absent or Present) x 2 (Search Task: Standard or Incentivized) x 2 (Feedback Type: Negative- or Positive) mixed-model ANOVA with reaction time (RT) serving as the dependent variable and Feedback Type serving as the only between-subjects factor. Polynomial contrasts were used to confirm that RT increased linearly as a function of set size. A significant Set Size x Target interaction would confirm the basic effect of target presence on search slope that is present in all visual search tasks involving target presence or absence. It was expected that reaction time will be faster for Target Present than Target Absent trials, and this effect will be more pronounced as Set Size increased (i.e., a flatter search slope for Target Present than Target Absent trials) indicating that search is more efficient for Target Present than Target Absent trials.

To establish whether monetary reward enhances visual search efficiency, the Set Size x Target x Search Task interaction was examined. If search was more efficient on the incentivized search task than on the standard search task, then the difference between small and large set sizes would be greater for the Standard version than the incentivized version (i.e., flatter search slope in the Monetary Reward version than the standard version). Finally, a significant Set Size x Target x Search Task interaction would indicate whether the type of search task (standard versus incentivized) affects the search slope (number of ms per item) for Target Present trials differently than Target Absent trials. It was expected that monetary reward would affect search efficiency to a greater degree for Target Absent than Target Present trials because search for Target Present trials is already very efficient without the presence of a monetary reward. If this is the case, then there will be a stronger Set Size x Target interaction for Target Absent than Target Present trials in the Monetary Reward version of the visual search task.

After confirming the basic linear effect of Set Size on RT in the ANOVA, linear search slope for Target Absent and Target Present trials was calculated for the standard and incentivized versions of the visual search task using the ordinary least squares (OLS) method. Efficiency of visual search was quantified by the slope of the mean reaction time x Set Size OLS regression line (the average milliseconds (ms) per item to search the search array). A smaller search slope signifies more efficient visual search and a larger (steeper) search slope indicates more inefficient search. Search slope will be calculated via the following equation:

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

If feedback type (positive or negative) influenced visual search efficiency differently across participants, then there would be a significant Set Size x Feedback x Search Task interaction. It was expected that individuals in the positive and negative feedback groups would not differ on the standard search task. Because individuals were randomly assigned to either group, there should not be systematic group differences in basic visual search efficiency before the experimental manipulations of monetary reward and feedback. It was expected that feedback type would affect both Target Present and Target Absent trials in the incentivized search task, so there should not be a four-way Target x Set Size x Search Task x Feedback interaction; . Because no one has reported on the effect of performance feedback in prior studies, strong predictions about which type of feedback will improve search efficiency more than another cannot be made. However, given the body of research on negativity biases, it is predicted that negative feedback will enhance search efficiency more than positive feedback in the incentivized search task.

Next, multiple linear regressions were carried out using Hayes & Matthes' (2009) MODPROBE procedure for SPSS to determine whether individual differences variables predicted incentivized search slope alone or if they interact with Feedback Type to produce unique effects on incentivized search efficiency. In all models, search slope during the standard search task was controlled for to ensure that individual differences variables and feedback predicted variance incentivized search slope above and beyond what would be predicted based on general visual search ability. Separate models were evaluated for Target Absent and Target Present conditions. It was expected that individuals reporting increased sensitivity to reward would exhibit flatter search slopes (i.e., more efficient search) in the incentivized search task for both Target Present and Target Absent trials. Because anhedonia reflects diminished sensitivity to reward or capacity to experience pleasure, it was expected that there will be a significant positive relationship between anhedonia and incentivized search slope for both Target Present and Target Absent trials. Moreover, it was expected that the effect of reward sensitivity and anhedonia would be stronger in the positive feedback group relative to the negative feedback group (i.e., there will be significant interactions between hedonic capacity and feedback type).

To evaluate interactions between individual differences variables and feedback type, the Johnson-Neyman Regions of Significance Test was used. The Johnson-Neyman technique identifies regions in the range of the moderator variable where the effect of the focal predictor on the outcome is statistically significant and not significant (Johnson & Neyman, 1936; Johnson & Fay, 1950; Potthoff, 1964; Hayes & Matthes, 2009). This method was chosen because it is free from homogeneity assumptions and, consequently, is the preferred method of evaluating categorical x continuous variable interactions in multiple regression because.

Results

Participant Characteristics

In all, 161 individuals (47 Male, 113 Female, and 1 Transgender) completed the visual search task and responded to questionnaires. Participant demographic characteristics can be seen in Table 1 and self-report questionnaire results can be seen in Table 2. Chi-square tests of independence were used to determine if the remitted MDD and the never-depressed groups differed on any categorical variables including gender, race/ethnicity, native language (English vs. Other), and psychotropic medication use (none versus one or more psychotropic medications). There was a significant difference between the never-depressed and rMDD groups in gender composition ($\chi^2(2) = 6.06$, $p = 0.048$) and psychotropic medication use (($\chi^2(1) = 9.209$, $p = 0.002$). As expected based on previous studies on the demographics of MDD (Weissman et al., 1996), the rMDD group contained a greater percentage of females than the never-depressed group. Also as expected, significantly more rMDD subjects than never-depressed subjects were taking psychotropic medications (mainly SSRIs and SNRIs). Differences in age between the control and rMDD group were assessed by an independent samples *t*-test. There was no significant difference in subject age between the control and rMDD groups ($t(99) = 0.21$, $p = 0.833$, Cohen's $d = 0.04$).

Self-Report Questionnaire Results

Participant questionnaire data for the whole sample, never-depressed group, and rMDD group can be seen in Table 2. Participants in the whole sample exhibited a wide range of scores on all self-report instruments. BDI-II and BAI ranged from minimal to severe symptoms of depression and anxiety (BDI-II range = 0-52; BAI range = 0-46; Beck & Steer, 1993; Beck et al., 1996), and SHAPS scores ranged from hedonic to anhedonic (range = 0-12, scores > 2 indicate presence of anhedonia; Snaith et al., 1995)[1].

Differences between the never-depressed and rMDD groups on continuous self-report measures were evaluated via independent samples *t*-tests. The rMDD group had significantly more symptoms of depression and anxiety than the control group as evidenced by significantly higher BDI-II ($t(99) = -4.68$, $p < 0.001$, Cohen's $d = 0.94$), BAI ($t(98) = -4.54$, $p < 0.001$, Cohen's $d = 0.92$), BIS ($t(99) = -3.08$, $p = 0.003$, Cohen's $d = 0.62$), MASQ General Distress - Depression ($t(99) = -4.32$, $p < 0.001$, Cohen's $d = 0.87$), and MASQ Anhedonic Depression scores ($t(99) = -3.80$, $p < 0.001$, Cohen's $d = 0.76$) despite not meeting criteria for current MDD based on the MINI. Although the rMDD group had significantly higher BDI-II scores on average than the never-depressed group ($M = 12.72$ vs. 6.74, respectively), both groups exhibited BDI-II scores that fall, on average, below cutoff scores for identifying the presence of depressed mood in college students (BDI-II cutoff = 16; Sprinkle et al., 2002).

The never-depressed and rMDD groups did not differ on many of our main measures-of-interest for anhedonia and reward sensitivity including the SHAPS ($t(99) = -1.14$, $p = 0.26$, Cohen's $d = 0.23$), SPSRQ-20 Sensitivity to Reward ($t(98) = 1.12$, $p = 0.27$, Cohen's $d = 0.23$), BAS: Reward Responsiveness ($t(99) = 0.30$, $p = 0.76$, Cohen's $d = 0.06$), and BAS: Fun Seeking ($t(99) =$

0.17, $p = 0.87$, Cohen's $d = 0.03$). However, they did differ on MASQ Anhedonic Depression ($p < 0.001$) and the BAS: Drive ($t(99) = 2.16$, $p = 0.03$, Cohen's $d = 0.43$). Given the increased negative affective evident in the rMDD group, the discrepancy between the SHAPS and MASQ Anhedonic Depression likely reflects previous findings that the Anhedonic Depression subscale of the MASQ includes more overlap with negative affective symptoms of depression (e.g., "Felt unattractive," or "Felt withdrawn from other people"; Watson et al., 1995) while the SHAPS is a more pure measure of anhedonia (i.e., the absence of pleasurable feelings; Franken et al., 2007). On the other hand, there is no evidence to suggest that BAS: Drive is related to negative affect, so the BAS: Drive findings suggest that the rMDD group is somewhat less motivated to pursue goals than the never-depressed group. Overall, though, the

MINI International Neuropsychiatric Interview Results

Out of the 161 total participants, a subsample of 126 participants completed the MINI. Because we oversampled for individuals reporting a history of depression, a wide range of psychopathology was present (see Table 3) including individuals completely free of psychopathology to individuals with a history of psychosis. Differences between the never-depressed and rMDD groups were determined via chi-square tests of independence. The only significant difference between the never-depressed and rMDD groups was in the presence of current and past panic disorder (both $p < 0.05$). There was a marginal but non-significant difference between the never-depressed and rMDD groups when examining the presence of any current DSM-5 anxiety disorder. This was likely driven by marginally increased rates of current panic disorder, agoraphobia ($\chi^2(1) = 3.56$, $p = 0.06$), and generalized anxiety disorder (GAD; $\chi^2(1) = 3.21$, $p = 0.07$) in the rMDD group. There was no difference between the never-depressed and rMDD groups in the rate of substance use disorders (all $p > 0.77$), Posttraumatic Stress Disorder

(PTSD; $\chi^2(1) = 1.09$, $p = 0.30$), Obsessive Compulsive Disorder (OCD; $\chi^2(1) = 0.03$, $p = 0.87$), or eating disorders (any current eating disorder; $\chi^2(1) = 1.40$, $p = 0.24$).

Subjects Excluded from All Visual Search Analyses

Out of the 161 participants, 16 subjects (9.94% of the total sample) were removed from all further analyses involving visual search data for the following reasons: computer or software malfunction ($n = 5$), failure to follow task instructions (e.g., subject used incorrect keys for the standard search task so the reaction times that the reward was based on in the incentivized search task were invalid; $n = 4$), self-reported medical condition that could robustly affect attention or reaction time (history of stroke or coma; current severe rheumatoid arthritis; $n = 3$), subject appeared to be intoxicated during the study with behavioral observations consistent with interview-reported current substance abuse ($n = 1$), and greater than three standard deviations between the predicted and observed *y*-values (standardized residuals ≥ 3) for all statistical models, suggesting that their data was of poor fit to the models tested and that they reflect outliers in the dataset ($n = 3$).

Basic Visual Search Findings

The first two purposes of this investigation were to determine if active, top-down reward-seeking strategies could be used to enhance visual search efficiency and to see if this was affected by the type of feedback that participants receive (positive versus negative). To answer these questions, we conducted a 4 (Set Size: 4, 8, 12, or 16 letters) x 2 (Target: Absent or Present) x 2 (Search Task: Standard or Incentivized) x 2 (Feedback Type: Negative- or Positive-Only) mixed-model ANOVA with reaction time (RT) serving as the dependent variable and Feedback Type serving as the only between-subjects factor. Mauchley's Test of Sphericity was severely violated for Set Size and any interactions involving Set Size (all $p \leq 2.088 \times 10^{-16}$, all $\varepsilon \leq 0.725$), indicating that the variances of the differences between all possible pairs of set sizes (e.g., variance of 4 vs. 8 compared to 8 vs. 12, etc.) are not equal. Violating the sphericity assumption can inflate the Type I error rate by resulting in *F*-critical values that are too small. When ε is less than 0.75 (as in this case), the Greenhouse-Geisser correction is the best method of correcting the *F*-critical value (and hence the *p*-value); thus, Greenhouse-Geisser corrected results are reported for the Set Size main effect and all interactions involving Set Size.

Replicating other basic visual search task findings (see Wolfe, 2007 for a review), there were robustly significant main effects of Target ($F(1,143) = 962.788$, $p = 2.173 \times 10^{-65}$, $\eta_p^2 = 0.871$) and Set Size ($F(1.365,195.125) = 91015.699$, $p = 4.111 \times 10^{-90}$, $\eta_p^2 = 0.877$) indicating that subjects were faster to respond to Target Present than to Target Absent arrays, and they were faster to respond to smaller than larger set sizes. Polynomial contrasts also confirmed the linear relationship between Set Size and RT ($F(1, 141) = 1179.236$, $p = 6.039 \times 10^{-71}$, $\eta_p^2 = 0.892$) indicating that an OLS linear quantification of search slope (ms/item) is appropriate. Also replicating previous research, there was a significant Set Size x Target interaction ($F(1.652, 236.347) = 366.807$, $p = 2.489 \times 10^{-66}$, $\eta_p^2 = 0.720$). Reaction times were faster for Target Present than Target Absent trials, and this effect was more pronounced as the Set Size increased. In other words, the search slope for Target Present trials was flatter than for Target Absent trials, indicating that search is more efficient for Target Present than Target Absent trials. These findings validate the use of search slopes as a measure of search efficiency in further analyses.

Effect of Monetary Reward on Visual Search

More importantly, there was a significant Set Size x Target x Search Task three-way interaction ($F(2.176, 311.158) = 428.056$, p = 4.417×10^{-94}, $\eta_p^2 = 0.750$) indicating that there is an interaction between the Target Absent and Target Present search slopes and Search Task (see Figures 3 and 4). As seen in Figure 3, participants became much more efficient at searching both Target Absent and Target Present arrays in the Incentivized Search Task than they were in the

Standard Search Task. Follow-up one-sample *t*-tests were run to confirm that the difference between the Standard and Incentivized Search Task search slopes were significantly different from zero for both Target Absent and Target Present trials. These *t*-tests indicated that subjects robustly improved their search efficiency for both Target Absent and Target Present trials on the Incentivized Search Task relative to the Standard Search Task (Target Absent: M_{diff} = 72.908 ms/item, $t(144) = 32.451$, $p = 4.237 \times 10^{-68}$, 95% $C.I._{diff}$ = 68.468-77.349; Target Present: M_{diff} = 21.908 ms/item, $t(144) = 22.830$, $p = 1.057 \times 10^{-49}$, 95% $C.I._{diff}$ = 20.079-23.885).

Consistent with other standard visual search task findings (Wolfe, 2007), subjects were less efficient at searching Target Absent than Target Present trials in the Standard Search Task (Target Absent M = 87.576 ms/item, Target Present M = 34.548 ms/item; $t(144) = 26.797$, $p = 8.001 \times 10^{-58}$, 95% C.I. = 49.117-56.940). However, subjects improved more for Target Absent than Target Present trials to the extent that the difference between Target Absent and Target Present search slopes in the Incentivized Search Task was no longer significant (See Figure 4; Target Absent M = 14.668 ms/item, Target Present M = 12.566 ms/item; $t(144) = 1.765$, p = 0.080, 95% *C.I.* = -0.252-4.455). Thus, it is possible that there was a floor effect on search efficiency that is governed by motor speed that makes it more difficult to improve visual search for Target Present arrays (which is already very efficient even without monetary rewards) than Target Absent arrays.

Effect of Positive and Negative Feedback on Incentivized Visual Search

There was also a significant main effect of Feedback Type (F(1, 143) = 6.917, p = 0.009) indicating that individuals in the Negative Feedback group were significantly faster than individuals in the Positive Feedback group; however, this was qualified by a significant Set Size x Search Task x Feedback Type interaction ($F(1.608, 229.876) = 9.335$, $p = 0.0004$, $\eta_p^2 = 0.061$). This significant three-way interaction indicates that subjects had flatter search slopes in the

Incentivized Search Task when they were only given negative feedback (*M* = 9.231 ms/item) versus positive feedback (*M* = 18.448 ms/item) across target types (Target Absent and Target Present trials collapsed; see Figure 5). Importantly, there was no difference in search slope between Feedback groups on the Standard Search Task (Negative Feedback: *M* = 61.248 ms/item; Positive Feedback: *M* = 60.857 ms/item). Thus, the observed group differences were specific to the experimental manipulation of feedback and not baseline group differences in attention or reaction time. The four-way Set Size x Target x Search Task x Feedback Type interaction ($F(2.176, 311.158) = 2.581$, $p = 0.073$, $\eta_p^2 = 0.018$) was not statistically significant, implying that the effect of Feedback Type during the Incentivized Search Task did not differentially affect Target Absent versus Target Present trials. This is likely because the effect of Feedback Type was only present in the Incentivized Search Task (as expected), and there was not a significant difference between Target Absent and Target Present search slopes ($p = 0.080$) on that task.

MDD Group x Feedback MANCOVA

The Group (Never-Depressed, rMDD) x Feedback Type (Positive, Negative) MANCOVA yielded significant main effects of Group ($F(1, 85) = 5.089$, $p = 0.027$, $\eta_p^2 = 0.056$) and Feedback Type ($F(1, 85) = 14.821$, $p < 0.001$, $\eta_p^2 = 0.148$) for Target Present trials. The novel Group main effect supports the *a priori* hypothesis that individuals with remitted MDD do not enhance search efficiency as well as never-depressed subjects when given the opportunity to earn money. This supports the hypothesis that monetary rewards are less effective for enhancing visual selective attention for rMDD subjects relative to never-depressed subjects. The main effect of Feedback Type reflects the original mixed model ANOVA finding that subjects as a whole improved search efficiency more in response to negative feedback than to positive feedback.

