Emotional Reactivity to Reward, Punishment, Nonreward, and Avoidance: Relationship to the Structure of BAS/BIS and Effects of Current and Past Depressive Episodes

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Abstract of the Dissertation

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Several theories of personality, affect, and behavior regulation posit a central role for a behavioral activation/approach system (BAS) and a behavioral inhibition system (BIS), which may underlie individual differences in emotional reactions. Although these theories are broadly similar, they do differ in theoretically and clinically important ways, including how BAS and/or BIS dysfunction may be related to depression. In this paper, I compare and contrast two models of BAS/BIS, one characterized mainly by the valence of emotional reactions and the other characterized mainly by the types of incentives eliciting those reactions. I also discuss the possible role of BAS/BIS dysfunction in depression. I then describe an experiment that assessed participants' (N = 138) self-reported emotional reactions in each of four conditions: reward, punishment, nonreward, and avoidance. I tested whether the pattern of correlations among reactions was more consistent with a valence model or an incentive model of BAS/BIS, and whether depressed participants' reactions differed from nondepressed participants' reactions. Results did not clearly support either model of BAS/BIS above the other. Rather, the valence model of BIS was strongly supported and the valence model of BAS was partially supported, whereas the incentive model of BAS was strongly supported and the incentive model of BIS was not supported. Currently-depressed participants' joviality reactivity in response to reward was significantly diminished compared with never-depressed participants', and nonsignificantly diminished compared with previously-depressed participants'. Currently-depressed, previously-depressed, and never-depressed participants did not differ in their emotional reactions to punishment, nonreward, or avoidance.

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Introduction

A group of theories posit a central role for two neuropsychological systems that underlie affect, motivation, and behavior regulation: an approach-oriented behavioral activation system (BAS) and a withdrawal-oriented behavioral inhibition system (BIS). Although these theories are similar in many respects, there are important points of divergence that warrant further investigation, particularly the relationship of BAS and BIS to different types of affect. Additionally, BAS and BIS have been utilized in models of vulnerability to depression and other disorders. There is substantial evidence for a model in which depression is characterized by diminished BAS activity, but this model is in need of further refinement. I will briefly review two major theoretical perspectives on the structure of individual differences in BAS and BIS, highlighting where the perspectives diverge. I will also briefly review evidence for the role of BAS and BIS in depression, highlighting some of the ambiguities in need of clarification.

The Nature of BAS and BIS

Several theorists have proposed similar models of neuropsychological systems that underlie affect, motivation, and behavior regulation, one oriented toward approach and another oriented toward avoidance or withdrawal (Davidson, 1998; Depue & Iacono, 1989; Fowles, 1994; Gray, 1994a). The approach-oriented system, hypothesized to regulate behavior in response to cues of pleasant or rewarding stimuli, is commonly referred to as the behavioral approach/activation system (BAS). The avoidance-related system, hypothesized to regulate behavior in response to threatening or aversive stimuli, is commonly referred to as the behavioral inhibition system (BIS). In all of these models, BAS is involved in generating positive affect (PA) in response to cues of reward and BIS is involved in generating negative affect (NA) in response to cues of punishment. Indeed, BAS and BIS may form the basis for dispositional tendencies to experience PA and NA, and individual differences in BAS and BIS sensitivity may form the basis for personality traits, or affective styles (Davidson, 1992, 1998; Gray, 1994a).

In this sense, models of BAS and BIS are similar to models of personality that include two preeminent traits of opposite affective valence. For example, the distinction between BAS and BIS is conceptually similar to the distinctions between Extraversion and Neuroticism (Eysenck, Eysenck, & Barrett, 1985; McCrae & Costa, 1987), between Positive Temperament and Negative Temperament (Clark & Watson, 1990), and between Positive Emotionality and Negative Emotionality (Harkness, Tellegen, & Waller, 1995). In fact, a recent review concluded that PA and NA are the subjective components of BAS and BIS, respectively (Watson, Wiese, Vaidya, & Tellegen, 1999).

Self-report measures of BAS and BIS sensitivity have shown a fairly consistent pattern of correlations with both trait affect and elicited affect. Self-reported BAS sensitivity correlates with self-reported PA and Extraversion, while self-reported BIS sensitivity correlates with self-reported NA and Neuroticism (Brenner, Beauchaine, & Sylvers, 2005; Campbell-Sills, Liverant, & Brown, 2004; Carver & White, 1994; Heubeck, Wilkinson, & Cologon, 1998; Jackson & Smillie, 2004; Jorm et al., 1999; Smillie & Jackson, 2006; Torrubia, Avila, Molto, & Caseras, 2001). Additionally, self-reported BAS sensitivity predicts happiness in anticipation of a reward and self-reported

BIS sensitivity predicts nervousness in anticipation of a punishment (Carver & White, 1994).

Additional work relating BAS and BIS to affect utilizes Davidson's (1992) model of separate neural circuits for BAS and BIS in which activity in the left prefrontal cortex is related to BAS and activity in the right prefrontal cortex is related to BIS. Several studies have reported results consistent with this model. Relative elevations in left frontal cortical activity have been found in response to incentives (Sobotka, Davidson, & Senulis, 1992) and pleasant stimuli (Fox & Davidson, 1988) while relative elevations in right prefrontal cortical activity have been found in response to punishment (Sobotka et al., 1992) and aversive stimuli (Davidson, Ekman, Saron, & Senulis, 1990; Davidson, Marshall, Tomarken, & Henriques, 2000). Self-reported BAS/BIS sensitivity has been found to correlate with resting frontal EEG alpha asymmetry (Coan & Allen, 2003; Diego, Field, & Hernandez-Reif, 2001; Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), bolstering the conclusion that these methodologies are tapping the same underlying neuropsychological systems. According to Davidson's model, resting frontal EEG alpha asymmetry may be indicative of affective style; there is evidence that resting EEG asymmetry predicts both affective responses (Tomarken, Davidson, & Henriques, 1990) and generalized affect (Tomarken, Davidson, Wheeler, & Doss, 1992).

Based on these, and conceptually similar results, there seems to be a relative consensus that BAS produces PA in anticipation of reward or goal attainment and BIS produces NA in anticipation of punishment. In other words, theorists tend to agree that BAS is engaged by cues of reward, regulates behavior in pursuit of goals, and produces PA (happiness, excitement) as part of this process. Likewise, BIS is engaged by cues of punishment, regulates behavior in avoidance of aversive stimuli, and produces NA (nervousness, anxiety) as part of this process. Recent revisions to Gray's (Gray, 1994b, 1994c) theory specify that the BIS is engaged by conflicting cues in the environment, such as the co-occurrence of both pleasant and threatening stimuli, rather than by cues of "pure" punishment (Smillie, Pickering, & Jackson, 2006). As part of these revisions, further emphasis is placed on the connection between BIS functioning and specific types of NA, specifically, anxiety as opposed to fear.

It is less clear which system is engaged by cues of frustrative nonreward (Amsel, 1958), which involves cues of reward but creates NA (frustration, anger, sadness). Likewise, it is unclear which system is engaged by cues of successful avoidance of threat or punishment, which involves cues of threat or punishment but creates PA (relief, calmness). These conditions are of particular theoretical relevance because they represent points of divergence between different models of BAS/BIS.

Gray (1994b; 1994c) proposed that frustrative nonreward engages BIS and avoidance of threat or punishment engages BAS. Revisions to Gray's theory have preserved these proposals (Smillie, Pickering et al., 2006). In fact, recent studies have utilized conditions of frustrative nonreward to engage BIS (Brenner et al., 2005) and active avoidance to engage BAS (Smillie & Jackson, 2005). Although not stated explicitly, these proposals suggest that BAS and BIS are each associated with a single affective valence, BAS with PA and BIS with NA, regardless of the types of cues eliciting the affect. This is consistent with the views of Watson et al. (1999), which specify that the two underlying neuropsychological systems are each associated with a single affective valence. This perspective could be termed a *valence model* of BAS and

BIS. According to this model, individual differences in BAS sensitivity will be associated with individual differences in the tendency to experience PA, whereas individual differences in BIS sensitivity will be associated with individual differences in the tendency to experience NA, regardless of the cues eliciting those affects. Figure 1 depicts these predictions graphically. Throughout the remainder of this paper, I will refer to this perspective as the valence model of BAS/BIS.

In contrast, Carver and Scheier (1998) have proposed an alternative model of BAS and BIS, in which each system produces both PA and NA. This model grew out of Higgins' theories of self-discrepancy (Higgins, 1987) and regulatory focus (Higgins, 1997). The model proposes that BAS and BIS operate as feedback mechanisms that monitor the success of action in pursuit of goals and avoidance of threats, respectively. Both BAS and BIS produce either PA or NA as part of the feedback process and the regulation of ongoing behavior (Carver, 2001; Carver & Scheier, 1998). According to this model, BAS monitors an individual's progress in obtaining rewards, compares it to some criterion, and generates PA (happiness, excitement) when progress exceeds the criterion or NA (frustration, sadness) when progress does not exceed the criterion. Likewise, BIS monitors an individual's progress in avoiding punishment, compares it to some criterion, and generates PA (calmness, relief) when progress exceeds the criterion or NA (nervousness, agitation) when progress does not exceed the criterion (Carver, 2001). According to this model, frustrative nonreward engages BAS and avoidance of threat or punishment engages BIS. In this way, BAS and BIS are defined by the types of cues (reward-related or punishment-related) that engage them. This view could be termed an *incentive model* of BAS and BIS. According to this view, individual differences in BAS and BIS sensitivity will each be associated with individual differences in the tendency to experience certain kinds PA and certain kinds of NA, depending on the cues eliciting those affects. Figure 2 depicts these predictions graphically. Throughout the remainder of this paper, I will refer to this perspective as the incentive model of BAS/BIS.