Although the Group x Feedback Type interaction was not significant (F(1, 85) = 1.785, p = 0.185, η_p^2 = 0.021), we conducted two follow-up independent samples *t*-tests to evaluate the *a priori* hypothesis that rMDD subjects would be less efficient than never-depressed subjects specifically in response to positive, but not negative, feedback. These follow-up *t*-tests indicated that rMDD subjects exhibited significantly less efficient visual search than never-depressed subjects in the positive ($t(42) = 2.565$, $p = 0.014$, Cohen's $d = 0.79$), but not negative ($t(46) = 0.844$, $p = 0.25$), feedback groups for Target Present trials, thus confirming this hypothesis (see Figure 6).

For Target Absent trials, the MANCOVA yielded a significant main effect of Feedback Type ($F(1, 85) = 14.053$, $p < 0.001$, $\eta_p^2 = 0.142$), but not Group ($F(1, 85) = 0.544$, $p = 0.463$, $\eta_p^2 = 0.006$), and the Group x Feedback Type interaction was similarly not significant. As with all other tests of individual differences and psychopathology, there was no relationship between depression history and Target Absent task performance. This is likely because there was much more variability in reaction time and overall search slope for these trials and/or because target identification was more goal-relevant than target absence. Thus, only Target Present findings are reported hereafter.

Tests of the Relationship between Reward Sensitivity and Search Efficiency

SPSRQ Sensitivity to Reward Regression. To evaluate whether or not the Sensitivity to Reward (SR) subscale of the Sensitivity to Reward Sensitivity to Punishment Questionnaire (SPSRQ) significantly enhanced visual search efficiency in the presence of monetary reward, we evaluated a multiple linear regression model with Target Present incentivized search slope serving as the dependent variable and the following serving as predictors: Sensitivity to Reward (SR; focal predictor), Feedback Type (moderator), Sensitivity to Reward (SR) x Feedback Type interaction term, and Target Present standard search task search slope (control variable). As described in the Methods section, all regressions were conducted using Hayes and Mathes' (2009) MODPROBE procedure. Sensitivity to Reward uniquely predicted Target Present search slope on the incentivized search task (*B* = -0.836, *S.E.* = 0.029, *p* = 0.004). As SR increases, Target Present incentivized search slope decreases, indicating that individuals who are more sensitive to reward are better are improving visual search efficiency in the presence of monetary reward.

The SR x Feedback Type interaction was not significant (*B* = -0.809, *S.E.* = 0.566, *t* = -1.429, *p* = 0.155); however, the Johnson-Neyman test revealed that the relationship between SR and incentivized search slope was significant for the positive feedback group (*B* = -1.26*, S.E.* = 0.438, *t* = -2.868, *p* = 0.005, *C.I.* = -2.124 - -0.391), but not the negative feedback group *B* = -0.449, *S.E.* = 0.365, *t* = -1.23, *p* = 0.221*, C.I.* = -1.170 – 0.273), supporting *a priori* hypotheses. The results were identical if Sensitivity to Punishment (SP) was added as a predictor; thus the effect of SR on incentivized search is cannot be accounted for by overlap with SP.

Sensitivity to Punishment Regression. The Sensitivity to Reward multiple regression was repeated with a Sensitivity to Punishment (SP) x Feedback Type interaction term instead of a Sensitivity to Reward x Feedback Type interaction and with Sensitivity to Punishment serving as the focal predictor instead of Sensitivity to Reward. In this model, neither Sensitivity to Punishment nor the SP x Feedback Type interaction were significant predictors of incentivized search slope (SP: *B* = 0.087, *S.E.* = 0.210, *t* = 0.415, *p* = 0.679; SP x Feedback Type: *B* = 0.520, *S.E*. = 0.415, *t* = 1.253, *p* = 0.212). The Johnson-Neyman test also supported the non-significant interaction term, indicating that SP had no relationship with search slope in either the presence of positive or negative feedback (both *p* > 0.136). Thus, there is no relationship between sensitivity to punishment and incentivized visual search, even in the presence of negative feedback.

BIS/BAS Scales Multiple Linear Regressions. To evaluate the relationship between different facets of behavioral approach, behavioral inhibition, feedback, and visual search efficiency, four multiple linear regressions were run using Carver and White's (1994) Behavioral Inhibition System/Behavioral Approach System (BIS/BAS) Scales. While controlling for BIS, Reward Responsiveness, Drive, and Target Present standard search slope, there was a significant interaction between Fun Seeking and Feedback Type (B = -1.320, *S.E.* = 0.590, t = -2.238, p = 0.027). The Johnson-Neyman test indicated that the relationship between Fun Seeking and Target Present incentivized search slope was only significant for the negative feedback group (B = 0.841, S.E. = 0.424, t = 1.982, p = 0.049, 95% C.I. = 0.002-1.679). Thus, in the presence of negative feedback, individuals who are higher on Fun Seeking are less efficient at the Incentivized Search Task than individuals who are lower on Fun Seeking, as evident by steeper search slopes, after controlling for the BIS and other facets of the BAS. There is no relationship between Fun Seeking and search efficiency in the presence of positive feedback.

The multiple regression model was repeated with a BIS x Feedback Type, BAS: Reward Responsiveness x Feedback Type, or BAS: Drive x Feedback Type interaction term in addition to the single BIS/BAS Scales, Feedback Type, and Target Present standard search slope as predictors. None of the single BIS/BAS Scales (BIS, BAS: Reward Responsiveness, BAS: Drive, or BAS: Fun Seeking) significantly predicted Target Present incentivized search slope in any model (all $p > 0.231$). In addition, none of the interactions were significant (BIS x Feedback Type: p = 0.311; Reward Responsiveness x Feedback Type: p = 0.502; Drive x Feedback Type: p = 0.726). Thus, no single BIS/BAS subscale is uniquely related to Target Present incentivized search slope, and the relationships between BIS, Reward Responsiveness, or Drive and Target Present incentivized search slope is not differentially affected by receiving positive or negative feedback.

Tests of the Relationship between Anhedonia, Depressive Symptoms, and Visual Search Efficiency

SHAPS Anhedonia Multiple Regression. To evaluate the relationship between Snaith-Hamilton Pleasure Scale (SHAPS) Anhedonia, Feedback Type, and incentivized search efficiency, a multiple linear regression with Target Present incentivized search slope serving as the dependent variable and the following variables serving as predictors: SHAPS Anhedonia (focal predictor), Feedback Type (moderator), SHAPS Anhedonia x Feedback interaction term, and Target Present standard search slope (control predictor). SHAPS Anhedonia did not significantly predict Target Present incentivized search slope alone (B = -0.055, *S.E.* = 0.116, t = -0.475, p = 0.636); however, there was a significant SHAPS Anhedonia x Feedback Type interaction (B = 0.463, *S.E.* = 0.230, t = 2.011, p = 0.046) indicating that the slope of the regression line is significantly different for the positive versus negative feedback groups. In the positive feedback group, incentivized search becomes less efficient as anhedonia increases whereas, in the negative feedback group, incentivized search becomes more efficient as anhedonia increases. However, the Johnson-Neyman tests indicated that the regression line of SHAPS Anhedonia predicting incentivized search slope was not significantly different from zero for either the positive (B = 0.190, *S.E.* = 0.160, t = 1.185, p = 0.238, *C.I.* = -0.127 – 0.507) or negative(B = -0.273, *S.E.* = 0.166, t = -1.652, p = 0.101, 95% *C.I.* = -0.601 – 0.054) feedback groups.

MASQ Anhedonic Depression Multiple Regression. To evaluate variance that is unique to anhedonic symptoms of depression versus general negative affective symptoms, a multiple linear regression was computed with Target Present incentivized search slope serving as the dependent variable and the following variables serving as predictors: MASQ Anhedonic Depression (focal predictor), Feedback Type (moderator), MASQ Anhedonic Depression x Feedback interaction term, and MASQ General Distress - Depression, MASQ General Distress

Anxiety, MASQ Anxious Arousal, and standard Target Present search slope serving as control predictors. As in the previous models, Hayes and Matthes' (2009) MODPROBE procedure was used to evaluate the regression model. There was a non-significant trend for a MASQ Anhedonic Depression x Feedback Type interaction (B = 0.149, SE = 0.085, t = 1.758, p = 0.081). However, the Johnson-Neyman test indicated that Anhedonic Depression was only associated with decreased search efficiency in the presence of positive feedback (B = 0.158, *S.E.* = 0.073, t = 2.175, p = 0.031, *C.I.* = 0.014 - 0.302; see Figure 10). There was no relationship between Anhedonic Depression and search efficiency in the negative feedback group (B = 0.009, *S.E.* = 0.074, t = 0.126, p = 0.900, *C.I.* = -0.137 - 0.156; see Figure 10). This confirms the *a priori* hypothesis that increased anhedonia would be specifically associated with decreased reward facilitation of visual search in the presence of positive feedback.

MASQ General Distress – Depression Multiple Regression. However, when the General Distress – Depression subscale of the MASQ replaced the Anhedonic Depression as the focal predictor and in the interaction term, and Anhedonic Depression became a control variable, the opposite pattern emerged. There was a non-significant trend for a General Distress – Depression x Feedback Type interaction (B = 0.239, *S.E.* = 0.121, t = 1.976, p = 0.050). However, the Johnson-Neyman Test of Significance indicated that General Distress – Depression is only associated with incentivized search efficiency in the presence of negative feedback. As General Distress – Depression increases, incentivized visual search becomes more efficient, but only in the presence of negative feedback (see Figure 11). Thus, while anhedonic symptoms of depression only uniquely influences incentivized search efficiency the presence of positive feedback, general negative affective symptoms of depression only uniquely impact search efficiency in the presence of negative feedback, indicating specificity of depressive symptoms on task performance.

Beck Depression Inventory, 2nd Edition (BDI-II) Multiple Regressions. To evaluate the effect of current symptoms of depression on visual search efficiency using the most common measure of depressive symptoms, a multiple regression model with Target Present incentivized search slope serving as the dependent variable and the following serving as predictors was used: BDI-II total score (focal predictor), Feedback Type (moderator), BDI-II x Feedback Type interaction term, and Target Present standard search slope (control predictor). In this model, BDI-II total score did not significantly predict Target Present incentivized search slope either alone (B = 0.071, S.E. = 0.063, t = 1.126, p = 0.262) or in combination with Feedback Type (*B* = 0.153, *S.E.* = 0.126, *t* = 1.215, *p* = 0.226). However, the Johnson-Neyman probing method indicated a trend toward a significant relationship between BDI-II total score and Target Present incentivized search slope in the positive (*p* = 0.065), but not negative (*p* = 0.981), feedback condition.

Given the hypothesis that anhedonic symptoms of depression would specifically be driving the relationship between depressive symptoms and incentivized search efficiency in the presence of positive affect, Beck Anxiety Inventory (BAI) total score was added to the model to account for overlap with negative affective symptoms. When BAI total was added as a predictor, there was a trend toward a significant relationship between BDI-II total score and Target Present incentivized search slope (*B* = 0.137, *S.E.* = 0.082, *t* = 1.671, *p* = 0.097), but the BDI-II x Feedback Type interaction term remained non-significant (*B* = 0.146, *S.E.* = 0.127, *t* = 1.153, *p* = 0.251). However, once anxiety symptoms were accounted for, the Johnson-Neyman test indicated that there was a significant relationship between BDI-II score and Target Present incentivized search slope in presence of positive feedback (*B* = 0.213, *S.E.* = 0.097, *t* = 2.224, *p* = 0.028, 95% C.I. = 0.024-0.402). Thus, depressive symptoms (as measured by the BDI-II) are marginally related to decreased reward facilitation of visual search in the presence of positive, but not negative, feedback once overlap with anxiety symptoms is partialled out. Given SPSRQ-20, SHAPS, and MASQ findings, this is likely driven by anhedonic symptoms.

Tests of the Relationship between Anxiety and Visual Search Efficiency

MASQ Anxiety Scales Multiple Regression Findings. To confirm that the interaction between the MASQ depression subscales and Feedback Type were specific to depressive symptoms and not anxiety, the multiple regression model was repeated with a General Distress – Anxiety x Feedback Type interaction term one model and an Anxious Arousal x Feedback Type interaction term in the other. As in the former models, there were no unique effects of any MASQ subscale (all $p > 0.145$ in all four models). In addition, neither General Distress – Anxiety nor Anxious Arousal yielded significant interactions with Feedback Type ($p = 0.256$ and $p = 0.720$, respectively); thus, the interactions between Feedback Type and the depression subscales of the MASQ were specific to depressive symptoms.

Beck Anxiety Inventory (BAI) Multiple Regression. In addition to evaluating symptoms of anxiety via the MASQ, the effect of anxiety as measured by the BAI was evaluated in a multiple regression model with Target Present incentivized search slope serving as the dependent variable and the following serving as predictors was used: BAI total score (focal predictor), Feedback Type (moderator), BAI x Feedback Type interaction term, and Target Present standard search slope (control predictor). In this model, BAI total score did not significantly predict Target Present incentivized search slope either alone ($B = -0.002$, $S.E. = 0.067$, $t = -0.015$, $p = 0.988$) or in combination with Feedback Type ($B = -0.013$, $S.E. = 0.133$, $t = -0.098$, $p = 0.922$).

Given research supporting the Tripartite Model of Depression and Anxiety (Brown, Chorpita, & Barlow, 1998; Clark & Watson, 1991; Watson, Clark, et al., 1995; Watson, Weber, et al., 1995), BDI-II total score was added to the model to control for overlap with depressive symptoms, including anhedonia, to see if anxiety could be uniquely related to visual search enhancement in the presence of negative feedback. In this model neither BAI total nor the BAI x Feedback Type interaction term was significant (BAI total score: B = -0.108, *S.E.* = 0.087, t = -1.238, p = 0.218; BAI x Feedback Type: B = -0.036, *S.E.* = 0.133, t = -0.274, p = 0.785). Thus, anxiety is unrelated to incentivized search efficiency regardless of depressive symptoms. This is consistent with null findings for SPSRQ-20 Sensitivity to Punishment and MASQ General Distress – Anxiety and Anxious Arousal.

Other Non-Significant Findings for Secondary Measures of Interest

Hypomanic Personality Scale Multiple Regressions. The HP Scale total score was unrelated to Target Present incentivized search slope by itself (B = -0.054, *S.E.* = 0.074, t = -0.733, p = 0.465) or in interaction with Feedback Type (B = -0.158, *S.E.* = 0.147, t = -1.077, p = 0.283). The Social Vitality, Mood Volatility, and Excitement subscales of the HP Scale were also unrelated to Target Present incentivized search slope either alone (all $p > 0.175$) or in interaction with Feedback Type (all $p > 0.217$). In addition, three multiple regressions were run to test the unique effect of each subscale alone and in interaction with Feedback Type following the same models used in the MASQ multiple regressions. For example, in the Social Vitality subscale model, Target Present incentivized search slope served as the dependent variable and the following served as predictors: Social Vitality (focal predictor), Feedback Type (moderator), Social Vitality x Feedback Type interaction term, and Mood Volatility, Excitement, and Target Present standard search slope as control predictors. No subscales significantly predicted Target Present incentivized search slope alone in any model as either a focal predictor or control variable (all $p > 0.162$). There were also no significant interaction between any subscale and Feedback Version (all $p > 0.150$). Thus, hypomanic personality is unrelated to incentivized visual search performance.

Toronto Alexithymia Scale (TAS-20) Multiple Regressions. The TAS-20 total score was unrelated to Target Present incentivized search slope by itself (*B* =0.036, *S.E.* = 0.054, $t = -0.665$, $p = 0.508$) or in interaction with Feedback Type (*B* = 0.014, *S.E.* = 0.106, $t = 0.128$, $p = 0.899$). The Difficulty Describing Feeling, Difficulty Identifying Feeling, and Externally-Oriented Thinking subscales of the TAS-20 were also unrelated to Target Present incentivized search slope either alone (all $p > 0.341$) or in interaction with Feedback Type (all $p > 0.419$). In addition, three multiple regressions were run to test the unique effect of each subscale alone and in interaction with Feedback Type following the same models used in the MASQ and HP Scale multiple regressions. None of the subscales uniquely predicted Target Present incentivized search slope either alone (all $p > 0.351$) or in interaction with Feedback Type (all $p > 0.382$). Thus, although alexithymia has been related to social anhedonia in previous research (Prince & Berenbaum, 1993), it was unrelated to incentivized search efficiency in this study.