In support of the incentive model of BAS/BIS, Carver (2004) has shown that self-reported BAS sensitivity predicts stronger self-reported frustration and sadness in a frustrative nonreward condition. Other results taken as evidence for the incentive model of BAS/BIS are findings that self-reported BAS is associated with both trait (Harmon-Jones, 2003; Smits & Kuppens, 2005) and induced anger (Carver, 2004). Frontal EEG alpha asymmetry putatively indicative of greater BAS activity has likewise been associated with both trait (Harmon-Jones & Allen, 1998) and induced anger (Harmon-Jones & Sigelman, 2001; Harmon-Jones, Sigelman, Bohlig, & Harmon-Jones, 2003). Studies linking BAS to anger do not all utilize methods specifically relevant to the incentive model of BAS/BIS, as many do not include a frustrative nonreward condition per se. However, these studies do provide evidence that the valence model may be insufficient, as they suggest that individual differences in BAS functioning are associated with individual differences in a negatively valenced emotion.

As can be seen, the relationship between BAS/BIS and affective valence is still a matter of some disagreement. To date, many studies of BAS and BIS have focused on the conditions in which the valence model and the incentive model make similar predictions: reward and punishment (Carver & White, 1994; Davidson et al., 2000; Fox & Davidson, 1988; Sobotka et al., 1992). There has been less work assessing the conditions in which the two models make different predictions: frustrative nonreward and avoidance of punishment. I am aware of only two studies linking frustrative nonreward to BAS/BIS. In the first, self-reported NA in response to frustrative nonreward correlated with self-reported BAS but not BIS (Carver, 2004). In the second, a frustrative nonreward (extinction) condition was equally correlated with changes in putative physiological indicators of both BAS and BIS (Brenner et al., 2005). I am aware of only one study linking avoidance of punishment to BAS/BIS. In this study, performance on an active avoidance task was correlated with self-reported BAS but not BIS (Smillie & Jackson, 2005). Clearly, additional studies using conditions of frustrative nonreward and avoidance of punishment are needed.

Studies to date have also been relatively limited in that each study utilizes only one or two of the four main conditions relevant to BAS/BIS models. For example, Carver's studies linking BAS to anticipation of reward (Carver & White, 1994), BAS to frustrative nonreward (Carver, 2004), and BIS to anticipation of punishment (Carver & White, 1994) were obtained from three separate samples, and each sample experienced only one condition. A more thorough examination of affective responses generated by BAS and BIS would benefit from testing the same participants under several conditions to more fully examine the patterns of individual differences. For example, the incentive model would be strengthened by evidence that self-reported BAS sensitivity predicts both greater PA in response to reward and greater NA in response to frustrative nonreward in the same participants.

The Role of BAS and BIS in Depression

Several theorists propose that depression is characterized by deficits or dysfunction in BAS (Davidson, 1998; Depue & Iacono, 1989; Fowles, 1988; Gray, 1994a). Self-report and electrophysiological studies have provided considerable support for this model, though there is also considerable evidence for a role of excessive BIS activity in depression.

According to the tripartite model of depression and anxiety (Clark & Watson, 1991), increased NA is a common factor in both anxiety and depression; depression is distinguished by decreased PA and anxiety by increased physiological arousal (Clark & Watson, 1991). In the context of the valence model of BAS/BIS (Watson et al., 1999), and in light of the consistent relationships between BAS sensitivity and PA and between BIS sensitivity and NA, the tripartite model suggests that depression is characterized by diminished BAS activity and excessive BIS activity. Further, because excessive BIS (increased NA) is a common factor in depression, anxiety, and other disorders (Mineka, Watson, & Clark, 1998), the distinguishing feature of depression is diminished BAS (decreased PA). Self-report studies of affect have been supportive of this model of depression (Mineka et al., 1998).

Additionally, studies using self-report measures of BAS/BIS sensitivity have shown a similar pattern. Although two studies have shown that depression is associated only with greater self-reported BIS sensitivity (Johnson, Turner, & Iwata, 2003; Meyer, Johnson, & Winters, 2001), others have shown that depression is associated with both greater self-reported BIS sensitivity and lower self-reported BAS sensitivity (Campbell-Sills et al., 2004; Kasch, Rottenberg, Arnow, & Gotlib, 2002; Pinto-Meza et al., 2006). Additionally, among depressed participants, self-reported BAS sensitivity, but not self-reported BIS sensitivity, has been found to predict both the severity and course of depression (Kasch et al., 2002; McFarland, Shankman, Tenke, Bruder, & Klein, 2006).

Also consistent with a diminished BAS model of depression are findings that depression is associated with decreased behavioral responsiveness to reward. A recent longitudinal study found that decreased capacity to correctly identify high-frequency, high-magnitude rewards was associated with both recent and future depression (Forbes, Shaw, & Dahl, 2007). In three studies using signal detection methods (Henriques & Davidson, 2000; Henriques, Glowacki, & Davidson, 1994; Pizzagalli, Jahn, & O'Shea, 2005), depressed participants showed a smaller change in their response bias in reaction to changing reward contingencies than did nondepressed participants. Because BAS is hypothesized to regulate behavior in response to cues of reward, these results support a model of diminished BAS in depression. Additionally, two of these studies (Henriques & Davidson, 2000; Henriques et al., 1994), also assessed changes in response bias in reaction to punishment contingencies and found that depressed participants did not differ from nondepressed participants. These results may indicate that depression was not associated with increased BIS in these samples, although the strength of the punishment manipulation was questionable.

A number of studies have compared depressed and nondepressed participants on resting frontal EEG alpha asymmetry, a putative indicator of relative activation of BAS and BIS. Many of these studies have found that depressed participants showed greater relative left-sided alpha power (indicative of less relative left-sided activity; Shagass, 1972) in depressed participants compared to nondepressed participants (Baehr, Rosenfeld, Baehr, & Earnest, 1998; Debener et al., 2000; Diego et al., 2001; Gotlib, Ranganath, & Rosenfeld, 1998; Henriques & Davidson, 1991; Pizzagalli et al., 2002; Schaffer, Davidson, & Saron, 1983), although contrary results have also been reported (Reid, Duke, & Allen, 1998). It is important to note that, because studies utilizing EEG asymmetry usually report a difference score of activity in the left vs. right hemisphere, these results are consistent with both diminished BAS and excessive BIS explanations for depression. That is, assuming that decreased left frontal activity indicates diminished BAS and increased right frontal activity indicates excessive BIS (see Coan & Allen, 2003 for a discussion of this assumption), then increased frontal asymmetry could indicate that depression is characterized by diminished BAS, excessive BIS, or a combination of the two. There is evidence that the asymmetry pattern characteristic of depression is driven by decreased left frontal activity (Allen, Iacono, Depue, & Arbisi, 1993; Gotlib et al., 1998; Henriques & Davidson, 1991), suggesting that diminished BAS may be a distinguishing feature of depression. There is also evidence of increased right frontal activity (excessive BIS) in anxiety (Davidson et al., 2000) and for greater frontal asymmetry in participants who are comorbid for anxiety and depression (Bruder, Fong, Tenke, & Leite, 1997). These results highlight the importance of assessing the role of anxiety in studies of BAS/BIS in depression (Heller & Nitscke, 1998; Shankman & Klein, 2003).

Taken together, these results provide substantial support for a model of depression as characterized primarily by deficits in BAS. However, several questions remain. First, the majority of the results reviewed above (i.e., self-reports and EEG) have focused on traitlike levels of BAS activity or sensitivity, as self-report studies typically include trait measures of BAS sensitivity, and EEG studies use resting EEG, which is hypothesized to be a stable risk factor. Although these results provide substantial evidence for diminished BAS as a traitlike risk factor for depression, they provide little information about the role of BAS in ongoing behavior and how it may be altered in depression. In other words, studies show that traitlike deficits in BAS are associated with risk for depression, but offer relatively limited evidence for decreased ongoing or momentary BAS function in depression. Those studies that do offer evidence of situational deficits in BAS among depressed participants have utilized signal detection rather than self-report methods, which makes them difficult to interpret in terms of emotional reactivity. Further, although there have been laboratory studies comparing depressed and nondepressed participants' reactions to reward and punishment contingencies, these studies have assessed only one (reward) or two (reward and punishment) of the four theoretically relevant situations that should engage either BAS or BIS. There remains a need for further research to understand what role BAS and BIS might play in depression in terms of influencing ongoing or momentary reactions to stimuli, particularly in situations of frustrative nonreward or avoidance of punishment.

The distinction between traitlike BAS deficits and the role of those deficits in ongoing behavior is conceptually similar to the distinction between moods and emotions, where moods are relatively persistent and emotions are relatively momentary. Rottenberg and colleagues (Rottenberg, 2005; Rottenberg & Gotlib, 2004; Rottenberg, Gross, & Gotlib, 2005) have emphasized this distinction and pointed out that, according to current formulations, depression necessarily involves a change in mood but not necessarily a change in emotional reactions. Rottenberg and Gotlib (2004) reviewed evidence for blunted emotional reactivity in depression and proposed the emotion context-insensitivity hypothesis, which states that depression is characterized by blunted emotional reactions to both positive and negative stimuli. A subsequent study yielded partial support for this hypothesis, as currently-depressed participants reported less sadness reactivity than both previously-depressed and never-depressed participants (Rottenberg et al., 2005). To the extent that emotional reactivity is indicative of BAS/BIS sensitivity, these findings are inconsistent with previous research when interpreted within the valence model of BAS/BIS. However, these findings provide additional insight into the possible role of BAS deficits in depression when interpreted within the incentive model of depression.