Barratt Impulsivity Scale (BIS-11) Multiple Regressions. The BIS-11 total impulsivity score was unrelated to Target Present incentivized search slope by itself (*B* =0.058, *S.E.* = 0.057, $t = 1.014$, $p = 0.312$) or in interaction with Feedback Type (*B* = -0.034, *S.E.* = 0.114, $t = -0.299$, $p = 0.765$). The Attentional Impulsivity, Motor Impulsivity, and Non-Planning Impulsivity subscales of the BIS-11 were also unrelated to Target Present incentivized search slope either alone (all $p > 0.148$) or in interaction with Feedback Type (all $p > 0.487$). Finally, when three multiple regressions were run to test the unique effect of each subscale alone and in interaction with Feedback Type (same modeling used in the MASQ, HP Scale, and TAS-20 multiple regressions), there were no unique effects of any subscale alone (all $p > 0.181$) or in interaction with Feedback Type (all $p > 0.492$). Thus, impulsivity is unrelated to changes in visual search efficiency as a function of either monetary reward or positive versus negative feedback.

Zuckerman Sensation Seeking Scale Multiple Regressions. The sensation seeking total score was unrelated to Target Present incentivized search slope by itself (B = 0.058, $S.E.$ = 0.112, t = 0.522, p = 0.603) or in interaction with Feedback Type (B = -0.164, $S.E.$ = 0.222, t = -0.741, p = 0.460). In addition, the Thrill and Adventure Seeking, Experience Seeking, Disinhibition, and Boredom Susceptibility subscales were unrelated to Target Present incentivized search slope either alone (all $p > 0.145$) or in interaction with Feedback Type (all $p > 0.110$). Finally, when four multiple regressions were run to test the unique effect of each subscale alone and in interaction with Feedback Type (same modeling used in the MASQ, HP Scale, TAS-20, and BIS-11 multiple regressions), Disinhibition, Thrill and Adventure Seeking, and Boredom Susceptibility were not uniquely associated with Target Present incentivized search (all p > 0.266).

There was a non-significant trend for Experience Seeking to uniquely predict Target Present Search Slope in all four models (all $p < 0.090$). In the model-of-interest for Experience Seeking in which Experience Seeking was included as the focal predictor and there was an Experience Seeking x Feedback Type interaction term, Experience Seeking trended toward a significant relationship with Target Present incentivized search slope (B = 0.648, $S.E.$ = 0.380, t = 1.701, p = 0.090), and the Johnson-Neyman test indicated that this was driven by the negative feedback condition (B = 0.944, $S.E.$ = 0.484, t = 1.951, p = 0.053, 95% C.I. = -0.013-1.901; positive feedback: p = 0.538). However, the Experience Seeking x Feedback Type interaction was not significant (B = -0.618, $S.E.$ = 0.669, t = -0.923, p = 0.358). Thus, there is no relationship between sensation seeking, generally speaking, and improvement in search efficiency as a function of reward or feedback. There may be a slight association between Experience Seeking, specifically, and incentivized search performance whereby individuals who report more Experience Seeking fail to improve search efficiency as much as people who report less Experience Seeking in the presence of negative feedback. Although this association is non-significant (p = 0.053), it follows the same general trend as the relationship between BAS Fun Seeking (a similar construct) and Target Present incentivized search efficiency and thus may be relevant.

Discussion

The findings in this investigation contribute to both basic cognitive and affective science and psychopathology research domains. Overall, monetary rewards and feedback robustly improved visual search efficiency (see Figures 3 and 4). Plus, individuals with greater self-reported sensitivity to reward were more efficient on the incentivized search task than individuals who were less sensitive to reward, specifically in the context of positively-reinforcing feedback (see Figure 8). Conversely, individuals with remitted MDD were less influenced by monetary rewards than individuals who had never been depressed in the context of positive feedback (see Figure 6). Finally, there was a double dissociation between feedback type and anhedonic versus negative affective symptoms of depression, which further indicates that decrements in search efficiency in the positive feedback group were specific to symptoms of anhedonia while negative affective symptoms of depression enhanced search efficiency in the context of negative, but not positive, feedback (see Figures 10 and 11). Together, these data suggest that individuals with greater hedonic capacity are able to use reward more efficiently to enhance cognition than individuals with reduced hedonic capacity while individuals who report more negative affective symptoms of depression (e.g., sadness, worthlessness, hopelessness) are excessively motivated to avoid negative feedback.

Findings Relevant to Basic Cognitive and Affective Science

Replicating Reward and Visual Selective Attention Findings. Providing subjects with monetary incentives and feedback about task performance led to massive enhancements in visual search efficiency (see Figures 3 and 4). In fact, the significant Set Size x Target x Search Task three-way interaction explained 75.0% of the variance in reaction time on the task (see

Figures 3 and 4). This replicates findings from research using other tasks indicating that reward enhances visual selective attention (Anderson et al., 2011a, b; Anderson & Yantis, 2013; Della Libera & Chelazzi, 2006, 2009; Della Libera et al., 2011; Ross et al., 2011) and other cognitive processes (Kanske & Kotz, 2011; Krebs et al., 2010, 2011; Savine & Braver, 2010). It also replicates Kristjánsson and colleagues' (2010) and Kiss and colleagues' (2009) findings that reward can be used to enhance visual search, and it extends their research in two key ways: 1) by demonstrating that effort-based reward mechanisms can be used to enhance visual search, and 2) by showing that reward can enhance more complicated feature search in addition to simple pop-out search. However, in terms of basic science findings, perhaps the greatest extension to the reward-facilitation of attention literature that this study provides concerns the robustness of the reward effect, and the effect of task feedback and individual differences on task performance.

Incentivization "Pop-out" Effect. This study is the first to our knowledge to eliminate the differences in search efficiency between Target Absent and Target Present trials as a result of motivational manipulations as opposed to manipulations of basic stimulus properties (i.e., without using a traditional "pop-out" search task). While reward enhanced visual search efficiency for both Target Present and Target Absent trials overall (see Figure 3), the monetary incentives and feedback provided in the incentivized search task nearly eliminated the differences in search efficiency between Target Absent and Target Present trials (see Figure 4). The lack of significant differences between Target Present and Target Absent trials combined with the nearly flat search slopes across set sizes observed in the incentivized visual search task mimic the findings observed in so-called "pop-out" search tasks. This is the first time, to the best of our knowledge, that such an effect has been seen on a visual search task when search efficiency was modulated solely by top-down (i.e., participant effort or goal-orientation) rather than bottom-up factors (e.g., basic stimulus properties such as color). However, this is consistent with findings by Shomstein and Johnson (2013) that methods of attentional guidance thought to be relatively automatic (e.g., object-based orienting) can be completely discarded in favor of a reward-maximizing strategy.

This pop-out effect could be explained by three possible mechanisms: 1) a floor effect on motor reaction time that makes it impossible to find differences in attentional capture when it is measured via motor speed; 2) increased salience for the letter F that makes it more efficient to both locate Fs and discard Es; and/or 3) the priming of pop-out phenomenon. Because monetary incentives and feedback reward successful identification of Fs, Fs may become more salient in the incentivized search task relative to the standard search task. Previous research indicates that the less salient the perceptual distinction between target and distractors, the steeper the resulting RT x Set Size functions and vice versa (Treisman & Gormican, 1988; Wolfe et al., 1989). Enhanced performance resulting from an interactive process between top-down goal-direction and increased salience for the letter F relative to the letter E is consistent with Wolfe's Guided Search theory of visual search (Wolfe, 2007; Wolfe et al., 1989). It is also consistent with a recent study by Theeuwes and Belopolsky (2012) using eye-tracking in which they found that stimuli associated with higher monetary reward value were associated with more saccades than stimuli with lower monetary reward value, indicating that reward increases the salience of stimuli. Future research utilizing alternative measures of attentional capture and salience that do not rely strictly on reaction time (e.g., ERPs, eye-tracking) is necessary to evaluate hypotheses regarding RT floor-effects and stimulus salience on this particular task.

One last, but less likely, explanation for the pop-out-like effect observed in the incentivized search task is the priming of pop-out phenomenon. Priming of pop-out (Maljkovic & Nakayama, 1994) is an effect observed in visual search tasks whereby priming certain feature characteristics (e.g., a letter with two horizontal lines versus three horizontal lines) increases the speed of attentional deployment to subsequent targets having the same feature characteristics and relative position. While previous researchers have found that the priming of pop-out phenomenon is rather impervious to task demands or voluntary control (i.e., top-down influences; Kristjánsson & Nakayama, 2003; Maljkovic & Nakayama, 1994), Kristjánsson and colleagues (2010) found that priming of pop-out can be significantly enhanced for targets associated with higher reward. Thus, it is possible that, in the context of this incentivized search task, the association between task behavior (i.e., response time) and task outcome (i.e., monetary reward and/or feedback) may result in an associative learning effect that mimics a priming of pop-out effect, although this would be contrary to previous findings on voluntary control of priming of pop-out effects (Kristjánsson & Nakayama, 2003; Maljkovic & Nakayama, 1994).

The Effect of Feedback on Reward-Facilitated Visual Selective Attention. The Set Size x Search Task x Feedback Type interaction (p = 0.0004, η_p^2 = 0.061) indicates that subjects were more efficient on the incentivized search task when they were given negatively-reinforcing feedback (*M* = 9.231 ms/item) as opposed to positively-reinforcing feedback (*M* = 18.448 ms/item) across target types (Target Absent and Target Present trials collapsed). Importantly, there was no difference in search efficiency between feedback groups on the standard search task (Negative feedback: *M* = 61.248 ms/item; Positive feedback: *M* = 60.857 ms/item); thus, the observed group differences were specific to the experimental manipulation of feedback type (negative vs. positive) and not baseline group differences in attention or reaction time. This replicates an abundance of previous research indicating that people, on average, are more heavily influenced by negative than positive affective information (Ito, Larsen, Smith, & Cacioppo, 1998; for a review, see Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001).

Sensitivity to Reward x Feedback Interaction. More importantly, however, the negativity bias was qualified by interactions between feedback type and several individual differences variables related to reward sensitivity and depressed mood. Foremost, as SPSRQ-20 Sensitivity to Reward increased, incentivized visual search efficiency increased (see Figure 7), but only in the presence positively-reinforcing feedback (see Figure 8). On the other hand, task performance in the negative feedback group was unrelated to most individual differences variables including symptoms of anxiety, SPSRQ Sensitivity to Punishment, or behavioral inhibition (BIS) as one might expect. Thus, individual differences in reward sensitivity matter for pursuit of monetary incentives, but they are particularly relevant in the context of positive feedback.

Interestingly, we found no relationship between the Reward Responsiveness or Drive subscales of Carver and White's (1994) BIS/BAS scales and incentivized search performance. This is somewhat inconsistent with Hickey and colleagues' (2010) finding that greater BAS: Drive predicted greater attentional capture by stimulus features related to reward. However, this investigation and their study tapped into different aspects of reward-facilitated visual selective attention. They evaluated the impact of reward-related stimulus properties on the efficiency of target identification while reward was determined by effortful target identification in this study. Although, the finding that Drive was related to attentional capture by reward (Hickey et al., 2010) but not the effort-based incentivized visual search task employed in this investigation is still somewhat contrary to what one would predict.

Findings Contributing to the Advancement of Psychopathology Research

Lifetime MDD x Feedback Interaction. Individuals with remitted Major Depressive Disorder were significantly less efficient than never-depressed individuals on the incentivized visual search task, particularly in the context of positive (p = 0.014), but not negative, feedback, even after controlling for current depressive symptoms (BDI-II total) and baseline visual search efficiency (see Figure 6). Because current symptoms of depression and search slopes from the standard search task were controlled for, the difference between rMDD and never-depressed subjects cannot be attributed to current residual depressive symptoms or differences between groups in general attentional capacity. Likewise, there was no difference between the rMDD and never-depressed groups in their rates of many other categories of psychopathology including current substance use disorders, eating disorders, or many anxiety disorders (see Table 3). Hence, these group differences are unlikely to be better explained by increased rates of other psychopathology or psychopathology as a whole in the rMDD group. Consequently, group differences can reasonably be attributed to the experience of, and potentially predisposition for, major depression, and one can conclude that individuals with a history of MDD are specifically less motivated than never-depressed individuals to improve task performance in the presence of positive reinforcement.

These findings add to a body of research indicating that both currently and remitted depressed individuals show deficits across the multiple areas of reward processing including “liking” (hedonic impact; remitted MDD - McCabe et al., 2009; current melancholic MDD – Shankman et al., 2011), “wanting” (incentive salience or motivation to seek out rewards; current MDD - Treadway et al., 2012), and “learning” (predictive associations and cognitions; current MDD – Pizzagalli et al., 2009; remitted MDD – Pechtel et al., 2013; c.f., Chase et al., 2010). By showing that motivational anhedonia persists in remitted depressed individuals in context of positive, but not negative, reinforcement, this study builds on Treadway and colleagues’ (2012) findings that current MDD subjects are less willing to expend effort for rewards than controls. Moreover, these findings demonstrate how decreased incentive salience negatively affects cognition and provides a model for positive emotion-cognition interactions that persist in remitted MDD.

The MDD Group x Feedback interaction indicating that rMDD subjects show less efficient reward-facilitation of attention in the presence of positive feedback also supports a large body of research indicating that low positive affect and reward learning deficits are trait-like features of MDD (Clark et al., 1994; Dichter et al., 2012; Gupta & Kar, 2012; McCabe et al., 2009; Pechtel et al., 2013) and supplements Pechtel and colleagues' (2013) findings that rMDD is characterized by reduced reward learning as a function of monetary and social reinforcement relative to individuals who have never been depressed. These results extend Pechtel and colleagues' (2013) findings to effort-based rather than associative reward processing mechanisms, and by comparing less "pure" control and rMDD groups. Likewise, the finding that the rMDD group did not differ from the never-depressed group in response to negative feedback is similar to findings by Murphy et al. (2003) indicating that currently depressed individuals did not differ from controls in their ability to use negative feedback to facilitate working memory task performance.

Unlike our study or several other investigations (e.g., Pizzagalli et al., 2009; Pechtel et al., 2013; Treadway et al., 2012), Chase and colleagues (2010) did not find any differences in reward learning between current MDD and control subjects in response to positive or negative feedback on a probabilistic selection task different, but similar to, that used by Pizzagalli et al. (2009) and Pechtel et al. (2013). While their negative feedback findings are consistent with Murphy et al. (2003) and our findings, the positive feedback findings are at odds with other literature. However, 91.3% of the MDD group in Chase and colleagues' (2010) study were taking psychotropic medications (mainly SSRIs and SNRIs) whereas none of the MDD participants in Pizzagalli et al. (2009), none of the rMDD participants in Pechtel et al. (2013), and only 27.7% of the rMDD group in this study were taking such medications; thus, an intriguing possibility is that antidepressant treatment could normalize positive reinforcement learning. This merits future research to determine if depressed individuals exhibiting reward learning deficits benefit more from certain pharmacological interventions than depressed individuals who do not exhibit such deficits.

Finally, the rMDD group in this investigation did not significantly differ from the never-depressed group on two out of our three self-report measures of reward sensitivity or anhedonia (SPSRQ Sensitivity to Reward or SHAPS anhedonia; see Table 2) that were related to task performance; thus, self-report and task-based measures of anhedonia are somewhat at odds in this study. However, as noted in a recent review by Treadway and Zald (2013), the *DSM* and many self-report measures of anhedonia tend to lump the motivational (i.e., “wanting”) and hedonic (i.e., “liking”) aspects of anhedonia together despite a large body of experimental research indicating that they are distinct (e.g., Berridge & Robinson, 1998; 2003; Berridge et al., 2009; Salamone et al., 2007). People in general tend to be very poor at accurately predicting how much they will enjoy an anticipated reward (Wilson & Gilbert, 2005), and depressed individuals are particularly pessimistic when it comes to positive mood prediction (MacLeod, & Salaminiou, 2001; Wenze, Gunthert, & German, 2012; for a review, see Miloyan, Pachana, & Suddendorf, 2014). Consequently, behavioral measures of the motivational and hedonic aspects of anhedonia may be useful as additional indicators of treatment progress or predictors of treatment outcome, but future research is necessary to confirm this.

Double Dissociation between Feedback Valence and Depressive Symptoms. In addition to the categorical group findings regarding remitted depression, the regressions evaluating current symptoms of anhedonia versus negative affective symptoms of depression (i.e., sadness, worthlessness) demonstrated that positive and negative feedback differentially impact motivation and cognition as a function of type of depressive symptoms. MASQ Anhedonic Depression was specifically associated with poorer performance on the incentivized search task in the presence of positive, but not negative, feedback (see Figure 10) while MASQ General Distress – Depression (negative affective symptoms of depression) was uniquely associated with enhanced performance in the presence of negative, but not positive, feedback (see Figure 11). In both of these models, MASQ General Distress – Anxiety and Anxious Arousal were controlled for. Thus, these interactions cannot be accounted for by overlap with anxiety symptoms.