The valence model specifies that sadness reactivity is regulated by BIS. Hence, when results indicating diminished sadness reactivity among depressed participants are interpreted within the valence model, they suggest diminished BIS sensitivity in depression. The bulk of previous research, however, suggests increased BIS sensitivity in depression. Thus, results supporting the emotion context-insensitivity hypothesis (i.e., diminished sadness reactivity among depressed participants) contradict previous research when they are couched in terms of the valence model of BAS/BIS. By contrast, the incentive model of BAS/BIS specifies that sadness reactivity is regulated by BAS, at least when it is in response to nonreward. Hence, when results indicating diminished sadness reactivity among depressed participants are interpreted within the incentive model, they suggest diminished BAS sensitivity in depression. This is consistent with several previous studies. Thus, the emotion context-insensitivity hypothesis appears to be more consistent with previous research when it is couched in terms of the incentive model of BAS/BIS. That is, the incentive model might predict that depression, to the extent that it is characterized by diminished BAS sensitivity, should be associated with a tendency to respond with less PA (happiness, excitement) to reward *and* a tendency to respond with less NA (sadness, frustration) to nonreward but *not* a tendency to respond with either more or less NA (anxiety, tension) to punishment. Although Carver and Scheier (1998) do not specifically make this prediction, it is consistent with their model, *if depression is characterized by decreased BAS sensitivity*, as suggested by self-report (Kasch et al., 2002; McFarland et al., 2006) and behavioral studies (Forbes et al., 2007; Henriques & Davidson, 2000; Henriques et al., 1994; Pizzagalli et al., 2005).

However, it is not clear whether Carver and Scheier's (1998) model would predict decreased BAS *sensitivity* in depression. In fact, the model characterizes depressed affect as an adaptive response produced by a properly functioning BAS in response to inadequate progress toward goals. The model might predict that persistent depressed affect would arise from persistent failure to make adequate progress toward goals. This prediction is made explicitly in Strauman's (2002) self-regulation model of depression. Like Carver and Scheier's model, Strauman's model grew out of Higgins' (1997) regulatory focus theory. Strauman's model, however, centers on two self/brain/behavior systems: the promotion system as an expansion of BAS and the prevention system as an expansion of BIS. The model conceptualizes depression as a failure of the promotion system based on persistent perceived failures to achieve promotion goals. That is, the promotion system fails to motivate goal-directed behavior or facilitate PA because the individual has experienced chronic perceived failures and the feedback loop is "stuck" generating NA. From this perspective, depression might be characterized not by diminished sensitivity in BAS, but by a "shift" in BAS function characterized by less (or less frequent) activation at the positive pole (resulting in decreased PA) but greater (or more frequent) activation at the negative pole (resulting in increased NA). Such a shift might be caused by cognitive biases; that is, the increased tendency to perceive failure may be the source of the dysfunction. If this were true, we might expect to see greater sensitivity to cues of frustrative nonreward among depressed individuals, possibly because they are more vigilant for these cues.

Thus, the relative lack of studies utilizing a frustrative nonreward condition leaves substantial theoretical ambiguities regarding the possible role of BAS in depression. The frustrative nonreward condition is also important within the valence model of BAS/BIS, which predicts that NA in response to frustrative nonreward will be nonspecifically associated with both anxiety and depression because NA is a common factor in both disorders. In sum, a number of ambiguities regarding the role of BAS/BIS in depression are in need of clarification, including the relative contributions of BAS and BIS, the nature of BAS dysfunction, and the role of BAS/BIS in ongoing or momentary behavior and affect.

Study Design

This study was designed to address some of these questions regarding both the nature, or "structure", of BAS/BIS and the role of BAS/BIS in depression. The study assesses participants' self-reported emotional reactions to reward, punishment, frustrative nonreward, and avoidance of punishment. It also provides an opportunity to compare currently-depressed, previously-depressed (recovered), and never-depressed participants' emotional reactions to each of these conditions. Participants completed four blocks (sets) of computerized puzzle tasks under different incentive conditions. Participants' success or failure was predetermined for each block in order to guarantee that each participant experienced reward, punishment, nonreward, and avoidance. This provided an opportunity to examine the pattern of individual differences in emotional reactivity to these conditions, and to test whether currently-depressed, previously-depressed, and never-depressed participants differ in their reactivity to any or all of these conditions.

This study design makes several important contributions to previous research. First, by testing emotional reactions to each of these four conditions with each subject, it provides an opportunity to determine whether individual differences fit more closely with the valence model of BAS/BIS or the incentive model of BAS/BIS. Specifically, by examining the pattern of correlations among individuals' reactions to the four conditions, it is possible to examine whether individual differences in emotional reactivity fall more reliably along the lines of emotional valence (as in Figure 1) or along the lines of the types of cues eliciting them (as in Figure 2).

The second major issue addressed in this study is whether differences exist among currently-depressed, previously-depressed, and never-depressed participants in reactions to any or all of these four conditions. These analyses have implications for both the valence model and the incentive model, regardless of which is supported by the first set of analyses. For example, the valence model predicts a strong correlation between PA in response to reward and PA in response to avoidance, as both are regulated by BAS. If depression is characterized by diminished BAS activity (decreased PA), the valence model predicts that depressed participants will experience less PA in response to both reward and avoidance. This study will seek to replicate previous research indicating that depressed participants are less responsive to cues of reward by showing that depressed participants report less PA in response to reward than nondepressed participants. It will also seek to extend previous research by testing whether currently-depressed participants also report less PA in response to avoidance than nondepressed participants.

The valence model also predicts a strong correlation between NA in response to punishment and NA in response to nonreward, as both are regulated by BIS. If depression is characterized by excessive BIS activity, the valence model predicts that depressed participants will experience more NA in response to both punishment and nonreward. Two previous studies did not find any differences between depressed and nondepressed participants' responsiveness to punishment, but this may have been due mainly to a weak punishment manipulation. This study will test whether depressed and nondepressed participants report similar levels of NA in response to punishment. It will also seek to extend previous research by testing whether depressed and nondepressed participants report similar levels of NA in response to nonreward.

The incentive model predicts a strong correlation between PA in response to reward and NA in response to nonreward, as both are regulated by BAS. Although the incentive model clearly predicts that depression is characterized by dysfunction in BAS, it is unclear whether it predicts decreased BAS sensitivity (i.e., decreased responsiveness to both reward and nonreward) or "shifted" BAS sensitivity (i.e., decreased responsiveness to reward and increased responsiveness to nonreward). This study will seek to replicate previous research by showing the depressed participants report less PA in response to reward. It will also seek to extend previous research by testing whether depressed participants report less NA in response to nonreward (i.e., decreased BAS sensitivity) or more NA in response to nonreward (i.e., "shifted" BAS sensitivity).

Method

Participants

A total of 138 Stony Brook University undergraduates completed the experiment in partial fulfillment of course requirements. This total sample was divided into four overlapping subsamples that were formed on the basis of data obtained during the experiment (shown schematically in Figure 3). The *normative subsample* consisted of 119 participants who represented the normal range of depressive symptoms. The normative subsample included all 96 participants who scored below 16 on the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996) during the experiment, plus a randomly-selected group of 23 out of the 42 participants who scored 16 or higher on the BDI-II during the experiment. This resulted in a 19% rate of dysphoric and potentially depressed BDI-II scores (Kendall, Hollon, Beck, & Hammen, 1987) in the normative subsample, which was identical to the rate estimated in the entire population participating in the participant pool (see below). Because BAS and/or BIS function is hypothesized to be altered in depression, all analyses concerning the structure of BAS and BIS function were conducted using the normative subsample, which represents the normal range of depressive symptoms.

The remaining three subsamples were defined on the basis of current depressive symptoms and lifetime history of Major Depressive Disorder (MDD) and Dysthymic Disorder (DD). These latter subsamples did not overlap with each other, but each overlapped partly or wholly with the normative subsample. The *never-depressed subsample* consisted of 43 participants who scored below 10 on the BDI-II during the experiment and had never met DSM-IV (APA, 1994) criteria for either MDD or DD (all 43 of these participants were also in the normative subsample). The *previously-depressed subsample* consisted of 19 participants who scored below 10 on the BDI-II during the experiment and met DSM-IV criteria for a past (but not current) diagnosis of either MDD or DD (all 19 of these participants were also in the normative subsample). The *currently-depressed subsample* consisted of 19 participants who scored 16 or higher on the BDI-II during the experiment and met criteria for a current diagnosis of either MDD or DD (eight of these 19 participants were also in the normative subsample).

Table 1 presents demographic and clinical data for the total sample and for each subsample. None of the demographic variables had a significant relationship with emotional reactions during the experiment and are therefore not included in any further analyses.

Materials

Depression screener. The BDI-II was administered during mass testing sessions in consecutive semesters to identify individuals currently experiencing clinically significant levels of depressive symptoms. In order to increase the size of the currently-depressed subsample, I recruited participants with scores of 16 or higher by phone and/or email. A total of 909 participants completed the BDI-II during mass testing; of these, 174 scored 16 or higher, resulting in an estimated 19% base rate of dysphoric and potentially depressed participants in the participant pool.

Assessment of clinical status and personality. During the experiment, participants completed a semi-structured diagnostic interview consisting of the mood disorders section of the Structured Clinical Interview for DSM-IV (SCID; First, Spitzer, Gibbon, & Williams, 1995). The interview assessed the current and lifetime presence or absence of MDD, DD, bipolar disorder, and psychotic symptoms. The assessments were conducted by the experimenter, who was an advanced graduate student and master's level clinician with more than three years of experience using the SCID.

Participants also completed the BDI-II during the experiment. As described above, BDI-II scores obtained during the experiment were used to define the various subsamples.

Participants also completed a modified version of the Mood and Anxiety Symptoms Questionnaire (MASQ; Watson & Clark, 1991; Watson, Weber, Assenheimer, & Clark, 1995) to assess current severity of symptoms of depression and anxiety. In order to maximally differentiate between symptoms specific to depression and symptoms specific to anxiety, the modified version was designed to consist only of the 22-item Anhedonic Depression scale and the 17-item Anxious Arousal scale from the MASQ. These scales have been shown to be most specific to depression and anxiety, respectively (Watson, Clark, Weber, & Assenheimer, 1995). Due to a typographical error, one item from the Anhedonic Depression scale ("Felt unattractive") was inadvertently omitted, and one item from the General Distress: Anxious Symptoms scale ("Upset stomach") was inadvertently included. I included this latter item with the anxiety scale during data analyses because previous research showed that this item actually loads highly and exclusively on the same somatic anxiety factor that the other 17 anxiety items load on (Watson, Clark et al., 1995). The modified version of the MASQ administered during the experiment therefore consisted of a 21-item Anhedonic Depression scale (MASQ-Dep) and an 18-item Anxious Arousal scale (MASQ-Anx).

Participants also completed a modified version of the General Temperament Survey (GTS; Clark & Watson, 1990) that included only the items assessing Positive Temperament (GTS-PT) and Negative Temperament (GTS-NT). This measure was used to assess dispositional tendency to experience PA and NA.

Participants also completed three measures designed to assess BAS and/or BIS sensitivity. The Behavioral Inhibition / Behavioral Activation System Scales (BIS/BAS; Carver & White, 1994) consist of three BAS subscales – Drive (BAS-Drive), Fun Seeking (BAS-Fun), and Reward Responsiveness (BAS-RR) – and a BIS subscale. The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia et al., 2001) consists of a Reward subscale (SPSRQ-R) that assesses BAS sensitivity and a Punishment subscale (SPSRQ-P) that assesses BIS sensitivity. The Appetitive Motivation Scale (AMS; Jackson & Smillie, 2004) yields a one-dimensional total score assessing BAS sensitivity. Table 2 displays means, standard deviations, and reliability coefficients for questionnaire measures.

Experimental Task. Participants completed four sets of 40 "unconscious processing" puzzles. Participants were told that the purpose of the experiment was to examine the effects of some aspects of personality, mood, and motivation on their ability to process information more quickly than they were consciously aware of. The experimenter explained that the puzzles were designed to assess their ability to find the right answer before they were consciously aware that they had looked at everything they needed to. Each block of 40 puzzles consisted of either anagram puzzles or figure rotation puzzles. Each block was administered under either a reward incentive (trying to earn $5.00 in cash) or a punishment incentive (trying to avoid performing a cold pressor task for 60 seconds). For each block of puzzles, success was defined as choosing the correct response for at least 65% of the puzzles. The appendix shows the complete set of instructions given to participants. Unbeknownst to the participants, each block of puzzles was predetermined to result in either success or failure.

For anagrams, participants saw a 12-letter, affectively neutral word (e.g., colloquially, weathercasts, dictionaries) in the center of the screen. On each side of the target word, in a slightly smaller font, was a string of 12 letters arranged alphabetically. For each puzzle, both letter strings contained 11 correct letters and one incorrect letter. Hence, both answer choices were wrong for every anagram puzzle. Each puzzle was preceded by a fixation point in the center of the screen that appeared for 1.7 seconds, followed by the puzzle for 2.2 seconds. Immediately afterward, a screen appeared with the stimulus prompt asking “Which was the same?” in the center of the screen, flanked by the letter Q on the left side of the screen and the letter P on the right side. Participants chose either the left or right answer choice by pushing either Q or P on the keyboard. This prompt remained on the screen until the participant chose either Q or P. Upon choosing an answer choice, the next trial began with the fixation point. Figure 4 shows a sample anagram trial.

For figure rotations, participants saw one of the complex 3-dimensional figures used by Shepard and Metzler (1971) in the center of the screen (images provided courtesy of Roger N. Shepard and downloaded from http://www.cog.brown.edu/~tarr/stimuli.html). On each side of the target figure was a slightly smaller recreation of a similar (but not identical) figure oriented to appear similar to the target figure having been rotated in space. The two answer choices were in fact identical to each other but rotated differently so as to appear maximally different. Hence, as with the anagram puzzles, each figure rotation puzzle had two incorrect answer choices that both looked very close to being correct. Figure 5 shows a sample figure rotation trial.

During each block of puzzles, participants received feedback regarding their performance at four time points: after completing 20, 30, 35, and 40 puzzles. These feedback messages appeared on the screen for 9 seconds each. The feedback messages indicated how many puzzles had supposedly been completed so far, what percent were correct, and what consequence would follow from the current level of performance. For example, during the reward block, the first feedback screen stated, “You have completed 20 puzzles with 70% correct. If you maintain this level of performance, you will receive $5.00 in cash.” During the punishment block, each feedback screen concluded with, “If your performance does not improve, you will be required to perform the cold pressor test.” During the nonreward block, each feedback screen concluded with, “If you maintain this level of performance, you will NOT receive $5.00 in cash.” During the avoidance block, each feedback screen concluded with, “If you maintain this level of performance, you will NOT be required to perform the cold pressor test.” The feedback screens were designed so that each one was consistent with the eventual (predetermined) outcome of the block (i.e., during the reward and avoidance blocks, all the percentages were above 65%, whereas during the punishment and nonreward blocks all the percentages were below 65%). In order to enhance the deception, the percentages fluctuated slightly but had an overall trend indicating improved performance over time.

For the first success block, the percentages were 70, 73, 69, and 70; for the second success block, the percentages were 75, 70, 74, and 73. For the first failure block, the percentages were 55, 53, 57, and 58; for the second failure block, the percentages were 60, 63, 57, and 60.

The blocks were administered in one of four set sequences to which participants were randomly assigned. The four sequences were based on a Latin square design that counterbalanced the position of the four conditions, how frequently success followed success vs. failure (and vice-versa), and how frequently the cash incentive was followed by the cold pressor incentive vs. the cash incentive (and vice-versa). The four sequences were as follows: (1) nonreward, punishment, reward, avoidance; (2) punishment, avoidance, nonreward, reward; (3) reward, nonreward, avoidance, punishment; and (4) avoidance, reward, punishment, nonreward. Hence, each condition appeared once in each position in the sequence; each position in the sequence was equally likely to result in success vs. failure; successful blocks were equally likely to be immediately preceded by successful or unsuccessful blocks; and blocks were equally likely to be immediately preceded by blocks utilizing the same or different incentive. Furthermore, within each incentive, success was equally likely to occur before or after failure (e.g., in two sequences, reward preceded nonreward and in two sequences nonreward preceded reward). It must be pointed out, however, that the two sequences in which nonreward preceded reward were also the two in which punishment preceded avoidance.

In order to enhance the deception, the sequences were also designed so that each participant experienced success on one type of puzzle (anagrams or figure rotations) and failure on the other type (e.g., for sequence 1, punishment and nonreward blocks were anagrams, whereas reward and avoidance blocks were figure rotations). Whether participants succeeded on anagrams or figure rotations was counterbalanced across the sequences. (For sequence 1 & 3, participants “failed” on anagrams and “succeeded” on figure rotations. For sequences 2 & 4, participants “failed” on figure rotations and “succeeded” on). Participants were also equally likely to start with a block of anagrams or with a block of figure rotations. Pilot testing indicated that emotional reactions were not affected by type of puzzle. Debriefing interviews revealed that almost all participants rated the puzzles they “failed” on as more difficult than those they “succeeded” on, suggesting that the perceived difficulty of each type of puzzle was almost entirely due to the feedback they received.

In between each block of puzzles, participants received the reward or punishment they had just earned (if applicable) and then spent between 3.5 and 4.5 minutes completing a filler task. The filler tasks were the Vocabulary and Matrix Reasoning subtests from the Wechsler Adult Intelligence Scale, Third Edition (WAIS-III; Wechsler, 1997). These were administered in a nonstandardized manner by starting in the middle and proceeding forward until a ceiling level was established and then backward until a basal level was established. As a result, participants were equally likely to be working on very difficult or very easy WAIS-III items when they proceeded to the next block of computerized puzzles.

Affect ratings. Immediately before and after each block of puzzles, participants rated their current mood on the computer. They rated themselves on a 1-9 scale on 10 adjectives presented in a fixed order: tense, discouraged, relaxed, happy, annoyed, nervous, sad, at ease, enthusiastic, frustrated. These adjectives were culled from the

Positive and Negative Affect Schedule – Expanded Form (PANAS-X; Watson & Clark, 1994) and from previous studies utilizing similar designs (Carver, 2004; Higgins, Shah, & Friedman, 1997). The items were chosen to represent theoretically important types of emotional reactions to the experimental conditions, with a particular emphasis on the frustrative nonreward condition.