Although there is an abundance of work on reward and punishment processing in depression (for a review, see Eshel & Roiser, 2010), this is the first behavioral investigation, to our knowledge, to dissociate the effect of positive and negative affective symptoms of depression on effort-based task outcome differentially based on the valence of performance feedback received. These results are highly consistent with Treadway and colleagues' (2009) finding that increased SHAPS Anhedonia is associated with less motivation to pursue rewards on an effort-based reward task, and they also extend those of Pizzagalli et al. (2009) and Chase et al. (2010) who found that increased anhedonia was specifically associated with decreased reward learning on two different probabilistic reward learning tasks. Finally, by separating the effects of positive and negative feedback, we were able to demonstrate that negative affective symptoms of depression may enhance task performance in the context of negative reinforcement. This suggests that individuals with more negative affective depressive symptoms (e.g., sadness, worthlessness, hopelessness) are excessively motivated to avoid negative feedback. This fits a large body of research on negativity biases in depression (Gotlib, Krasnoperova, Yue, & Jorrmann, 2004; Leppanen, 2006; Naudin et al., 2014; Siegle, Steinhauer, Thase, Stenger, & Carter, 2002; Wenze et al., 2012).

However, an alternative interpretation of this finding is that reward-facilitation of attention can be spared if depressed individuals are given negative reinforcement when they fail to earn rewards. To the best of our knowledge, no one has demonstrated an interaction between negative affect and motivated behavior in depression. However, these findings are consistent with the *Joint Subsystems Hypothesis*, which explains instances in which emotional states that are generally thought of as behavioral inhibition system (BIS)-mediated (e.g., anxiety, depression) lead to motivated behavior (Corr, 2002; Gray & McNaughton, 2000). One possible mechanism for this is activation of mesolimbic dopamine circuitry, particularly the nucleus accumbens, in the context of aversive motivation. Although there is a large body of evidence indicating that Individuals with current or remitted MDD exhibit decreased activation of this circuitry in the context of reward (McCabe et al., 2009; Smoski et al., 2009; for reviews, see Nestler & Carlezon, 2006; Nestler et al., 2002; Russo & Nestler, 2013), experimental evidence indicates that increased dopamine in the nucleus accumbens (NAcc) enhances both appetitive and aversive motivation (see Salamone et al., 2007 for a review). Moreover, NAcc activation is enhanced in response to aversive stimuli in individuals with psychopathology related to depression such as PTSD (Liberzon et al., 1999). Thus, it is possible that reward facilitation of attention is spared in the negative feedback group because of greater recruitment of mesolimbic dopamine circuitry in the context of aversive motivation while there are deficits in reward facilitation of attention in the positive feedback group because of hypoactivation of this circuitry in the context of appetitive motivation in depressed subjects. Further research on the relationship between attentional control mechanisms and neurocircuitry underlying appetitive and aversive motivation in depression is necessary to confirm this.

In addition to supporting previous depression research, these data build on the Treadway et al. (2009), Pizzagalli et al. (2009), and Chase et al., (2010) findings in several major ways. First, these data are the first to show that anhedonic individuals are specifically impaired on an effort-based task in the context of positive reinforcement while reward pursuit may be spared or enhanced if anhedonic individuals are provided with negative reinforcement. Treadway and colleagues (2009) tried to similarly evaluate the effect of reinforcement on task behavior on their EEfRT task by evaluating the effect of anhedonia on trial-by-trial effort based on the immediately preceding trial type ("win" versus "no-win"). Similar to our findings, they found that preceding-trial feedback influenced subsequent-trial effort in high, but not low, anhedonic subjects; however, their study design did not allow them to make strong conclusions about the specific responses to win or no-win feedback because both trial types were presented across time. Splitting subjects into two different feedback groups allowed us to make stronger conclusions about how positively versus negatively reinforcing feedback affects task behavior based on anhedonia. Moreover, partialing out General Distress – Depression allowed us to make stronger conclusions about the specific effect of anhedonic versus negative affective symptoms of depression on search efficiency.

The MASQ findings in this investigation are particularly interesting in light of Pizzagalli and colleagues' (2009) findings because both their investigation and our investigation demonstrate a unique relationship MASQ Anhedonic Depression and deficient reward processing, but they do so via two different types of reward processing. These findings show that increased MASQ Anhedonic Depression is associated with diminished motivated task performance (i.e., decreased "wanting") while Pizzagalli and colleagues (2009) found the same effect for an associative reward learning task (i.e., decreased "learning"). Furthermore, this study obtained similar results using a less diagnostically "pure" sample (e.g., allowance of psychotropic medication and any or no psychopathology) and a greater range of MASQ scores.

Because Pizzagalli et al. (2009) only included positive-reinforcing feedback and did not report on the effect of MASQ General Distress - Depression, it is unknown if the MASQ Anhedonic Depression or General Distress – Depression findings in our sample would differ from theirs. Using a different probabilistic reward-learning task, Chase et al. (2010) evaluated the effect of positive versus negative feedback on task performance. Similar to our findings and Pizzagalli and colleagues' (2009) findings, Chase et al. (2010) found that SHAPS anhedonia was related to decreased response to positive feedback across control and currently depressed individuals. However, they found the opposite pattern of response to negative feedback as our study. Chase and colleagues found that greater SHAPS anhedonia was related to blunted responding to negative feedback while we found no relationship between MASQ Anhedonic Depression and task performance in the negative feedback group, and we found the opposite pattern of response in the negative feedback group in relation to the SHAPS (greater SHAPS anhedonia, more efficient search in the context of negative feedback). This may be due to differences between the effort-based cognitive task employed in this study and the probabilistic learning task employed in their study, or because of the addition of a monetary reward in this study. In fact, Chase and colleagues (2010, p. 439) specifically note that, "experimental details of the paradigms used are likely to be significant" with regards to negativity biases found in depression. These discrepancies may also be due to participant characteristics, particularly the number of subjects taking psychotropic medication (45.6% of their total sample vs. 18.0% of this sample). As previously mentioned, it is possible that psychotropic medication use affects reward learning, and this may extend to negative as well as positive reinforcement. Future investigations should evaluate the role of antidepressants in reward learning versus motivational tasks as well as how they affect responses to reinforcement.

Implications for RDoC

The double dissociation between feedback and depressive symptoms on this task is highly relevant for the NIMH's goals of addressing limitations in the current psychiatric diagnostic system through their Research Domain Criteria (RDoC) initiative. The RDoC initiative was created to generate research to create new psychiatric nosologies based upon neuroscience and behavioral science rather than descriptive phenomenology as in the current *DSM* (American Psychiatric Association, 2013) system (Cuthbert, 2014; Cuthbert & Insel, 2013; Insel et al., 2010). The NIMH RDoC workgroup has created a matrix to organize neurobiological dimensions thought to underlie current categories of psychopathology (e.g., negative valence systems, positive valence systems, cognitive systems, etc.) with the units of analysis supporting those dimenions (e.g., genes, circuits, behavior, paradigms, etc.). The incentivized search task involved in this study supports the RDoC goals by validating a behavioral paradigm for assessing RDoC cognitive systems (e.g., attention and attentional control) and positive and negative valence systems (e.g., appetitive and aversive motivation) as they relate to multiple dimensions self-reported depressive symptomology (e.g., anhedonic versus negative affective symptoms).

However, the remitted depression findings highlight several important caveats that needs to be considered before abandoning all categorical approaches to psychopathology. First, individuals who were not currently depressed but had a history of MDD still exhibited decreased reward-facilitation of attention relative to individuals who have never been depressed, even after controlling for current depressive symptoms and even though the groups did not differ in diagnosis of current psychopathology across multiple diagnostic categories. Thus, the presence versus absence of categorical depression history still provided useful information regarding emotion-cognition interactions that were not evident in dimensional self-report or behavioral data alone. This is particularly relevant given that the remitted and never-depressed groups did not differ on many self-report measures of reward sensitivity and anhedonia while they differed on nearly all measures of negative affect but exhibited no differences in response to negative feedback on this task. Although both dimensional self-report and behavioral task data are highly important to many areas of psychopathology research, these data suggest that it is perhaps still important to consider categorical diagnostic history.

Implications for Depression Treatment

Given that anhedonia and reduced reward learning are associated with persistence of MDD and poorer treatment outcome (Spijker et al., 2001; Vrieze et al., 2014), it is highly important that we identify components of reward processing that are disrupted on an individual patient basis and that we identify treatments, behavioral and pharmacological, that can ameliorate these dysfunctions. Perhaps in the future, doctors could conduct neuroimaging evaluations of neural response to reward to help decided which treatment could best treat their patients' symptoms, but for now this would be prohibitively expensive. However, computerized behavioral tests such as the incentivized search task in this investigation could provide cheaper and more efficient alternatives as lab tests to identify which treatment(s) a patient is most likely to benefit from. In the service of RDoC goals for treatment optimization, future research should be done to evaluate whether the incentivized search task is a useful predictor of treatment outcome and, more specifically, if it can be used to identify which treatments would be most beneficial for patients suffering from anhedonic symptoms.

Behavioral Activation. Behavioral Activation (BA) is an empirically-supported treatment for depression that shows theoretical promise for addressing motivational deficits because it was designed to help individuals increase engagement with positively reinforcing behaviors and activities (Jacobson, Martell, & Dimidjian, 2001; Martell, Addis, & Jacobson, 2001; for reviews, see Dimidjian, Barrera, Martell, Muñoz, & Lewinsohn, 2011; Kanter et al., 2010). It is highly effective for diminishing depressive symptoms in patients with acute MDD (Dichter et al., 2009;

Dimidjian et al., 2006; for a meta-analysis, see Mazzucchelli, Kane, & Rees, 2009), for producing lasting symptom improvement after depression treatment has ended (Dobson et al., 2008), and for increasing well-being in non-clinical populations (Mazzucchelli, Kane, & Rees, 2010).

Despite the large body of research on BA treatment for depression, only one small study has been published its effects on anhedonic symptoms specifically, or on whether any behavioral, neural, or psychophysiological indicators of reward processing are predictive of treatment outcome. Dichter and colleagues (2009) are, to the best of our knowledge the only group that has provided data on self-reported hedonic capacity before and after BA treatment in MDD patients. While the increase in self-reported hedonic capacity and behavioral approach from pre- to post-treatment was not significant in this investigation, the treatment group was very small (n = 12), so this study was likely too underpowered to detect such effects. However, they did find that BA treatment significantly increased activity in brain reward regions during reward selection, anticipation, and feedback. Future investigations are needed to see if pre-treatment measures of reward processing are predictive of who does well in BA and whether BA treatment can improve dysfunctional areas of reward processing. Given that the incentivized search task in this investigation specifically addresses goal-seeking and response to reinforcement, it seems that it would be a good candidate task for evaluating who is likely or not likely to benefit from BA.

Novel Neurocognitive Interventions. The findings in this investigation could also be used to inform the development of novel neurocognitive interventions for depression that target goal-seeking and response to positive reinforcement as a means of enhancing coupling between positive emotionality and cognition. Recently Siegle and colleagues (2014) found that a neurocognitive intervention targeting the cognitive control deficits underlying rumination successfully decreased rumination and intensive outpatient service usage in severely depressed patients. In addition, pre-intervention physiological indicators of task engagement predicted treatment response. Such research provides an impetus to develop interventions for deficits underlying other features of depression such as motivational anhedonia as observed in this investigation.

Limitations

Although the findings in this investigation are promising, there are a number of limitations to consider. First, the participants in this investigations were disproportionately female and in the young adult age range. There is some evidence for gender differences in effort-based reward seeking (e.g., Treadway et al., 2009), but data from more male participants will need to be obtained before strong conclusions could be drawn about the effect of gender in these data. Perhaps more importantly, the individuals in both the rMDD group and total sample in this investigation had an early age-of-onset (rMDD: M = 15.60 years, Range = 10-25; total sample: M = 14.83, Range = 7-25) and recurrent course of MDD. These individuals may be at risk for a more severe course of MDD than samples that include individuals with a later age-of-onset and less recurrence. Treadway and colleagues (2012) found that the longer the duration of the current major depressive episode the less effort currently depressed subjects were likely to exert to earn monetary rewards. Thus, it is possible that recurrence or duration of previous depressive episodes may affect incentivized search efficiency, but it was not possible to evaluate this in the context of this study. Data on duration of past depressive episodes was not obtained, and many participants reported that they have had so many past depressive episodes that they could not count how many they have had.

Additionally, because no state mood measures were included before or after the visual search tasks, the effect the incentivized search task had on the subjects' mood is unknown. Indeed, the data suggest that positive feedback is not an effective method of motivating anhedonic individuals or individuals with a history of MDD to work harder to obtain rewards (see Figures 6, 8, 9, and 10). On the contrary, these data suggest that providing negative feedback may motivate these individuals to seek rewards to the same degree as individuals with greater hedonic capacity or without a history of mood disorder (see Figures 9 and 11). It is important that future investigations evaluate whether anhedonic individuals experience greater positive affect after completing the task even though they were less efficient at obtaining monetary rewards than individuals with greater hedonic capacity. On the contrary, it is important to know whether negative feedback makes individuals feel more depressed after the task, even though it helped them win more money, or if they felt just as depressed prior to starting the task. If depressed and/or anhedonic individuals feel less depressed or anhedonic after winning money (hence, after being rewarded), then it is important to know what effect positive versus negative reinforcing feedback has on the magnitude of that change in feelings. These basic science findings have direct implications for maximizing the effectiveness of psychotherapy. If greater contact with rewarding events reduces depression in individuals with MDD, then these data would suggest that perhaps therapists should not just provide their client with positive reinforcement in sessions. Future research is needed to determine if this is different for more anhedonic individuals.

Conclusion

In sum, providing monetary incentives and feedback greatly enhances visual search efficiency, but the amount that search is enhanced depends on the emotional valence of feedback received and individual differences related to hedonic capacity and depression history. Greater sensitivity to reward was associated with enhanced search efficiency in the presence of positive feedback, but it was unrelated to search efficiency in the presence of negative feedback. Remitted depression, which has been previously associated with trait-like low positive affect and decreased reward learning, was associated with less efficient incentivized search in the positive, but not negative, feedback conditions. Finally, there was a double dissociation between current depressive symptom valence (positive versus negative) and feedback type whereby increased negative affective symptoms of depression were associated with enhanced incentivized search in the presence of negative, but not positive, feedback while anhedonic symptoms were associated with decreased incentivized search efficiency in the presence of positive, but not negative, feedback. As a whole, the incentivized search results provide a cohesive account of the relationship between emotion and attention as it relates to both basic cognitive and affective science and the studies of individual differences and psychopathology. Future investigations should explore whether behavioral task findings such as these predict treatment response for individuals with psychopathology where anhedonia is a primary feature.

Footnote

Footnote 1. Clinical cut-off scores have only been made using the original binary scoring method proposed by Snaith et al., 1995; however, subsequent research has shown that a dimensional scoring system shows better psychometric properties and more dispersion of scores (Franken et al., 2007). Thus, clinical description of scores for demographics purposes are displayed using the original score system for descriptive purposes only. All further scoring and statistical tests use the dimensional scoring method proposed by Franken and colleagues (2007).