The appendix includes the rationale presented to participants for assessing affect, as well as a sample affect assessment. The affect ratings were collected eight times during the experiment (i.e., before and after each block of puzzles.) The first set of affect ratings was collected after the participants had completed the instructions (including five sample anagrams and five sample figure rotations). After completing this first set of affect ratings, the instructions for the first block of puzzles appeared. Hence, the affect ratings before each block of puzzles were collected *before* participants knew which incentive or which type of puzzles the block would consistent of. The second set of affect ratings (the set collected immediately after the completion of the block) was collected immediately following the final feedback screen but before the reward or punishment was administered (if applicable). Thus, for each block of puzzles, two sets of affect ratings were collected: a pre-block set of ratings taken before the participants knew anything about what the block would contain, and a post-block set of ratings taken immediately after either success or failure but before receiving the external consequences of success or failure.

Reward and Punishment. As noted above, the reward was $5.00 in cash and the punishment was 60 seconds holding one hand in a cold pressor. The cold pressor used during the experiment consisted of a foam cooler filled with ice water and several ice packs. The temperature of the cold pressor was relatively constant at around 34 degrees Fahrenheit. Immediately after completing the post-block affect ratings following the reward block, participants saw a screen stating, “You have completed this assessment. You will now receive $5.00 in cash. Please see the experimenter.” The experimenter then gave them $5.00 in cash and asked them to rate on a scale of 1-10 how nice it was to receive it. Similarly, immediately after completing the post-block affect ratings following the punishment block, participants saw a screen stating, “You have completed this assessment. You will now perform the cold pressor test. Please see the experimenter.” Participants then held their hand in the cold pressor for 60 seconds, or until they indicated they could not stand it any longer. The experimenter then asked them to rate on a scale of 1-10 how bad it was to hold their hand in the cold pressor.

Procedure

Participants were greeted by the experimenter, who explained that the purpose of the experiment was “to examine the effects of personality, emotion, and motivation on unconscious processing.” The experimenter then briefly explained the procedures involved in the experiment, including the reward and punishment and the assessment of symptoms of depression. Participants were reminded several times that they were volunteers and had the right to leave at any time with no penalty. Furthermore, both the written consent form and the experimenter’s verbal instructions clearly stated that participants should not perform the cold pressor for any longer than they felt they could reasonably stand it. After a thorough overview of the experiment, each participant read and signed an informed consent form, which was countersigned by the experimenter.

To make the incentives more salient, the experimenter showed the participants an envelope containing cash and then showed them the cold pressor. Participants were also asked to rate on a scale of 1-10 how nice they thought it would be to receive $5.00 in cash, and to rate on a scale of 1-10 how bad or unpleasant it would be to have to hold their hand in the cold pressor for 60 seconds. Most participants rated the anticipated pleasantness of the potential reward very highly (*M* [*SD*] = 7.30 [2.15]), but many rated the anticipated unpleasantness of the cold pressor relatively lowly (*M* [*SD*] = 5.95 [2.22]). In order to heighten the threat of the cold pressor, the experimenter casually remarked, "Most people rate it at least an eight."

Participants did not perform the cold pressor test until after they had completed the punishment block. This was because pilot testing indicated that rankings of anticipatory nervousness after the punishment block were higher when participants had not yet performed the cold pressor than when they had performed it at the beginning of the testing session to become familiar with it. Thus, when participants completed the punishment block and rated their post-punishment mood, none had yet performed the cold pressor test. However, when participants completed the avoidance block and rated their post-avoidance mood, half of them had previously performed the cold pressor test (i.e., because the punishment block preceded the avoidance block) and half had not (i.e., because the avoidance block preceded the punishment block). This asymmetry in experiential familiarity with the cold pressor test is discussed further below.

After completing the four blocks of computerized puzzles, participants completed the clinical interview and the questionnaires. They were then thoroughly debriefed and thanked for their participation. As part of the debriefing, participants who reported clinically significant affective symptoms were referred to the University Counseling Center for mental health services. All participants were given a list of contact information for several nearby mental health services providers.

Results

Data Reduction

I combined affect ratings to form composite scores representing target emotions, each of which is theoretically relevant to a particular experimental condition. As shown in Table 3, emotion composites consisted of the mean of two items each for the reward, punishment, and avoidance conditions. For the nonreward condition, which is of particular theoretical relevance, the mean of four items comprised the composite. This latter combination might appear problematic because two of the items (discouraged, sad) represent low-arousal negative affects and two (frustrated, annoyed) represent high-arousal negative affects. However, all four adjectives were strongly correlated (as shown in Table 3). To be more specific, discouraged and sad correlated $r = .45$, $p < .001$, and frustrated and annoyed correlated $r = .68$, $p < .001$. In turn, a low-arousal sadness composite (i.e., the mean of discouraged and sad) and high-arousal frustration composite (i.e., the mean of frustrated and annoyed) correlated $r = .67$, $p < .001$. Furthermore, results presented below do not differ meaningfully when either the low-arousal or high-arousal composite is used in place of the four-adjective Sadness/Frustration composite described in Table 3.

Manipulation Check

I tested the effectiveness of the experimental manipulation in inducing changes in target emotions. To do so, I compared participants' ratings on affect composites (Joviality, Anxiety, Sadness/Frustration, and Serenity) immediately before and after target blocks. As shown in Table 4, paired-samples *t*-tests revealed that ratings on target emotions were significantly higher immediately after target blocks than immediately before, indicating that each manipulation produced the intended effect on participants' affect ratings.

I also tested the effectiveness of the filler task in allowing emotional reactions to dissipate before the next experimental block. To do so, I compared participants' ratings on affect composites immediately after target blocks and immediately before the next block (i.e., after spending 3.5-4.5 minutes on the filler task). As shown in Table 5, paired-samples *t*-tests revealed that ratings on target composites were significantly lower after the filler task than immediately after the target block, indicating that target emotions decreased during the filler task.

Strength of Reward and Punishment

A comparison of effect sizes in Table 4 reveals that the reward and nonreward conditions induced substantially greater changes in target affect ratings than the punishment and avoidance conditions. In fact, effect sizes were roughly twice as large for the reward and nonreward conditions as for the punishment and avoidance conditions. These results suggest that the $5.00 cash reward represented a much stronger incentive than the 60-second cold pressor punishment. This makes comparisons among the various conditions problematic, as the different incentives appear to have differed not only qualitatively, but quantitatively as well. Indeed, participants' subjective ratings (1-10) of "how nice or pleasant" it was to receive $5.00 (*M* [*SD*] = 8.39 [1.72]) were significantly higher than their subjective ratings (1-10) of "how bad or unpleasant" it was to hold their hand in the cold pressor for 60 seconds (*M* [*SD*] = 7.74 [2.08]), $t(134) = 3.10$, $p = .002$, Cohen's $d = .34$.

In contrast, some additional data collected during the experiment suggested that the reward and punishment may have been roughly equivalent in subjective intensity. At the end of the experiment, participants were asked how much money the experimenter would have to pay them to get them to perform the cold pressor test again. They were also asked how much money they would be willing to pay the experimenter in order to get out of performing the cold pressor test again. The order of these two questions was counterbalanced across participants, and each price was negotiated in order to reach the most realistic monetary value possible. After eliminating two extreme outliers (amounts greater than $250.00), the mean (*SD*) amount participants said they would hold out for was $6.33 (9.51) and the mean (*SD*) amount they said they would be willing to pay was $3.35 (6.96). The grand mean (*SD*) of all these ratings was $5.08 (8.56), which is nearly identical to the $5.00 reward. Thus, there is some limited evidence that participants experienced the reward and punishment as being roughly equal in intensity. However, the preponderance of evidence suggests that the reward/nonreward manipulation was substantially more powerful than the punishment/avoidance manipulation. Thus, analyses that directly compare reactions to the various conditions must be interpreted cautiously.

Structure of BAS and BIS Sensitivity

I compared participants' emotional reactions to reward, punishment, nonreward, and avoidance in order to test whether the pattern of correlations fit more closely with the valence model or the incentive model of BAS and BIS sensitivity. As indicators of emotional reactivity, I calculated regressed change scores for each composite emotion rating during target blocks. That is, I created standardized residuals of composite ratings at the end of target blocks after controlling for ratings at the beginning of target blocks by conducting four separate linear regressions predicting end-of-block composite ratings from beginning-of-block composite ratings and saving the standardized residuals as regressed change scores. This method is preferred over calculating simple difference scores because it removes the influence of beginning-of-block ratings, yielding a purer measure of change (Cohen, Cohen, West, & Aiken, 2003). For purposes of comparison, however, I also calculated simple difference scores by subtracting beginning composite ratings from ending composite ratings. Table 6 shows the correlation matrix for regressed change scores and simple difference scores. Notably, regressed change scores and simple difference scores were highly correlated: correlations between regressed change scores and simple difference scores ranged from $r = .87$ for Joviality to $r = .99$ for Sadness/Frustration. When I repeated the analyses below using simple difference scores, the results were nearly identical but generally slightly weaker statistically (i.e., some significant results were reduced to trend levels).

Among the correlations presented in Table 6, four are of particular interest because they represent predictions made by the valence and incentive models of BAS and BIS reactivity. The valence model predicts that the correlation between Joviality and Serenity (BAS) and the correlation between Anxiety and Sadness/Frustration (BIS) should be relatively stronger than other correlations because they represent reactivity within the same valence. The incentive model predicts that the correlation between Joviality and Sadness/Frustration (BAS) and the correlation between Anxiety and Serenity (BIS) should be relatively stronger than other correlations because they represent reactivity within the same incentive. Figure 6 depicts these four correlations within the normative subsample. Results revealed that the correlation between Joviality and Serenity (predicted by the valence model of BAS) was positive but nonsignificant ($r = .13$, $p = .17$) and the correlation between Sadness/Frustration and Anxiety (predicted by the valence model of BIS) was positive and significant ($r = .30$, $p = .001$). Conversely, the correlation between Joviality and Sadness/Frustration (predicted by the incentive model of BAS) was positive and significant ($r = .39$, $p < .001$) and the correlation between Serenity and Anxiety (predicted by the incentive model of BIS) was essentially zero ($r = -.03$, $p = .71$). Thus, these results do not clearly support one model of BAS/BIS more than the other. Rather, the incentive model of BAS and the valence model of BIS were most clearly supported.

Order Effects

Each participant experienced the four experimental conditions in one of four set sequences, as outlined above. To test whether the order of presentation of conditions had an effect on participants' emotional reactions, I conducted four separate one-way ANOVAs using regressed change scores within the normative subsample (n = 119). Results showed that the order of experimental blocks had a significant effect on Serenity regressed change scores, $F(3, 115) = 5.39$, $p = .002$. Follow-up comparisons with Tukey's honestly significant difference test revealed that Serenity regressed change scores were significantly smaller for the fourth sequence (avoidance, reward, punishment, nonreward) than for both the first sequence (nonreward, punishment, reward, avoidance) and the second sequence (punishment, avoidance, nonreward, reward). Serenity regressed change scores for the third sequence (reward, nonreward, avoidance, punishment) were intermediate and not significantly different from any other sequence. Regressed change scores for Joviality, Anxiety, and Sadness/Frustration did not differ significantly across sequences (all Fs < 1.6, all ps > .20).

As noted above, an important (though unintended) consequence of the study design was that roughly half of the participants had not yet experienced the cold pressor test when they completed the avoidance block, and, hence, did not know experientially what they were avoiding. Thus, a logical a priori division of the four sequences is to compare the two in which punishment preceded avoidance (i.e., the first and second sequences) with the two in which avoidance preceded punishment (i.e., the third and fourth sequences). An independent-samples t-test revealed that Serenity regressed change scores were significantly larger for participants who experienced punishment before avoidance (M [SD] = 0.28 [0.83], n = 59) than for participants who experienced avoidance before punishment (M [SD] = -0.30 [1.07], n = 60), $t(117) = 3.30$, $p = .001$. Regressed change scores on Joviality, Anxiety, and Sadness/Frustration did not differ significantly between these subsets (all ts < 1.3, all ps > .20).

To test whether the relative order of punishment and avoidance significantly affected the relationship between Serenity and either Joviality or Anxiety, I conducted two separate regression analyses. In each regression analysis, the predictor variables entered were Serenity regressed change scores, sequence (punishment before avoidance vs. avoidance before punishment), and the interaction of Serenity regressed change scores and sequence. For the first regression analysis, the criterion variable was Joviality regressed change. Results revealed that the interaction term was significant (standardized beta = -.78, p = .02), indicating that the relationship between Serenity regressed change and Joviality regressed change depended on the relative order of punishment and avoidance. For the second regression analysis, the criterion variable was Anxiety regressed change. Results revealed that the interaction term was not significant (standardized beta = -.26, p = .45), indicating that the relationship between Serenity regressed change and Anxiety regressed change did not depend on the relative order of punishment and avoidance. Table 7 presents the correlation matrix of regressed change scores in target emotions obtained from the participants within the normative subsample who experienced punishment before avoidance (above the diagonal) and the participants within the normative subsample who experienced avoidance before punishment (below the diagonal). The only notable difference between the two groups is that the correlation between Serenity and Joviality regressed change was positive and significant when punishment preceded avoidance (r = .34, p = .008), whereas it was essentially zero when avoidance preceded punishment (r = -.04, p = .77).

The pattern of results obtained when punishment preceded avoidance is of particular interest because, under these circumstances, the avoidance manipulation was significantly stronger and therefore more comparable to the other conditions. Furthermore, the avoidance condition was more similar to the reward and nonreward conditions when punishment preceded avoidance because participants knew experientially what was at stake. Figure 7 depicts the results obtained using the participants within the normative subsample who experienced punishment before avoidance. Notably, both correlations predicted by the valence model are significant, indicating relatively strong support for the valence model. However, the correlation between Joviality and Sadness/Frustration is also significant (and of the greatest magnitude), suggesting that the valence model is inadequate to fully explain the results. In fact, the only predicted relationship not obtained from these results is the correlation between Serenity and Anxiety predicted by the incentive model of BIS.

Self-report Measures

Table 8 shows the correlation matrix of self-report scales within the normative subsample (n = 119) and the full sample (N = 138). Scales representing tendency to experience positive emotions (GTS-PT, BAS scales, SPSR-R, AMS) were all significantly and positively correlated. Likewise, scales representing tendency to experience negative emotions (GTS-NT, BIS, SPSRQ-P, MASQ-Anx, MASQ-Dep, BDI-II) were all significantly and positively correlated. Positive and negative scales tended to correlate negatively, though these correlations were often not significant. Additionally, the theoretically unexpected, but commonly observed (Smillie, Jackson, & Dalgleish, 2006), positive correlation between BAS-RR and BIS was present in these results.

To explore the utility of the self-report scales in predicting emotional reactions to reward, punishment, nonreward, and avoidance, I computed correlations between each scale and ratings on target composite emotions at the end of each target block (i.e., self-report scales predicting ending level of emotions). As shown in Table 9, there were few significant relationships between self-report scales and end-of-block ratings on target emotions. A few significant correlations were observed where theoretically predicted: GTS-PT was positively correlated with Joviality after reward; SPSRQ-R was positively correlated with Joviality after reward and with Sadness/Frustration after nonreward; and MASQ-Dep was negatively correlated with Joviality after reward. A few additional correlations were observed that appear reasonable logically but are not clearly predicted theoretically. MASQ-Anx was significantly correlated with Sadness/Frustration after nonreward but not with Anxiety after punishment. Furthermore, MASQ-Dep and BDI-II were both negatively correlated with Serenity after avoidance, which is not expected beyond a general negative relationship between measures of depression and measures of positive emotions. Perhaps the most unexpected relationship observed was a significant negative correlation between BAS-Fun and Anxiety after punishment. Again, this correlation is broadly consistent with a negative relationship between a given negative emotion and the tendency to experience positive emotions, but the more-clearly-hypothesized relationship between BAS-Fun and Joviality after reward was not observed. In fact, several of the most clearly hypothesized relationships did not approach significance (e.g., BAS scales and Joviality after reward, BIS and Anxiety after punishment).

The results presented in Table 9 show the utility of self-report measures in predicting end-of-block ratings without controlling for beginning-of-block ratings. I also tested the utility of self-report measures in predicting end-of-block ratings after controlling for beginning-of-block ratings by using regressed change scores. Table 10 presents bivariate correlations between self-report scales and regressed change scores on target emotions. Results were generally similar to those obtained using end-of-block scores, and only a few significant correlations were observed. A few correlations that were significant in Table 9 were also significant in Table 10: SPSRQ-R was positively correlated with both Joviality and Sadness/Frustration regressed change; MASQ-Dep was negatively correlated with Joviality regressed change. Several correlations that were significant in Table 9 were not significant in Table 10: GTS-PT and Joviality; BAS-Fun and Anxiety; SPSRQ-P and Anxiety; MASQ-Anx and Sadness/Frustration; BDI-II and Sadness/Frustration. Additionally, two correlations that were not significant in Table 9 were significant in Table 10: BAS-RR and BIS were each positively correlated with Anxiety regressed change.

Differences among Never-depressed, Previously-depressed, and Currently-depressed Participants

I compared emotion ratings and emotional reactivity among the never-depressed subsample ($n = 43$), the previously-depressed subsample ($n = 19$), and the currently-depressed subsample ($n = 19$). Table 11 displays means and standard deviations of target emotion composite scores before and after each target block for each subsample. Currently-depressed participants' ratings tended to be lower on positive emotions and higher on negative emotions than never-depressed participants'. This tendency was statistically significant for Joviality after reward, Sadness/Frustration before and after reward, and Serenity before and after avoidance. Previously-depressed participants' ratings tended to be intermediate between currently-depressed and never-depressed participants', often not differing significantly from either. Previously-depressed participants' ratings were significantly lower than currently-depressed participants' ratings on Anxiety before punishment and Sadness/Frustration before nonreward.

I conducted four separate ANOVAs comparing the never-depressed, previously-depressed, and currently-depressed participants' regressed change scores on target emotions. Results revealed a significant difference among groups on Joviality regressed change scores, $F(2, 78) = 3.63$, $p = .031$. Follow-up comparisons using Tukey's honestly significant difference revealed that the currently-depressed participants had significantly lower Joviality regressed change scores (M [SD] = -.45 [.88]) than the never-depressed participants (M [SD] = .22 [.82]), $p = .030$. Previously-depressed participants' Joviality regressed change scores (M [SD] = .20 [1.23]) appeared to be much more similar to the never-depressed participants' than to the currently-depressed participants', but were only marginally different from the currently-depressed participants' scores, $p = .093$. ANOVAs revealed no significant differences among groups on Anxiety, Sadness/Frustration, or Serenity reactivity, all Fs < 1.3, all ps > .30. An additional ANOVA comparing groups on Sadness reactivity using only low-arousal adjectives (i.e., discouraged, sad) also revealed no significant differences, $F(2, 78) = .06$, $p = .94$.