Table 1: Subject characteristics by group for all subjects who participated. Subjects may be taking more than one class of psychotropic medication. RT = reaction time, M = mean, S.D. = Standard Deviation; †$p < 0.10$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

	Whole Sample	**Never Depressed**	**Remitted Depressed**
Sample Size (N)	161	55	47
Valid RT Data (%)	148 (91.9%)	47 (85.5%)†	45 (95.7%)†
Gender (%)			
Female	113 (69.8%)	23 (41.8%)*	10 (21.3%)*
Male	47 (29.0%)	31 (56.4%)*	37 (78.7%)*
Transgender	1 (0.6%)	1 (1.8%)	0 (0%)
Race (%)			
Caucasian/White	112 (69.1%)	36 (65.5%)	36 (76.6%)
Asian/Pacific Islander	10 (6.2%)	5 (9.1%)	2 (4.3%)
African American/Black	22 (13.6%)	9 (16.4%)	4 (8.5%)
Latino/Hispanic	11 (6.8%)	2 (3.6%)	5 (10.6%)
Biracial/Multiracial	4 (2.5%)	2 (3.6%)	0 (0%)
Other	3(1.8%)	0 (0%)	0 (0%)
Native Language (%)			
English	146 (90.6%)	47 (85.5%)	44 (93.6%)
Chinese/Mandarin	3 (1.8%)	1 (1.8%)	0 (0%)
Hmong	4 (2.5%)	2 (3.6%)	1 (2.1%)
Spanish	4 (2.5%)	1 (1.8%)	2 (4.3%)
Other	4 (2.5%)	4 (7.2%)	0 (0%)
Age (S.D.)	22.08 (6.21)	22.33 (6.72)	22.09 (4.79)
Range	18-55	18-53	18-37
Taking Any Psych Meds (%)	29 (18.0%)	3 (5.6%)**	13 (27.7%)**
Any SSRI or SNRI	17	2	10 (21.3%)
Bupropion (Wellbutrin)	3	0	3 (6.4%)
Nortriptyline	1	0	1 (2.1%)
Any benzodiazepine	4	0	3 (6.4%)
Any stimulant	6	1	3 (6.4%)
Any anticonvulsant	3	0	0 (0%)
Lithium carbonate	2	0	1 (2.1%)
Any atypical antipsychotic	3	0	0 (0%)
Any other hypnotic (e.g., zolpidem)	4	0	2 (4.3%)
Methadone	1	0	0 (0%)
Unknown medication for depression	2	0	0 (0%)

Table 2. Self-report questionnaire data means, standard deviations (S.D.), and ranges. Differences between Never-Depressed and rMDD subjects † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

	Whole Sample	Control	Remitted MDD
SPSRQ Sensitivity to Reward (S.D.)	4.92 (2.3)	5.28 (2.4)	4.76 (2.2)
SPSRQ Sensitivity to Punishment (S.D.)	4.69 (3.0)	3.96 (2.8)*	5.39 (2.9)*
Snaith-Hamilton Pleasure Scale (S.D.)	22.48 (5.5)	21.70 (4.8)	22.89 (5.7)
BDI-II (S.D.)	12.06 (10.0)	6.74 (5.4)***	12.72 (7.4)***
BAI (S.D.)	10.35 (9.4)	5.42 (5.8)***	11.53 (7.7)***
MASQ Subscales (S.D.)			
General Distress Anxiety	19.09 (6.6)	15.70 (4.9)***	20.49 (6.3)***
Anxious Arousal	25.28 (9.6)	21.85 (5.84)*	24.98 (8.27)*
General Distress Depression	25.18 (10.8)	19.57 (6.3)***	26.30 (9.28)***
Anhedonic Depression	58.98 (15.2)	52.09 (13.4)***	62.43 (14.0)***
BIS/BAS Scales (S.D.)			
BIS	20.91 (4.1)	19.61 (4.0)**	22.04 (3.9)**
BAS Reward Responsiveness	17.60 (2.0)	17.57 (2.18)	17.45 (2.03)
BAS Drive	11.45 (2.4)	11.85 (2.47)*	10.81 (2.37)*
BAS Fun Seeking	12.47 (2.2)	12.35 (2.37)	12.28 (2.14)
Hypomanic Personality Scale (S.D.)			
Hypomanic Personality Total	20.00 (8.5)	19.91 (8.0)	19.09 (10.2)
Social Vitality	8.60 (4.5)	9.33 (4.52)†	7.68 (4.54)†
Mood Volatility	7.86 (3.3)	7.00 (2.96)†	8.15 (3.73)†
Excitement	3.54 (2.8)	3.57 (2.68)	3.26 (3.33)
Barratt Impulsivity Scale (BIS-11) (S.D.)			
Total Impulsivity	63.37 (10.8)	58.49 (8.9)**	64.77 (10.2)**
Attentional Impulsivity	17.34 (4.5)	15.15 (4.5)***	18.02 (3.6)***
Motor Impulsivity	21.47 (4.2)	20.34 (3.3)	21.40 (4.0)
Non-Planning Impulsivity	24.57 (5.0)	23.00 (4.4)*	25.34 (5.1)*
Zuckerman Sensation Seeking Scale (S.D.)			
Total Sensation Seeking	19.41 (5.9)	19.37 (6.7)	19.15 (5.6)
Thrill and Adventure Seeking	6.23 (2.9)	6.50 (2.6)	5.91 (3.1)
Experience Seeking	5.52 (2.0)	5.28 (2.1)	5.64 (2.0)
Disinhibition	4.90 (2.3)	4.94 (2.6)	4.74 (2.0)
Boredom Susceptibility	2.75 (1.8)	2.65 (1.9)	2.85 (1.7)
Toronto Alexithymia Scale (TAS-20) (S.D.)			
Total Alexithymia	47.36 (12.0)	43.09 (11.0)***	50.13 (9.1)***
Difficulty Describing Feelings	13.25 (4.8)	11.83 (4.5)*	14.06 (4.0)*

Difficulty Identifying Feelings	15.27 (6.0)	12.91 (5.3)***	17.38 (5.6)***
Externally Oriented Thinking	18.85 (4.6)	18.35 (4.7)	18.68 (4.0)

Table 3: MINI results. Categories are not exclusive. All psychopathology is current unless otherwise specified. Differences between Never-Depressed and rMDD subjects † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

	Whole Sample	**Control**	**Remitted MDD**
Major Depressive Disorder			
Never Depressed	55 (50.0%)	55 (100%)	0 (0%)
Remitted MDD	47 (42.7%)	0 (0%)	47 (100%)
Current MDD	8 (7.3%)	0 (0%)	0 (0%)
Bipolar Disorders (Lifetime)			
Bipolar 1 Disorder	3 (2.4%)	0 (0%)	0 (0%)
Bipolar 2 Disorder	3 (2.4%)	0 (0%)	0 (0%)
Bipolar NOS	4 (3.2%)	0 (0%)	0 (0%)
Other Specified Mood Disorders			
Other Specified Depressive Disorder	3 (2.4%)	0 (0%)	0 (0%)
Recurrent Subthreshold depressive episodes	1 (0.8%)	0 (0%)	0 (0%)
Current Subthreshold depression	2 (1.6%)	0 (0%)	0 (0%)
Mood Disorder NOS	2 (1.6%)	0 (0%)	0 (0%)
Unclear if unipolar or bipolar depressive disorder	2 (1.6%)	0 (0%)	0 (0%)
Anxiety Disorders			
Any Current DSM-5 Anxiety Disorder	36 (28.6%)	8 (14.5%)†	14 (29.8%)†
Past Panic Disorder	14 (11.1%)	3 (5.5%)*	9 (19.1%)*
Current Panic Disorder	5 (4.0%)	0 (0%)*	3 (6.4%)*
Agoraphobia	13 (10.3%)	1 (1.8%)†	5 (10.6%)†
Social Phobia	10 (7.9%)	3 (5.5%)	1 (2.1%)
Generalized Anxiety Disorder (GAD)	23 (18.3%)	4 (7.3%)†	9 (19.1%)†
Posttraumatic Stress Disorder (PTSD)	13 (10.3%)	2 (3.6%)	4 (8.5%)
Obsessive-Compulsive Disorder (OCD)	4 (3.2%)	2 (3.6%)	2 (4.3%)
Substance Use Disorders			
Any Current Substance Use Disorder	20 (15.9%)	6 (10.9%)	6 (12.8%)
Alcohol Dependence	6 (4.8%)	1 (1.8%)	1 (2.1%)
Alcohol Abuse	10 (7.9%)	4 (7.3%)	3 (6.4%)
Substance Dependence	3 (2.4%)	0 (0%)	0 (0%)
Substance Abuse	9 (5.6%)	4 (7.3%)	3 (6.4%)
Eating Disorders			
Any Current Eating Disorder	5 (4.0%)	1 (1.8%)	3 (6.4%)
Bulimia Nervosa	1 (0.8%)	0 (0%)	0 (0%)
Eating Disorder NOS – Subthreshold Anorexia Nervosa	3 (2.4%)	1 (1.8%)	2 (4.3%)
ED-NOS – Subthreshold Bulimia Nervosa	1 (0.8%)	0 (0%)	1 (2.1%)

Psychosis			
Schizoaffective Disorder, Bipolar Type	1 (0.8%)	0 (0%)	0 (0%)
Current MDD w/ past Mood-Congruent Hallucinations	1 (0.8%)	0 (0%)	0 (0%)

Figure 1. Example of a standard visual search task trial for a Set Size of 8

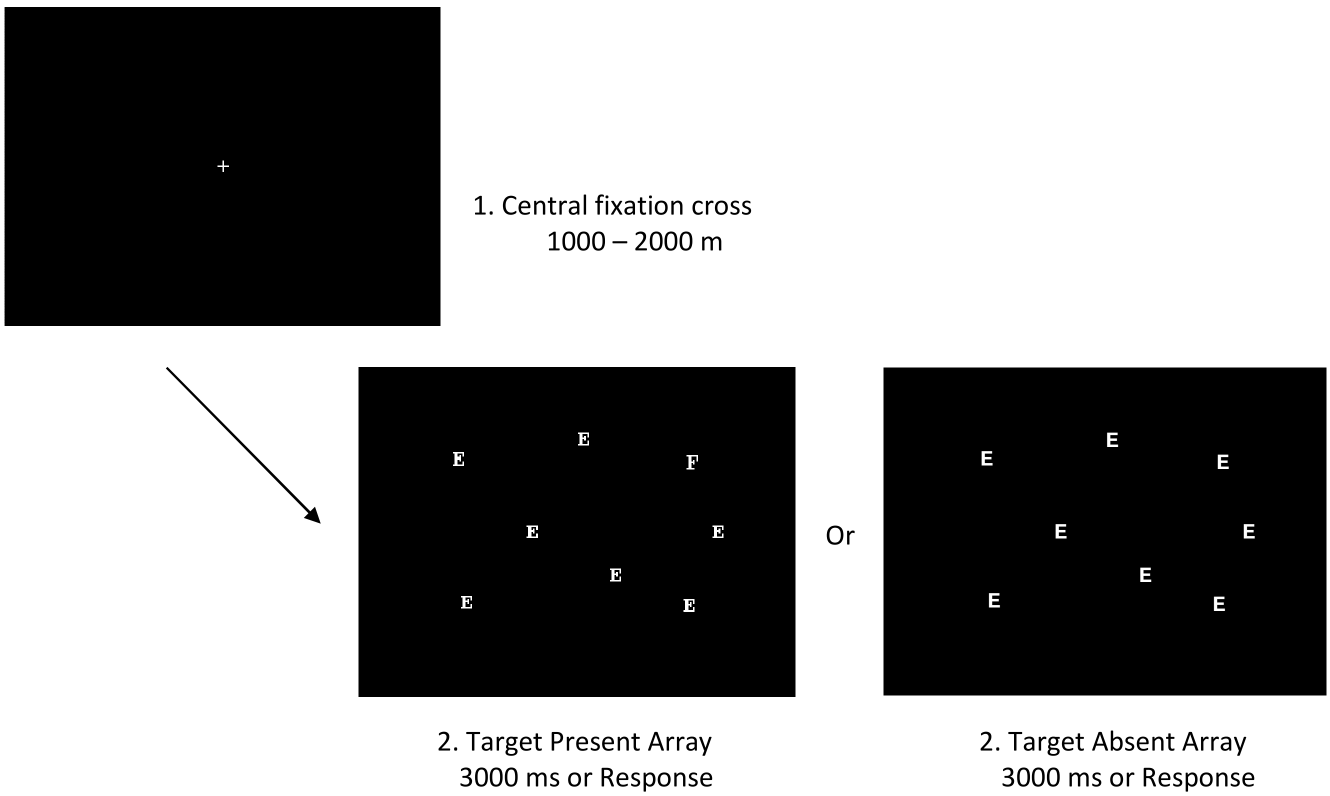


Figure 2. Example of a monetary reward visual search task trial. In the Positive Feedback version of the task, subjects will receive "Correct and Fast" feedback if they respond correctly and at least one standard deviation faster than they did on average in the Standard version of the task. They will not receive any feedback if any other response occurs. In the Negative Feedback version, subjects will receive "Incorrect," "Too Slow," or "Incorrect and Too Slow" Feedback if they do not respond correctly and one standard deviation faster than they did in the Standard version of the task. They will not receive any feedback if they respond correctly and fast enough.

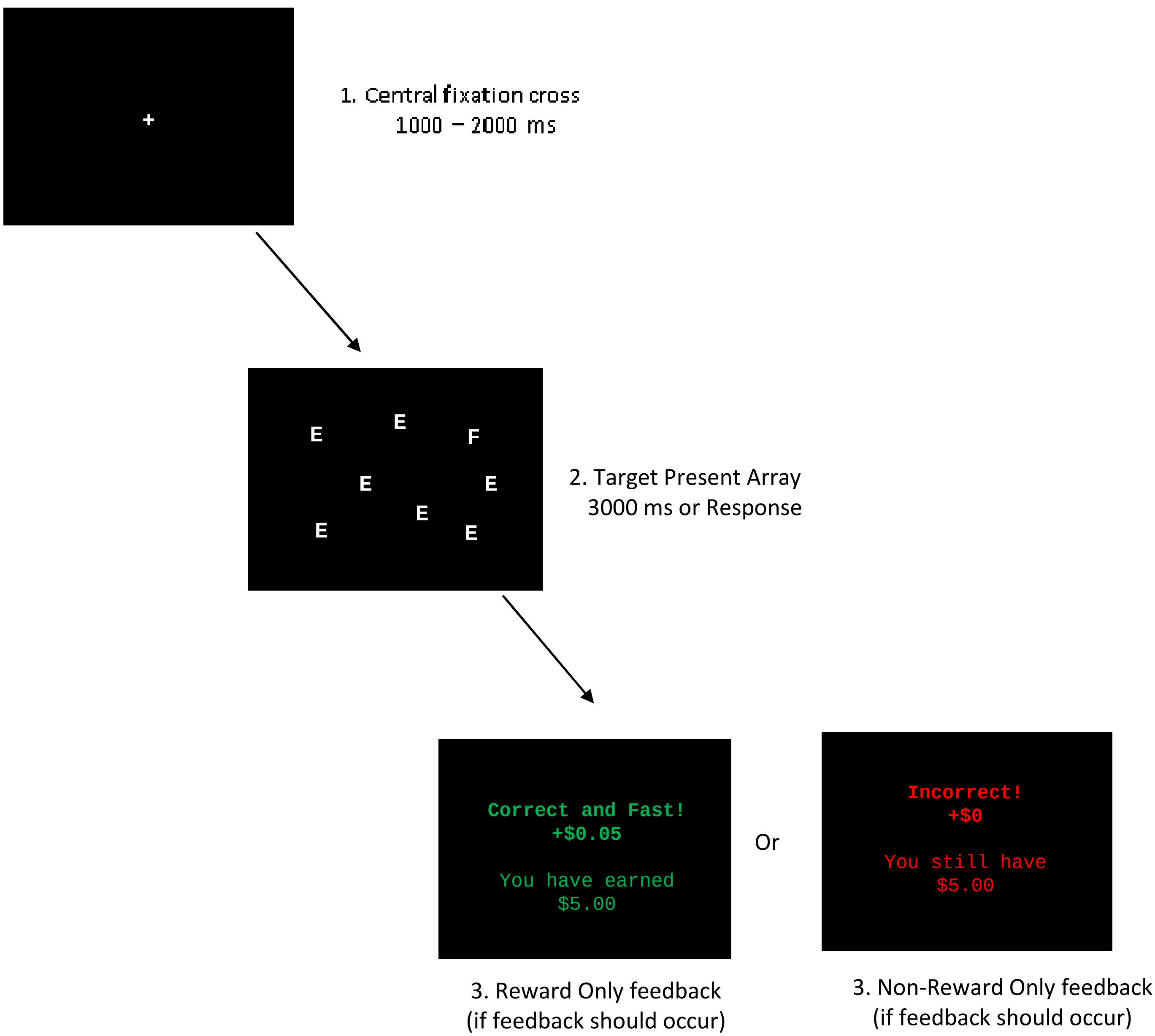


Figure 3. Set Size x Target x Search Task interaction highlighting improvement by target type. Visual search is significantly more efficient for the Incentivized Search Task than the Standard Search Task. There was more improvement for Target Absent than Target Present trials.