I also compared the never-depressed, previously-depressed, and currently-depressed participants on their responses to self-report scales. Table 12 shows means and standard deviations on questionnaire scores for the three groups. By definition, the currently-depressed participants scored higher on the BDI-II than the never-depressed and previously-depressed participants because current BDI-II score was used in defining groups. Separate one-way ANOVAs revealed significant differences among groups on all scales except BAS-Fun and SPSRQ-R. Follow-up comparisons with Tukey's honestly significant difference test revealed that for all scales on which a significant difference among groups was observed, the currently-depressed participants' scores were significantly different from the never-depressed participants' scores, except BAS-RR. Compared with never-depressed participants, currently-depressed participants scored significantly lower on GTS-PT, BAS-Drive, BAS Total, and AMS, and significantly higher on GTS-NT, BIS, SPSRQ-P, MASQ-Anx, and MASQ-Dep. Previously-depressed participants' scores again tended to be intermediate between never-depressed and currently-depressed participants', but were generally much more similar to never-depressed participants' than to currently-depressed participants' scores. On GTS-PT, BAS-Drive, BAS Total, BIS, AMS, MASQ-Anx, and MASQ-Dep, previously-depressed participants' scores were significantly different from currently-depressed participants' but not significantly different from never-depressed participants'. On GTS-NT and SPSRQ-P, previously-depressed participants' scores were significantly different from both other groups'. The exception to this pattern was BAS-RR, on which previously-depressed participants' scores were significantly higher than currently-depressed participants' but not significantly different from never-depressed participants'.

Discussion

This study was designed to explore two main questions. First, I explored the structure of BAS/BIS sensitivity by testing whether the valence model or the incentive model better captured the pattern of individual differences in emotional reactions to various conditions. To this end, I tested whether individual differences in emotional reactions were more closely related to the valence of the emotions or to the types of incentives eliciting the reactions. Second, I explored the role of BAS/BIS in depression by testing whether depressed participants differed significantly from nondepressed participants in their emotional reactions to various conditions or in their responses to self-report measures of BAS/BIS sensitivity.

Structure of BAS/BIS

Structural analyses did not clearly support either the valence model or the incentive model of BAS/BIS. Instead, each model received partial support. Support for the valence model of BIS was consistently observed, but support for the valence model of BAS was limited and depended on the order in which participants experienced the various conditions. Conversely, support for the incentive model of BAS was consistently observed, but support for the incentive model of BIS was completely absent.

Specifically, the valence model of BIS predicts that individual differences in the tendency to experience anxiety (tension, nervousness) in response to punishment should be related to individual differences in the tendency to experience sadness and frustration in response to nonreward. This portion of the model was supported by a significant positive correlation between anxiety reactivity and sadness/frustration reactivity, which was independent of the order in which the various conditions occurred. The valence model of BAS predicts that individual differences in the tendency to experience joviality (happiness, enthusiasm) in response to reward should be related to individual differences in the tendency to experience serenity (relaxation, ease) in response to successful avoidance of punishment. This portion of the model was supported only for participants who experienced avoidance after having previously experienced punishment. When punishment preceded avoidance, the correlation between joviality reactivity and serenity reactivity was positive and significant. However, when avoidance preceded punishment, the correlation between joviality reactivity and serenity reactivity was essentially zero. It can be argued that the strongest test of the valence model of BAS is obtained when punishment precedes avoidance, because it makes the successful avoidance of the punishment more salient. Indeed, when participants knew experientially what they had successfully avoided, their reactions were significantly stronger. The added salience and strength of the avoidance condition when it was preceded by punishment would serve to make it more equivalent to the reward condition, which was quite salient, as participants had previously seen the cash reward and rated the prospect of receiving it very highly. Among participants who experienced this order of events, the valence model of BAS/BIS is clearly supported. Nonetheless, the lack of support for the valence model of BAS among participants who experienced a different order of events, as well as the presence of strong correlations not predicted by the valence model of BAS/BIS, suggest that the valence model may be inadequate.

On the other hand, the incentive model of BAS predicts that individual differences in the tendency to experience joviality in response to reward should be related to individual differences in the tendency to experience sadness and frustration in response to nonreward. This portion of the model was supported by a significant positive correlation between joviality reactivity and sadness/frustration reactivity, which was independent of the order in which the various conditions occurred. The incentive model of BIS predicts that individual differences in the tendency to experience anxiety in response to punishment should be related to individual differences in the tendency to experience serenity in response to avoidance. This portion of the model was not supported, as the correlation between anxiety reactivity and serenity reactivity was essentially zero, regardless of the order in which the various conditions occurred. This pattern of support for the incentive model of BAS but not BIS may have been influenced by the fact that the reward manipulation was stronger than the punishment manipulation. However, the punishment manipulation was not so weak as to fully account for the lack of support for the incentive model of BIS.

Overall, then, the pattern of individual differences in self-reported emotional reactions to the various conditions in this experiment provided substantial support for the incentive model of BAS and the valence model of BIS, as well as modest but inconsistent support for the valence model of BAS. This suggests that, overall, affective valence may be more broadly applicable than incentive as a defining dimension of personality and affective style. However, the relationship between reactions to reward and nonreward, which is not captured by the valence model, demands further consideration.

The valence model is based mainly on the work of Gray and his colleagues, which focuses much more explicitly on the role of BIS than BAS. Indeed, Gray's model of BAS was articulated more or less as speculation (Smillie, Pickering et al., 2006) to complement his well-developed model of BIS. It is perhaps not surprising, then, that the results of this experiment provided much stronger support for Gray's model of BIS than his model of BAS. By the same token, the incentive model is based mainly on the work of Carver and his colleagues, which has focused much more explicitly on the role of BAS than BIS. To date, Carver and his colleagues have published several studies explicitly linking reactions to reward and nonreward with BAS but only one study explicitly linking reactions to punishment with BIS. His published work has not yet included any empirical support for a link between reactions to avoidance and BIS. It is perhaps not surprising, in turn, that the results of this experiment provided strong support for Carver's model of BAS but no support for his model of BIS. In summary, the results of the structural analysis of BAS/BIS are consistent with previous work in confirming the most developed aspects of each theory.

These results do perhaps call into question the viability of utilizing a nonreward condition as an experimental induction to engage BIS. These results, and those of Carver (2004) suggest that nonreward induces particular affective reactions that are at least partially distinct from the increased anxiety that is characteristic of BIS functioning. Furthermore, the significant positive correlation in this experiment between joviality and sadness/frustration reactivity suggests that reactivity to nonreward may be mediated by BAS more than BIS. In fact, the joint subsystems hypothesis (Corr, 2002), in which BAS and BIS are mutually inhibitory, would predict that sadness/frustration reactivity should be *negatively* correlated with joviality reactivity. Again, the fact that they were significantly positively correlated in this study may indicate that the nonreward condition engages BAS more than BIS. On the other hand, the joint subsystems hypothesis also predicts that joviality reactivity should be negatively correlated with anxiety reactivity, and these were also significantly positively correlated in this study. This suggests that the positive correlations observed among regressed change scores may be due at least partly to individual differences in general emotional reactivity (i.e., reactivity in all emotions, rather than emotions related to a particular valence or incentive) (Larsen & Diener, 1987). Hence, the positive correlation observed between joviality and sadness/frustration reactivity may not necessarily indicate that nonreward is particularly related to either BAS or BIS. Nonetheless, these results combine with previous studies to suggest that reactions to nonreward are at least partially mediated by BAS.

Two recent physiological studies of BAS/BIS sensitivity offer further suggestion that nonreward may engage BAS. One study examined oscillations in theta and high frequency EEG as an index of emotional arousal (Knyazev & Slobodskoj-Plusnin, 2007). Results showed that individuals with high self-reported BAS-Drive scores exhibited increased emotional arousal following reward (money added for good performance) and decreased emotional arousal following punishment (money deducted for poor performance). These results were taken as support for the joint subsystems hypothesis, as they suggested that individuals with increased BAS reactivity exhibited diminished BIS reactivity (Knyazev & Slobodskoj-Plusnin, 2007). In other words, there was evidence that increased BAS sensitivity was associated with increased reactivity to reward and decreased reactivity to punishment. Contrast these results with those obtained from a study that examined reactivity in respiratory sinus arrhythmia (RSA), a putative physiological measure of BAS functioning (Brenner et al., 2005). Results showed increased RSA reactivity during both reward (money added for correct responses) and nonreward (no money added, despite correct responses). Furthermore, during reward, self-reported BAS-Drive and BAS-RR scores were nonsignificantly but positively correlated with RSA reactivity; during nonreward, self-reported BAS-Drive was nonsignificantly positively correlated with RSA and BAS-RR was significantly positively correlated with RSA (Brenner et al., 2005). Hence, there was evidence, albeit limited, that increased BAS sensitivity was associated with increased reactivity to both reward and nonreward. Taken together, these two studies provide some evidence to suggest that increased BAS is associated with increased responsiveness to both reward and nonreward but decreased responsiveness to punishment. Again, this was not the same pattern observed in the current study, but the pattern of findings across the three studies does suggest the need for further inquiry as to whether nonreward conditions engage BAS, BIS, or both.