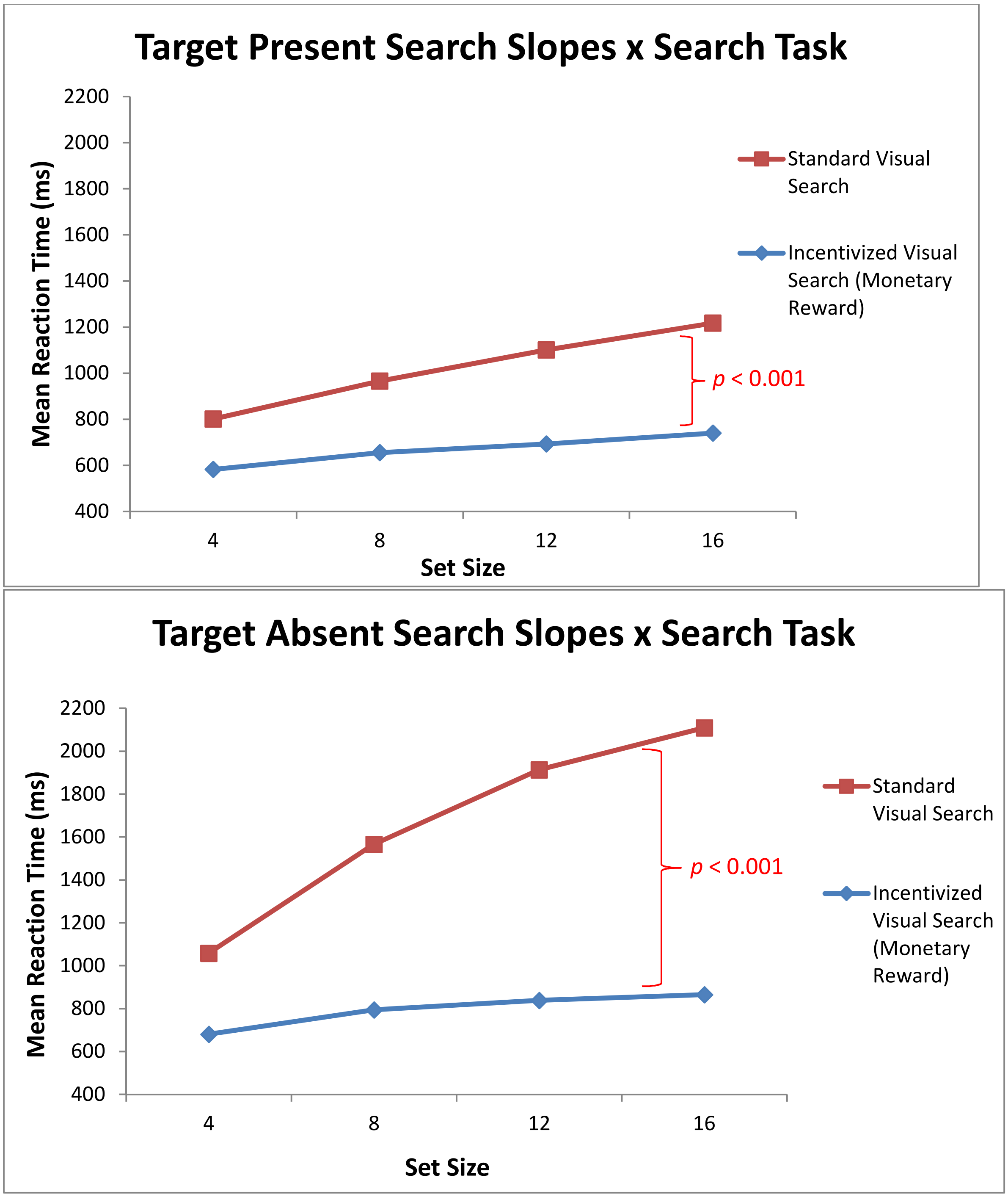
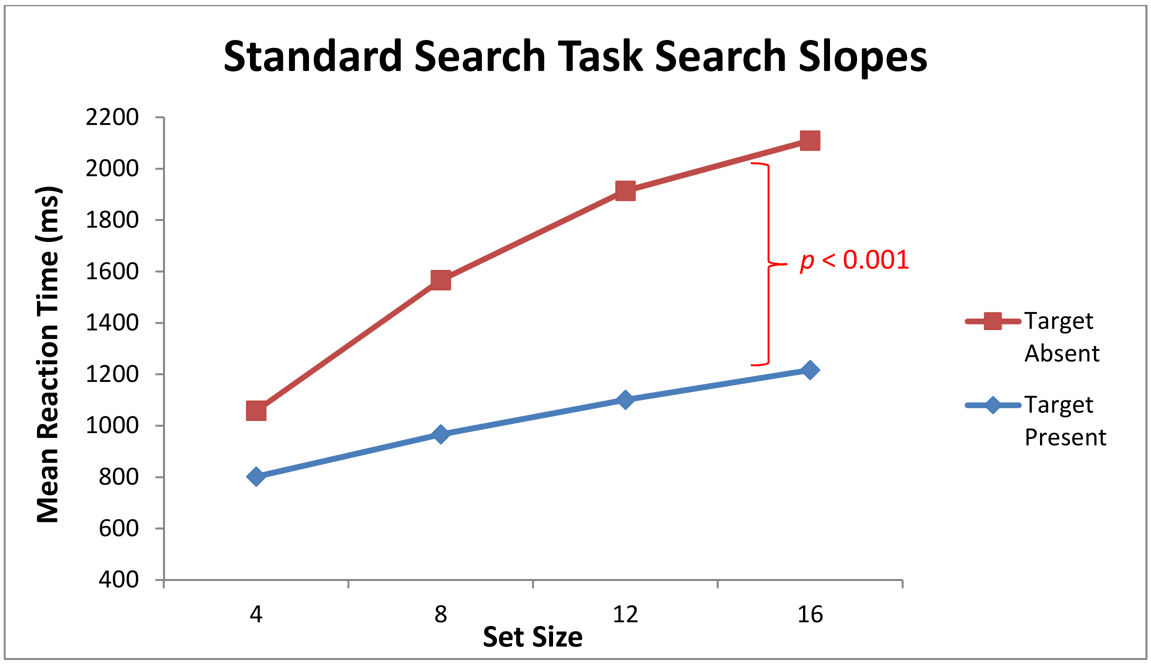


Figure 4. Set Size x Target x Search Task interaction highlighting search task. Subjects were significantly more efficient at searching Target Present arrays in the Standard Search Task, but there was little difference between Target Present and Target Absent search efficiency in the Incentivized Search Task.



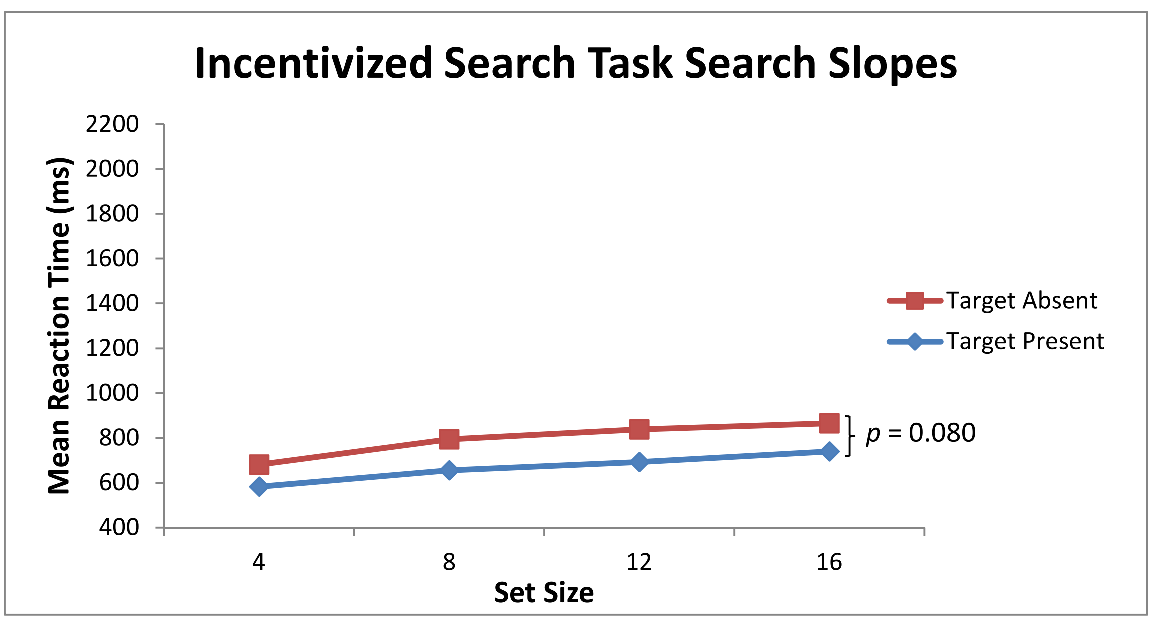
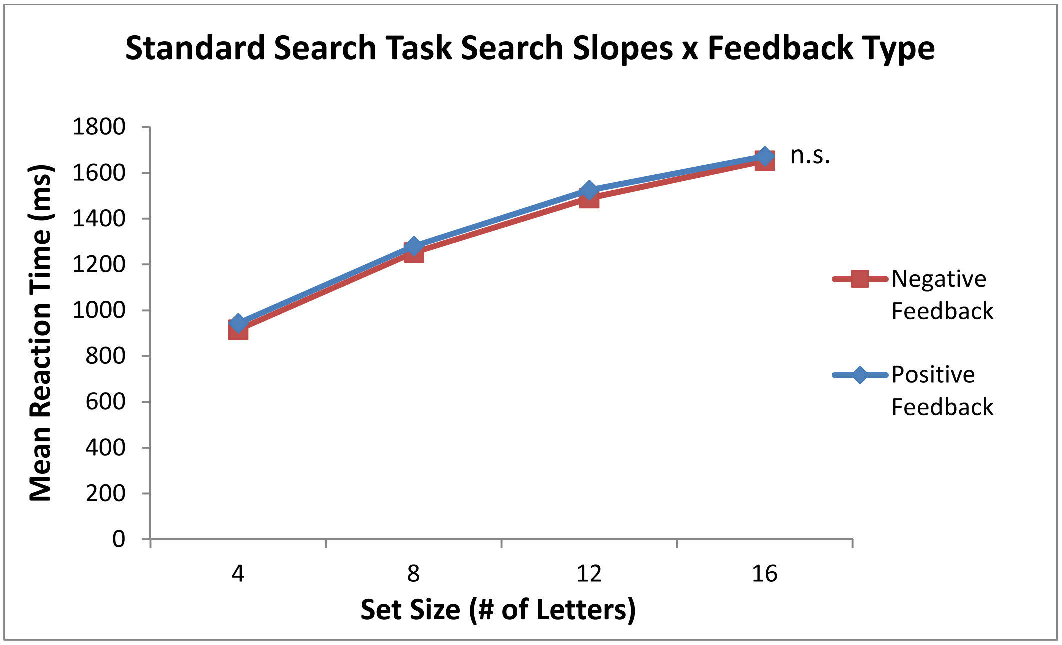


Figure 5. Set Size x Search Task x Feedback Type interaction. Subjects were more efficient at the Incentivized Search Task when they were given only negative feedback (M = 9.231 ms/item) than when they were given only positive feedback across target types (M = 18.448 ms/item; Target Absent and Target Present trials collapsed). There was no difference in search slope between Feedback groups on the Standard Search Task.



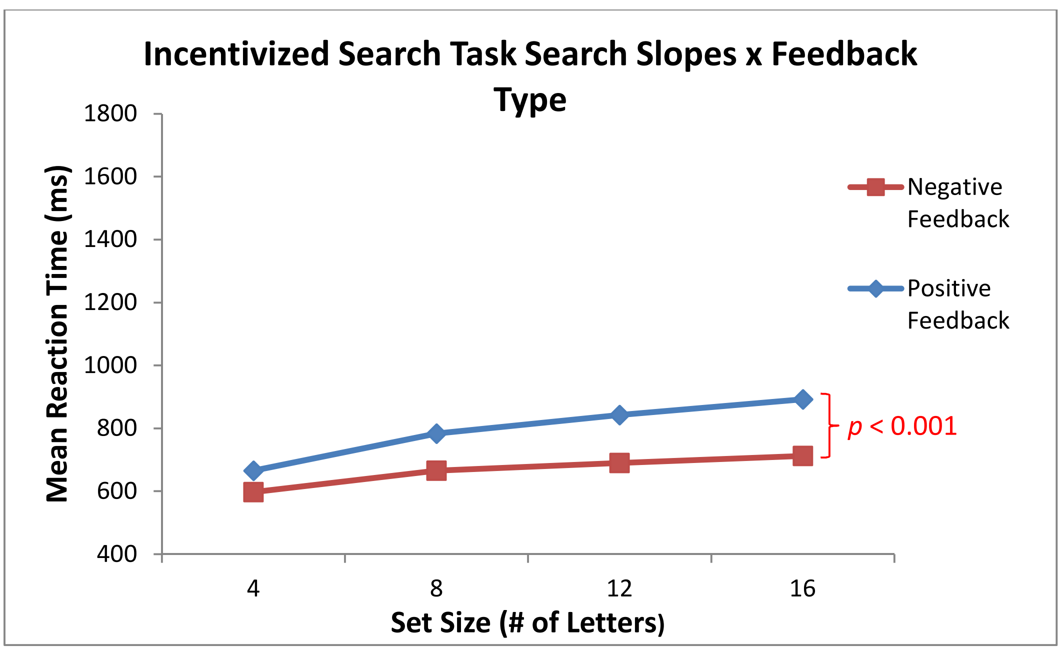


Figure 6. MDD Group x Feedback Type results for Target Present trials. rMDD subjects were significantly less efficient at searching Target Present arrays than never-depressed subjects on the incentivized search task especially when they were only provided with positive feedback.

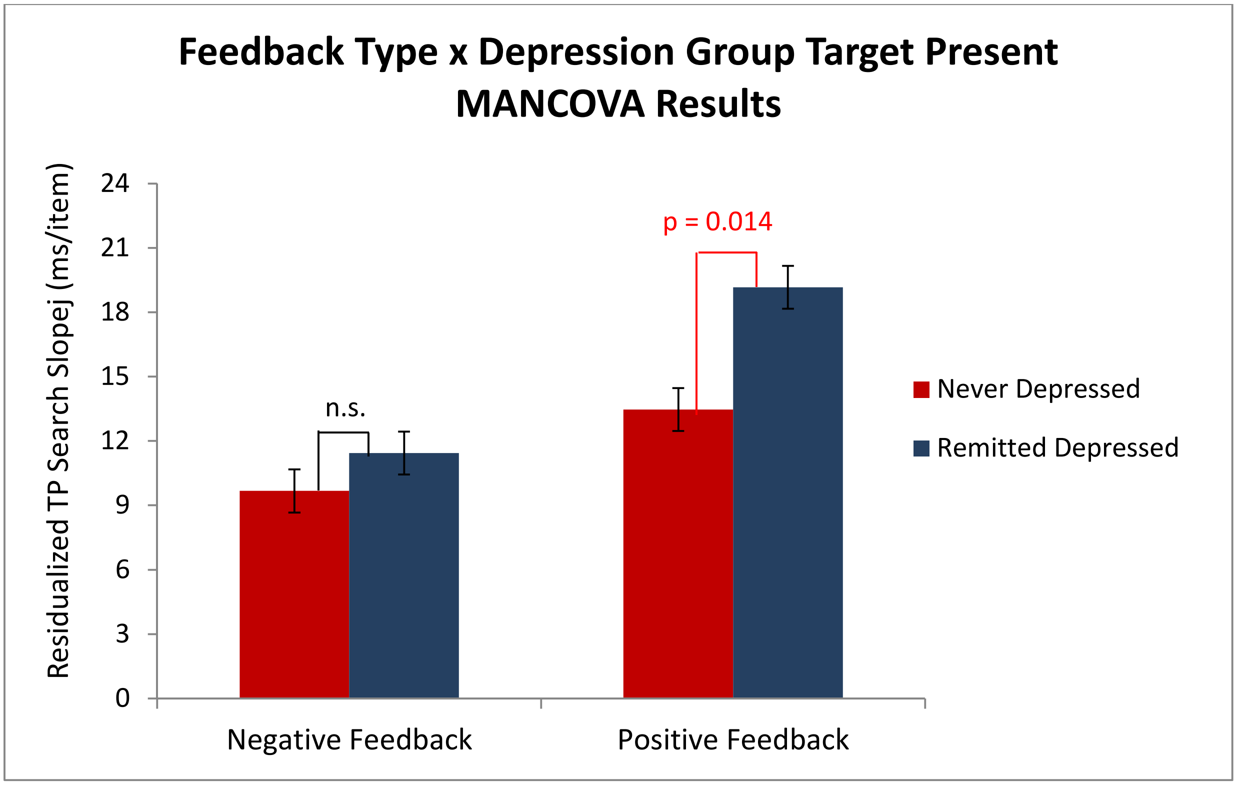


Figure 7. SPSRQ Sensitivity to Reward and Incentivized Visual Search. As sensitivity to reward increases, incentivized visual search efficiency increases (p = 0.004). TP = Target Present, SPSRQ = Sensitivity to Punishment Sensitivity to Reward Questionnaire, r_p^2 = squared semipartial correlation.

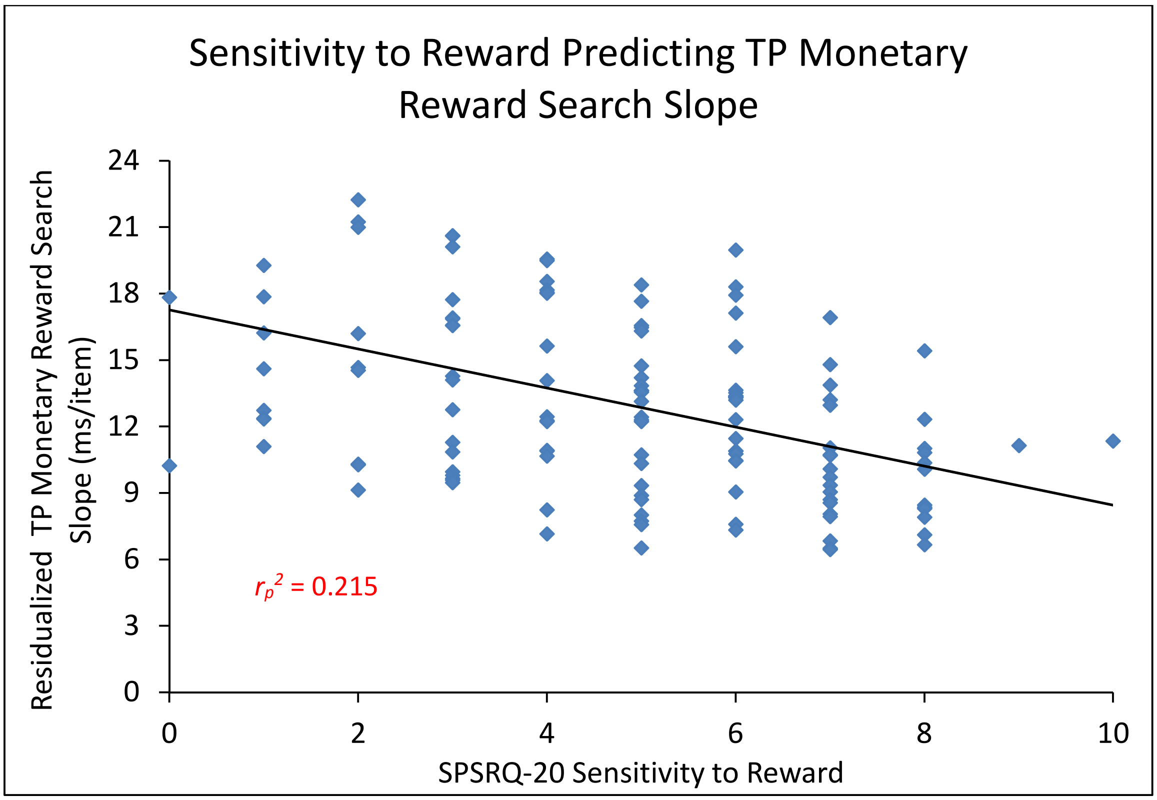


Figure 8. SPSRQ Sensitivity to Reward x Feedback interaction. As sensitivity to reward increases, search efficiency increases (i.e., search slope decreases). This is particularly true in the presence of positive feedback as the regression line was significantly different from zero in the positive (*p* = 0.005), but not negative feedback condition (*p* = 0.221). TP = Target Present, SPSRQ = Sensitivity to Punishment Sensitivity to Reward Questionnaire

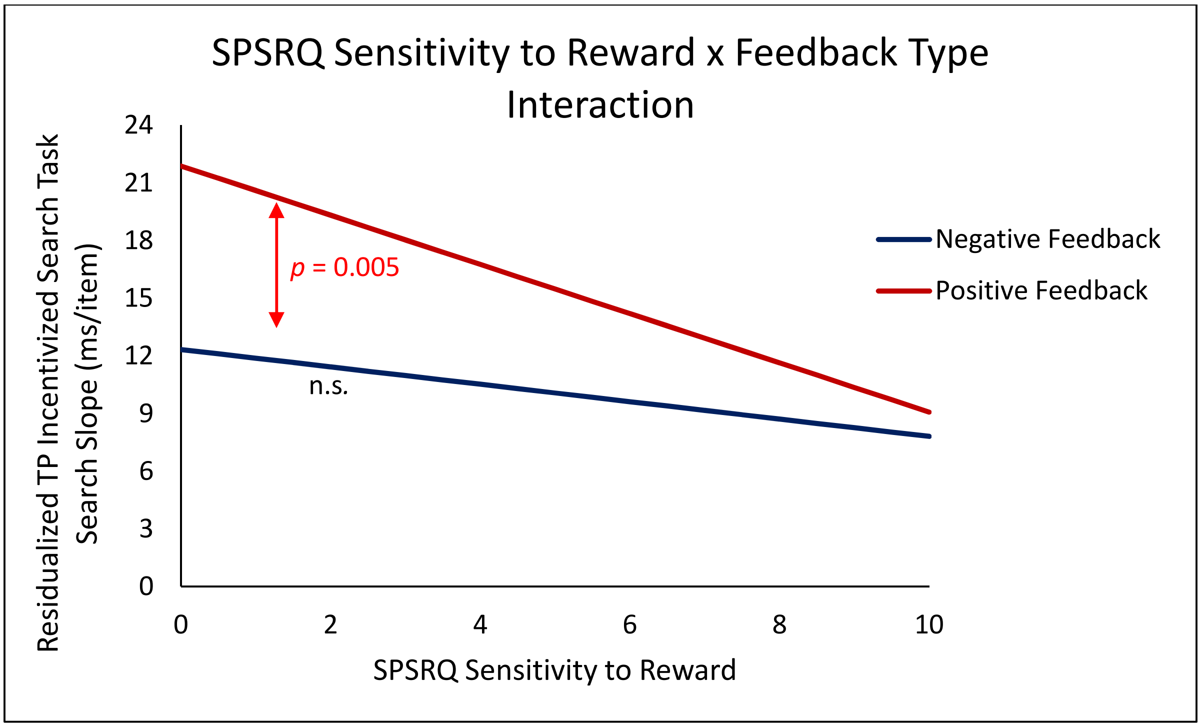


Figure 9. SHAPS Anhedonia x Feedback Type interaction. As anhedonia increases, incentivized search slopes increase (i.e., search becomes less efficient) in the presence of positive feedback. In the presence of negative feedback, search slopes decrease (i.e., search becomes more efficient) as anhedonia increases. However, the slopes of the negative and positive feedback regression lines were not significantly different from zero.

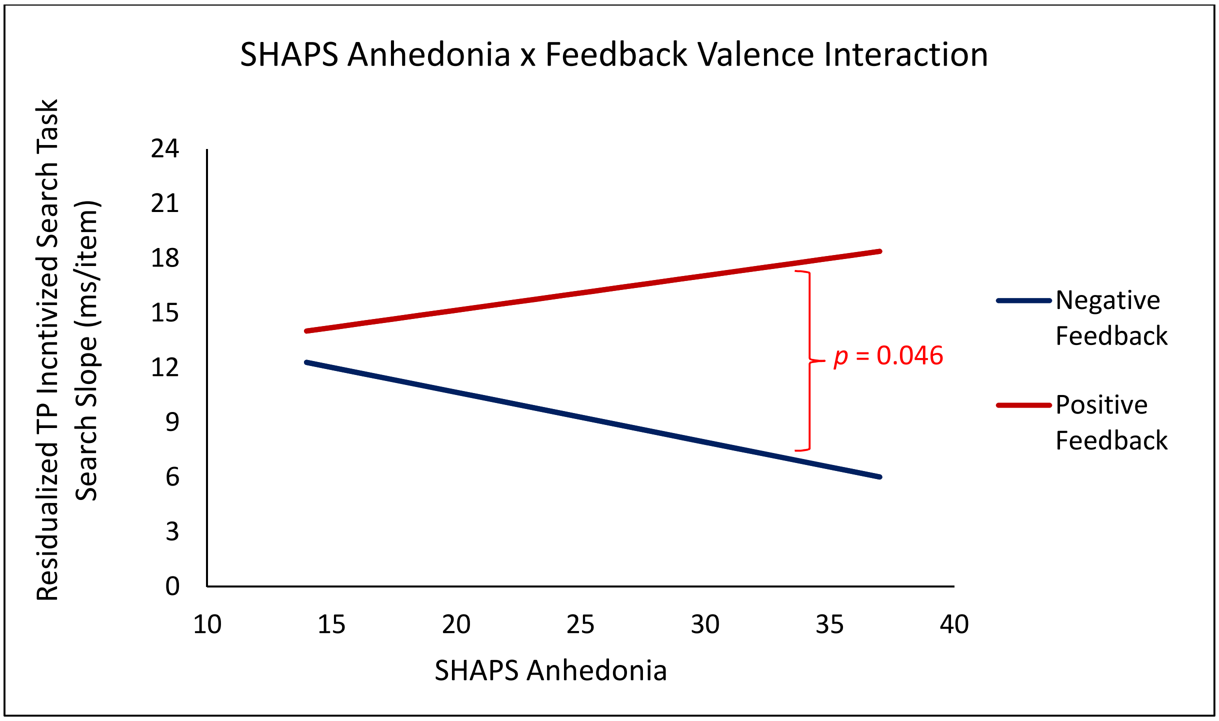


Figure 10. MASQ Anhedonic Depression x Feedback Type interaction. Holding other negative affective subscales of the MASQ constant, there is a significant positive relationship between MASQ Anhedonic Depression and search slope that is specific to the positive feedback group. Thus, in the presence of positive feedback, greater anhedonia is specifically associated with less efficient incentivized search task performance.

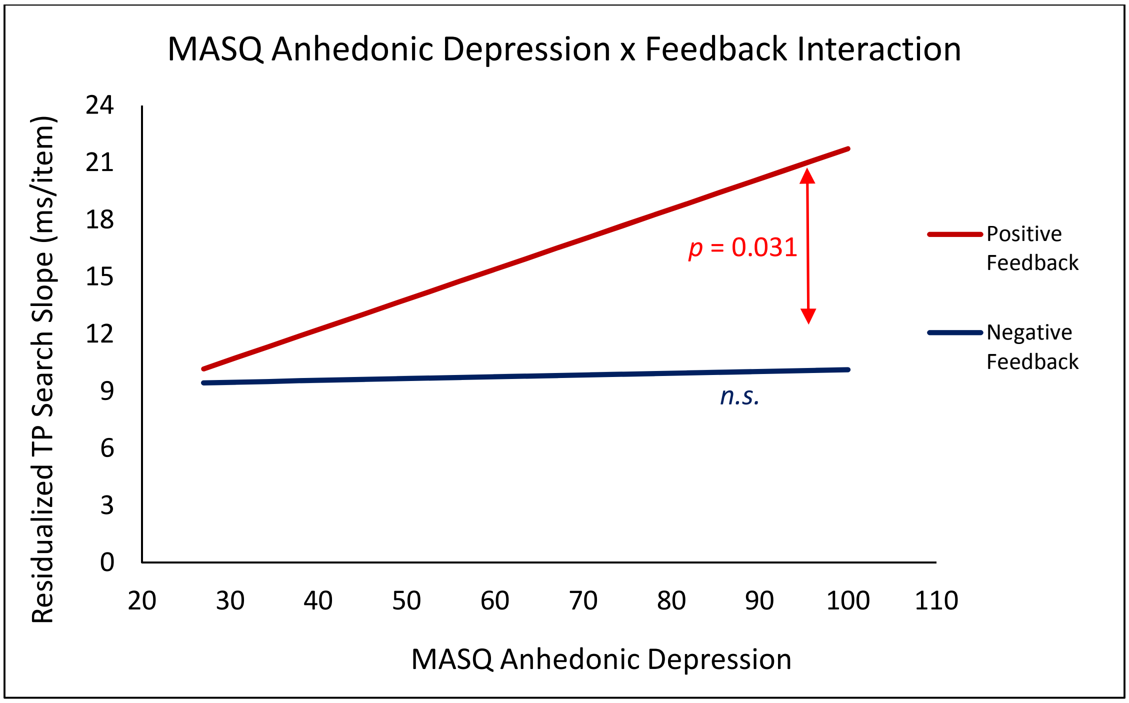
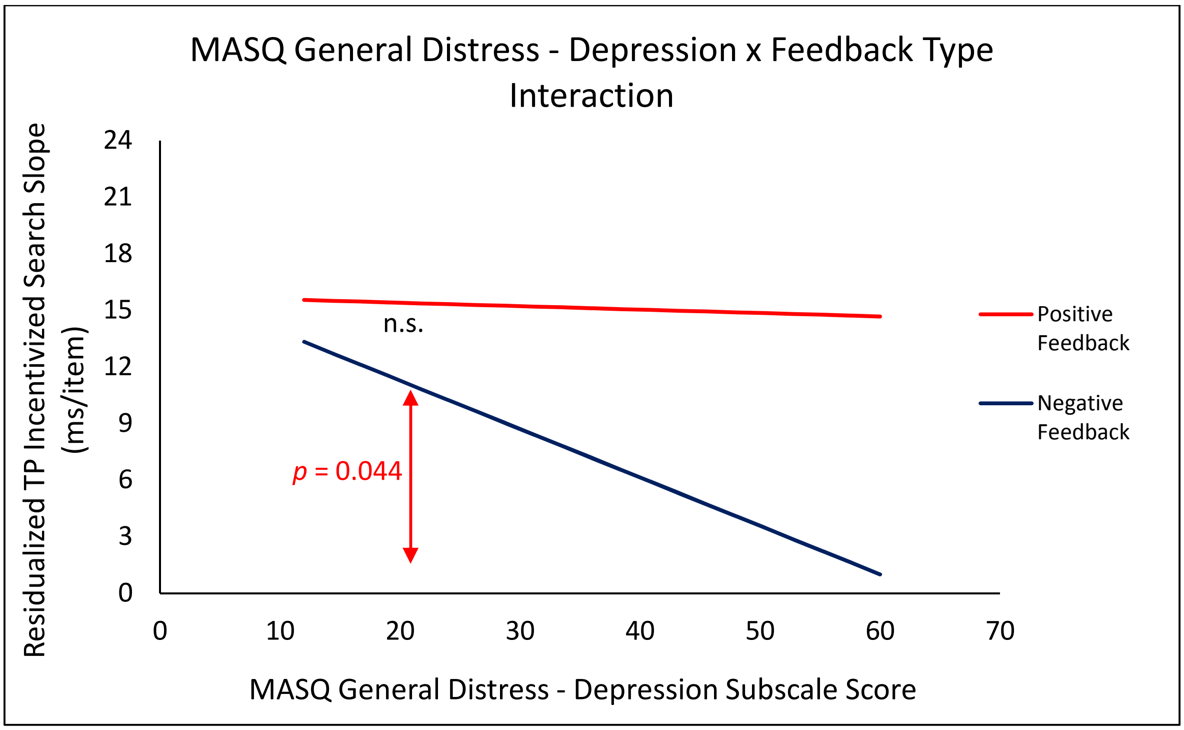


Figure 11. MASQ General Distress Depression x Feedback Type interaction. Holding the General Distress-Anxiety, Anxious Arousal, and Anhedonic Depression subscales constant, there is a significant negative relationship between MASQ General Distress Depression and search slope that is specific to the negative feedback group. Thus, in the presence of negative feedback, increased general negative affective symptoms of depression (e.g., sadness) are specifically associated with more efficient incentivized search task performance.



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Lauren E. Taubitz

Curriculum Vitae

EDUCATION

2008 – Present — University of Wisconsin – Milwaukee
Doctoral Program in Clinical Psychology
Major: Clinical Psychology
Minor: Quantitative Methods
Advisor: Christine L. Larson, Ph.D.
Dissertation: *Facilitating Visual Selective Attention via Monetary Reward: The Influence of Reward Sensitivity and Lifetime Major Depressive Disorder*
Defended: August 4, 2014

2008 - 2011 — University of Wisconsin - Milwaukee
M.S. - Clinical Psychology
Thesis: *Elaborating the Time Course of Attentional Bias in Dysphoria: Combining ERP and Behavioral Measures*
Defended: March 8, 2011

2004 – 2008 — Michigan State University
B.S. – Psychology, Honors College, with Honor
Honors Thesis: *Predicting Remission of ADHD: A Molecular Genetic Study*

RESEARCH POSITIONS

2010 - 2014 — Emotion Regulation Dysfunction as a Predictor of Acute and Long-Term Post-Trauma Distress
Role: Graduate Research Assistant
Location: University of Wisconsin – Milwaukee, Medical College of Wisconsin
Directors: Terri de Roon-Cassini, Ph.D., & Christine L. Larson, Ph.D.

- Assessed individuals from a Level-I trauma center for symptoms of Acute Stress Disorder using the Acute Stress Disorder Interview
- Collected structural and functional MRI data and DTI data
- Analyzed functional MRI data using AFNI software
- Assessed individuals 6 months post-MRI for symptoms of PTSD using the PTSD Symptom Scale Interview (PSSI)
- Presented data at national and international conferences and collaborated on manuscript preparation

2008 – 2011 fMRI and ERP Studies of Rumination in Depression
Role: Graduate Research Assistant
Location: University of Wisconsin – Milwaukee
Director: Christine L. Larson, Ph.D.

- Administered the Structured Clinical Interview for DSM-IV Axis I disorders (SCID-I) to assess for current and past psychopathology
- Collected structural and functional MRI data and analyzed it using AFNI and FreeSurfer software
- Collected EEG data and analyzed event-related potentials (ERPs) offline using Neuroscan, EEGLAB, and ERPLAB software
- Collaborated on conference presentations and manuscript preparation

2006 – 2008 MSU Attention Study Genetics Project, ADHD Longitudinal Project
Role: Undergraduate Research Assistant
Location: Michigan State University
Director: Joel T. Nigg, Ph.D.

- Assessed children ages 6-17 with and without Attention Deficit/Hyperactivity Disorder and related psychopathology
- Assessed parents of child participants
- Administered neuropsychological tests including the CPT and subtests from the WAIS, WISC, WIAT, WRAT, Woodcock-Johnson, and D-KEFS with children and parents
- Scored and entered neuropsychological assessments and child and parent self-report scales
- Completion of senior honors thesis and presentation of the data at a local conference

PUBLICATIONS

Lewis, K.L., **Taubitz, L.E.**, Duke, M., Steuer, E., & Larson, C.L. (*in press*). State rumination enhances elaborative processing of negative material as evidenced by the late positive potential. *Emotion.*

Taubitz, L.E., Pedersen, W.S., & Larson, C.L. (2015*)*. BAS Reward responsiveness: A unique predictor of positive outcomes. *Personality and Individual Differences,80,* 107-112. doi:10.1016/j.paid.2015.02.029

Belleau, E.L., **Taubitz, L.E.**, & Larson, C.L. (2015). Imbalance of default mode and regulatory networks during externally-focused processing in depression. *Social Cognitive and Affective Neuroscience, 10,* 744-751. doi: 10.1093/scan/nsu117

Taubitz, L.E., Robinson, J.S., & Larson, C.L. (2013). Modulation of the Startle Reflex across time by unpleasant pictures distinguishes dysphoric from non-dysphoric women. *International Journal of Psychophysiology, 87,* 124-129. doi: 10.1016/j.ijpsycho.2012.11.002

Larson, C. L., **Taubitz, L.E.**, & Robinson, J. S. (2010). MAOA T941G polymorphism and the time course of emotional recovery following unpleasant pictures. *Psychophysiology,47,* 857-862.

MANUSCRIPTS IN PREPARATION (in draft form)

deRoon-Cassini, T., **Taubitz, L.E**., Belleau, E.L., Blaisdell, J., & Larson, C.L. Dysregulation in affect-related neural circuitry immediately post-trauma predicts chronic PTSD symptoms.

Taubitz, L.E., & Larson, C.L. Reward sensitivity and lifetime major depressive disorder moderate the degree to which reward enhances visual selective attention.

SYMPOSIA

Larson, C.L., deRoon-Cassini, T., **Taubitz, L.E**., & Belleau, E.L. *Neural markers of emotion dysregulation in acute trauma survivors predict chronic PTSD.* Presented at the annual meeting of the Anxiety and Depression Association of America, April 9-12, 2015, Miami, FL.

Larson, C., **Taubitz, L.**, Belleau, E., & deRoon-Cassini. *Neural markers of emotion dysregulation in acute trauma survivors predict chronic PTSD*. Presented at the 28th Annual Meeting of the Society for Research in Psychopathology, September 18-21, 2014, Evanston, IL.

Larson, C.L., deRoon-Cassini, T., **Taubitz, L.E.,** & Belleau, E.L. *Divergent neural correlates of hyperarousal and intrusive symptoms in acute trauma survivors.* Symposium presentation at the annual meeting of the Society for Psychophysiological Research, September 10-14, 2014, Atlanta, GA.

Belleau, E.L., **Taubitz, L. E.,** & Larson, C. L. *Default mode and regulatory networks during externally focused processing in depression.* Symposium presentation at the annual meeting of the Society for Psychophysiological Research, September 10-14, 2014, Atlanta, GA.

deRoon-Cassini, T., **Taubitz, L.**, & Larson, C. *Prediction of Chronic PTSD using Early fMRI Evidence of Emotion Dysregulation in Trauma Survivors.* Presented at the Society of Biological Psychiatry 69th Annual Scientific Meeting, May 8-10, 2014, New York, NY.

Taubitz, L.E. *Reward, Visual Selective Attention, and its Relevance for MDD.* Presented at the University of Wisconsin – Milwaukee 15th Annual Graduate Student Research Symposium, April 5, 2013.

Taubitz, L.E. *Elaborating the time course of attentional bias in dysphoria: Combining event-related potential and behavioral measures.* Presented at the University of Wisconsin – Milwaukee 13th Annual Graduate Student Research Symposium, April 8, 2011.

Taubitz, L.E. *MAOA polymorphism is associated with the time course of responses to unpleasant pictures*. Presented at the University of Wisconsin – Milwaukee 11th Annual Graduate Student Research Symposium, April 17, 2009.

POSTER PRESENTATIONS

Taubitz, L. E., & Larson, C. L. *Reduced Reward Enhancement of Visual Selective Attention in Anhedonia and Lifetime Depression*. Presented at the 28th Annual Meeting of the Society for Research in Psychopathology, September 18-21, 2014, Evanston, IL.

Belleau, E. L., **Taubitz, L. E.,** & Larson, C. L. *Imbalance of Default Mode and Regulatory Networks during Externally-Focused Processing in Depression*. Presented at the 28th Annual Meeting of the Society for Research in Psychopathology, September 18-21, 2014, Evanston, IL.

Haworth, K., **Taubitz, L.**, & Larson, C. *Gender Differences in Reward Sensitivity.* Presented at the 28th Annual Meeting of the Society for Research in Psychopathology, September 18-21, 2014, Evanston, IL.

Taubitz, L.E., & Larson, C.L. *Reduced Effectiveness of Reward in Enhancing Visual Search Efficiency in Remitted Major Depressive Disorder and Low Reward Sensitivity.* Presented at the Inaugural Conference of the Society for Affective Sciences, April 24-26, 2014, Bethesda, MD.

Belleau, E. L., **Taubitz, L. E.,** & Larson, C. L. *Rumination-Related Neural Network Dysfunction in Depression.* Presented at the Inaugural Conference of the Society for Affective Sciences, April 24-26, 2014, Bethesda, MD.

Haworth, K., **Taubitz, L. E.,** & Larson, C. L. *Gender Differences in Reward Sensitivity.* Presented at the Inaugural Conference of the Society for Affective Sciences, April 24-26, 2014, Bethesda, MD.

Taubitz, L.E., & Larson, C.L. *Lifetime Major Depressive Disorder and Low Reward Responsiveness are Associated with Reduced Ability to Use Reward to Enhance Visual Search*. Presented at the Association for Behavioral and Cognitive Therapies 47th Annual Convention, November 21-24, 2013, Nashville, TN.

Taubitz, L.E., deRoon-Cassini, T., Blaisdell, J., Birmingham, T., & Larson, C.L. *Default Mode Network Function Differentiates Acutely Traumatized Individuals With and Without Acute Stress Disorder.* Presented at the 26th Annual Meeting of the Society for Research in Psychopathology, October 4-7, 2012, Ann Arbor, MI.

Taubitz, L.E., deRoon-Cassini, T., Blaisdell, J., Birmingham, T., & Larson, C.L. *Medial Prefrontal and Cingulate Cortex Activity Differentiate Those with and without Acute Stress Disorder during Trauma Imagery.* Presented at the 52nd Annual Meeting of the Society for Psychophysiological Research, September 19-23, 2012, New Orleans, LA.

Blaisdell, J.A., deRoon-Cassini, T., **Taubitz, L.E.,** Birmingham, T., & Larson, C.L. *Neural Correlates of Face Processing in Acute Stress Disorder.* Presented at the 52nd Annual Meeting of the Society for Psychophysiological Research, September 19-23, 2012, New Orleans, LA.

Taubitz, L.E., Lewis, K.L., & Larson, C.L. *Emotion Modulation of the P2 ERP Component in Dysphoric and Non-Dysphoric Subjects and its Modifcation by SSRI Treatment.* Presented at the Society of Biological Psychiatry 67th Annual Scientific Convention & Program, May 3-5, 2012, Philadelphia, PA.

Belleau, E.L., **Taubitz, L.E**., Larson, C.L., & Castro, M. *The impact of rumination on neural functioning in response to emotional information.* Presented at the Society of Biological Psychiatry 67th Annual Scientific Convention & Program, May 3-5, 2012, Philadelphia, PA.

Taubitz, L.E., Lewis, K.L., & Larson, C.L. *Elaborating the Time Course of Attentional Bias in Dysphoria: Combining Event-Related Potential and Behavioral Measures.* Presented at the 51st Annual Meeting of the Society for Psychophysiological Research, September 14-18, 2011, Boston, MA.

Lewis, K.L., Steuer, E.L., Duke, M.W., **Taubitz, L.E**., Belleau, E.L., & Larson, C.L. *Frontal Late Positive Potential Predicts Subsequent Memory for Pleasant Pictures.* Presented at the 51st Annual Meeting of the Society for Psychophysiological Research, September 14-18, 2011, Boston, MA.

Belleau, E.L**., Taubitz, L.E.**, Larson, C.L., & Castro, M. *The Impact of Rumination on Neural Functioning in Response to Emotional Information.* Presented at the 51st

Annual Meeting of the Society for Psychophysiological Research, September 14-18, 2011, Boston, MA.

Taubitz, L.E., Belleau, E., & Larson, C.L. *Decreased BAS Reward Sensitivity Predicts Anhedonia Better than General Distress Symptoms of Depression*. Presented at the Association of Behavioral and Cognitive Therapies' 44th annual convention, November 18-21, 2010, San Francisco, CA.

Belleau, E.L., **Taubitz, L.E.**, & Larson, C.L. *Ruminative thinking and cognitive reappraisal predict the experience of depressive symptomology.* Presented at the Association for Behavioral and Cognitive Therapies 44th Annual Convention, November 18-21, 2010, San Francisco, California.

Taubitz, L.E., Larson, C.L., & Robinson, J.S. *Elaborating the time course of the emotion-modulated startle reflex in dysphoria*. Presented at the Social and Affective Neuroscience Society 4th Annual Conference, October 29-31, 2010, Chicago, IL.

Duke, M.W., Steuer, E.L., **Taubitz, L.E**., Belleau, E.L., & Larson, C.L. *EEG responses to emotional images: examination of the effects of rumination and distraction in depression.* Presented at the 50th Annual Meeting of the Society for Psychophysiological Research, September 29 - October 3, 2010, Portland, OR.

Duke, M.W., Steuer, E.L., **Taubitz, L.E.**, Belleau, E.L., & Larson, C.L. *EEG responses to emotional images: examination of the effects of rumination and distraction in depression.* Presented at the Society for Social & Affective Neuroscience Society 4th Annual Conference, October 29-31, 2010 Chicago, IL.

Taubitz, L.E., Larson, C.L., & Robinson, J.S. *Elaborating the Time Course of the Emotion Modulated Startle Reflex in Dysphoria.* Presented at the 50th Annual Meeting of the Society for Psychophysiological Research, September 29 - October 3, 2010, Portland, OR.

Taubitz, L.E., Robinson, J.S., & Larson, C.L. *MAOA Polymorphism Associated with the Time Course of Responses to Unpleasant Pictures.* Presented at the Association for Psychological Science 21st annual convention, May 22-25, 2009, San Francisco, CA.

Taubitz, L.E., & Nigg, J.T. *Predicting Remission of ADHD: A Molecular Genetic Study.* Presented at the University Undergraduate Research & Arts Forum, April 2008, East Lansing, MI. Selected for a merit award in psychology research.

AWARDS

2012	UWM Graduate School Travel Award
2012	Sigma Xi Grants-in-Aid of Research Recipient

2011	UWM Clinical & Translational Research Institute Research Fellowship
2008	University Undergraduate Research & Arts Forum Merit Award
2006	Cole International Study Award
2004	Michigan State University Valedictorian Scholarship
2004	Michigan State University Spartan Scholarship for Academic Excellence
2004	National Honor Society Scholarship

TEACHING EXPERIENCE

2010 – 2013	Teaching Assistant, Psychology 210: Psychological Statistics
2008 – 2009	Teaching Assistant, Psychology 412: Psychopathology

PROFESSIONAL AFFILIATIONS

Society for Affective Sciences, 2013 - Present
Society for Psychophysiological Research 2010 - Present
Social & Affective Neuroscience Society 2010 - Present
American Psychological Association 2009 - Present
Association for Psychological Science 2008 – Present
Association for Behavioral and Cognitive Therapies 2012 – Present

CLINICAL EXPERIENCE

2014-Present — VA Ann Arbor Healthcare System Psychology Internship, Ann Arbor, MI

- **Major Rotation**: Veterans Empowerment and Recovery Center (VEAR)
    - Ann Arbor VA's Psychosocial Rehabilitation and Recovery Center program
    - Conduct evidence-based individual and group therapies for veterans with severe mental illness using a mental health recovery model of care.
    - Individual EBPs provided: Behavior Activation for depression, CBT for depression, CBT for social phobia
    - Groups Co-facilitated: Problem-Solving, Cognitive Behavioral Social Skills Training, Ending Self-Stigma, Mental health recovery psychoeducation group (acute inpatient)
    - Supervisor: Dr. C. Beau Nelson
- **Minor Rotation**: Substance Use Disorders Clinic (SUDC)
    - Conduct SUDC intake assessments
    - Implement evidence-based individual and group therapies for veterans that address substance use

- (e.g., CBT for substance use, Motivational Enhancement Therapy) and other co-occurring conditions (e.g., CBT for insomnia, chronic pain, and depression)
    - Co-facilitated group therapy for the intensive outpatient program (SUD-IOP) including CBT, Motivational Interviewing, and mindfulness-based recovery interventions.
    - Supervisor: Dr. Jennifer Coughlin
- **Major Rotation** (starting approx. 3/1/2015): Female Veterans Mental Health
    - Will conduct individual Prolonged Exposure therapy and other evidence-based individual and group therapies for treatment of PTSD in female veterans
    - Will receive specialty training in PE in the context of Military Sexual Trauma
    - Supervisor: Dr. Mindy Sexton
- **Minor Rotation** (starting approx. 3/1/2015): Assessment
    - Will conduct neuropsychological assessment batteries, write reports based on the findings, and present the results to veterans and their caretakers.
    - Supervisor: TBD
- Completing Prolonged Exposure (PE) VA roll-out training
    - Supervisor: Dr. Heather Cochran

2012-2013 UWM Specialty Team for Anxiety Disorders, Milwaukee, WI

- Assisted in group supervision of clinical psychology doctoral students' therapy training
- Provided feedback regarding implementation of exposure-based protocols for the treatment of anxiety disorders
- Primary interventions observed included Prolonged Exposure for PTSD, Exposure and Ritual Prevention for OCD and Cognitive Behavior Therapy for Social Phobia.
- Supervised by Dr. Shawn Cahill

2011-2012 Rogers Memorial Hospital Eating Disorder Center, Oconomowoc, WI

- Conducted individual therapy in a residential eating disorder center with adolescent and adult men and women with severe eating disorders (Anorexia Nervosa, Bulimia Nervosa, Binge Eating Disorder, and ED-NOS) and severe comorbid anxiety disorders
- Evidence-based treatments implemented include:
    - Exposure and Response Prevention for OCD
    - Behavior Activation for depression

- CBT for social phobia
- Interoceptive Exposure Therapy for panic disorder
- Prolonged Exposure for PTSD

- Co-facilitated process groups and DBT skills groups.
- Contributed to multidisciplinary team meetings that included psychiatrists, nurses, dieticians, psychologists, master's level therapists, AODA counselors, art therapists, and other experiential therapists.
- Supervised by Dr. Bradley Riemann and Dr. Mary Fitzpatrick

2010 – 2014 UWM Psychology Clinic Student Therapist, Milwaukee, WI

- Conducted individual therapy with children and adults for treatment of anxiety, depression, and eating disorders
- Primary interventions implemented were Prolonged Exposure for PTSD, Behavior Activation for depression, Exposure and Response Prevention for OCD, CBT for eating disorders, and CBT for childhood anxiety, and DBT skills
- Wrote intake, quarterly, and termination summaries of treatment
- Established treatment plans with clients
- Administered standardized self-report measures to assess treatment progress
- Supervised by Drs. Shawn Cahill, Gwynne Kohl, & Robyn Ridley

2008 - 2010 UWM Psychology Clinic Assessment Practicum, Milwaukee, WI

- Completed comprehensive assessments with 5 adults and 1 child with integrative reports
- Conducted semi-structured and structured clinical interviews
- Administered a variety of tests of cognitive abilities, achievement, attention, memory, and executive functioning measures
- Administered and interpreted tests of personality, psychopathology, and academic functioning
- Made DSM-IV-TR multiaxial diagnostic impressions
- Wrote integrated reports based on assessment data I collected
- Provided feedback for clients individually and in a school environment
- Supervised by Dr. David Osmon and Dr. Bonnie Klein-Tasman

2007 – 2008 Relief Residential Technician, Clinton-Eaton-Ingham County Community Mental Health, Lansing, MI

- Worked on increasing proficiency with activities of daily living and behavioral management with adults with severe and persistent mental illness and developmental disabilities
- Assisted residents in utilizing therapy skills in the home environment including implementation of DBT skills.
- Coordinated group-home care with other treatment team members including schools, psychiatric and medical providers, and government agencies