Higgins' group has consistently found differences between failing to prevent something bad from happening (i.e, punishment) and failing to make something good happen (i.e., nonreward), whether these conditions are experimentally induced or measured as chronic individual differences in perception (Higgins, Bond, Klein, & Strauman, 1986; Idson, Liberman, & Higgins, 2000; Shah & Higgins, 2001; Strauman, 1989, 1992; Strauman & Higgins, 1987). They interpret these findings within the framework of regulatory focus theory, where punishment represents failure within a prevention focus and nonreward represents failure within a promotion focus. Although prevention and promotion orientations are very similar to the incentive models of BIS and BAS, respectively, they include added cognitive complexities, including the concept of the self and participants' awareness of the self. Within this framework, prevention orientation is consistently associated with emotional reactions on a dimension of agitation-quiescence and promotion orientation is consistently associated with emotional reactions on a dimension of cheerfulness-dejection. This pattern has not been fully explained within a more basic framework of BAS/BIS, and indeed it may not be conceptually possible to do so. In other words, it is possible that the distinctions between punishment and nonreward and between reward and avoidance are only meaningful within a more complex theoretical framework that includes the self (Strauman, 2002).

Another methodological issue in this area concerns the assertion that BIS is engaged by conflict between incentives. According to the recent revisions to Gray's theory, conflicting incentives in the environment engage BIS, which heightens anxiety as the organism cautiously approaches threatening or unpleasant stimuli (McNaughton & Corr, 2004). Great care has been taken to distinguish BIS from the fight/flight/freeze system (FFFS), which creates fear to facilitate active avoidance of threat (McNaughton & Corr, 2004; Smillie, Pickering et al., 2006). Some authors have criticized researchers who implicitly simplify BIS as engaged simply by cues of punishment (which may instead engage the FFFS), rather than specifying the necessity of conflict between cues. However, as recently discussed by Brenner et al. (2005), a "pure punishment" condition that could be used to test individual differences in FFFS is probably impossible to ethically establish with human participants. Therefore, it seems likely that previous research with human participants that included punishment conditions engaged BIS rather than FFFS. In the current experiment, both the punishment and nonreward conditions involve both aversive aspects (i.e., cues of impending punishment or nonreward) and appetitive aspects (i.e., the opportunity to earn credit by completing the experiment). As such, both conditions meet the basic criteria specified as necessary to engage BIS and represent potentially valid conditions for assessing individual differences in BIS. In fact, the question arises whether any experiment with human participants is free of conflicting incentives. Certainly, the time and effort involved in participating in an experiment represents an unpleasant or aversive experience for most, if not all, human participants. Thus, a "pure reward" condition that would engage BAS but not BIS may not exist, and BIS may be activated during all such experiments. This potential confound may also have contributed to the unexpected positive correlation between joviality and anxiety reactivity.

Self-reported BAS/BIS scores had very few significant relationships with emotional reactivity during the experiment. Of the two scales assessing self-reported BIS functioning, only one significantly predicted anxiety reactivity after punishment, and neither significantly predicted sadness/frustration reactivity after nonreward. Among several scales assessing self-reported BAS functioning, only SPSRQ-R significantly predicted joviality reactivity after reward. Notably, SPSRQ-R also significantly predicted sadness/frustration reactivity after nonreward but not serenity reactivity after avoidance. This finding could be taken as further support for the incentive model of BAS. However, this conclusion is seriously undermined by the fact that BAS-Drive, BAS-Fun, BAS-RR, BAS Total, and AMS (all of which were significantly correlated with SPSRQ-R) all failed to predict either joviality or sadness/frustration reactivity. A potential alternative explanation for the positive correlation of SPSRQ-R with both joviality and sadness/frustration is the fact that five of the 24 SPSRQ-R items deal explicitly with financial reward. In fact, a recent study validating a Romanian version of the SPSRQ identified a separate "sensitivity to financial incentive" factor (Sava & Sperneac, 2006). When I calculated SPSRQ-R separately for financial and non-financial items, I found that the two subscales correlated significantly, the correlation of each subscale with joviality reactivity remained significant, the correlation of the financial subscale with sadness/frustration reactivity remained significant, and the correlation of the non-financial subscale with sadness/frustration reactivity was reduced to a trend level. Thus, the significant correlation between SPSRQ-R and sadness/frustration reactivity may be at least partly due to the fact that the nonreward condition utilized a monetary incentive. In some ways, this fact further underscores the importance of the incentive model of BAS, as it demonstrates that the specific form of reward/nonreward may make a difference.

As noted above, a positive correlation between BAS-RR scores and BIS scores is frequently observed (Jorm et al., 1999; Smillie, Jackson et al., 2006). In this experiment, BAS-RR and BIS were not only positively correlated, but both predicted anxiety reactivity after punishment. Apparently, whatever common factor is captured by the variance shared by these two scales is related to self-reported changes in momentary nervousness and tenseness in response to punishment. It is noted that most of the items in these two scales deal explicitly with emotions per se, whereas the items in the BAS-Drive and BAS-Fun scales deal mainly with behaviors. In turn, the reactivity scores obtained in the experiment explicitly represent changes in emotions per se. It may be that the variance shared among BAS-RR, BIS, and anxiety reactivity represents a more general emotional reactivity dimension (Larsen & Diener, 1987). This could explain why BAS-RR came much closer to significantly predicting joviality reactivity than either BAS-Drive or BAS-Fun. As noted above, this same general emotional reactivity factor could also help explain the unexpected positive correlation between joviality and anxiety reactivity.

Self-report measures of BAS/BIS sensitivity have been criticized as problematic conceptually and psychometrically (Cogswell, Alloy, van Dulmen, & Fresco, 2006). These measures have demonstrated a consistent pattern of correlations with traitlike measures of affect (e.g., Heubeck et al., 1998), but have been more limited in predicting state affect (Carver, 2004; Heponiemi, Keltikangas-Järvinen, Puttonen, & Ravaja, 2003), and are often quite limited in predicting behavioral (Smillie & Jackson, 2005) or physiological changes (Brenner et al., 2005). It is perhaps not surprising, then, that these scales showed very limited utility in predicting emotional reactivity during this experiment. This may be related to the fact that self-report measures of BAS/BIS sensitivity assess traitlike tendencies, whereas reactivity scores represent emotional changes occurring across the span of a few minutes. Apparently, participants' judgments of traitlike tendencies of BAS/BIS functioning are not closely related to their tendency to experience short-lived changes in momentary affect. This suggests that these measures of self-reported BAS/BIS functioning may be more related to mood than emotion. Indeed, each of these measures of self-reported BAS/BIS functioning was strongly related to self-reported mood over the past week (MASQ) or two weeks (BDI-II) and to self-reported temperamental tendencies to experience positive or negative moods (GTS).

BAS/BIS in Depression

I compared currently-depressed, previously-depressed, and never-depressed participants on their emotional reactivity to reward, punishment, nonreward and avoidance. Comparisons revealed group differences in emotional reactivity only for joviality in response to reward. Currently-depressed participants' joviality reactivity was significantly lower than never-depressed participants' joviality reactivity and nonsignificantly lower than previously-depressed participants' joviality reactivity. Regressed change scores did not differ significantly among groups for anxiety in response to punishment, sadness/frustration in response to nonreward, or serenity in response to avoidance.

These results are consistent with several lines of research demonstrating that depressed participants exhibit diminished responsiveness to pleasant stimuli/reward. As reviewed briefly by Rottenberg et al. (2005), previous studies have found that depressed participants exhibit diminished responsiveness to pleasant stimuli, as indicated by both subjective experience and emotionally expressive behavior. Additionally, previous studies have found that depressed participants exhibit diminished responsiveness to reward, as indicated by changes in response bias during behavioral tasks (Guyer et al., 2006; Henriques & Davidson, 2000; Pizzagalli et al., 2005). The results of this experiment extend these findings by demonstrating that depressed participants exhibited diminished responsiveness to reward, as indicated by self-reported momentary affect. Furthermore, the current findings that depressed participants did not differ from nondepressed participants in their reactions to either punishment or nonreward are consistent with several studies in which depressed participants exhibited diminished responsiveness to pleasant stimuli but did not differ from nondepressed participants in their responsiveness to unpleasant stimuli (Larson, Nitschke, & Davidson, 2007; Sloan, Strauss, Quirk, & Sajatovic, 1997; Sloan, Strauss, & Wisner, 2001).

Two recent studies did find evidence of reduced reactivity of negative emotions among depressed participants. The first used an affect-startle probe as an index of emotional reactivity in response to pleasant, unpleasant, and neutral film clips (Kaviani et al., 2004). In that study, depressed participants exhibited both reduced self-reported mood reactions and diminished startle-probe reactivity to both pleasant and unpleasant films. However, when the depressed group was split according to symptom severity, only the more severely depressed subgroup differed from controls. When the depressed group was split according to severity of anhedonia, which was highly correlated with depression severity, results again revealed that only the more severely affected group differed from controls. Participants with milder symptoms of depression (and less anhedonia) rated the pleasant film clip as less pleasant than controls, but did not differ in their ratings of the unpleasant film clip or in their responses to the affect-startle probe during either film clip (Kaviani et al., 2004). The second study compared depressed, recovered, and control participants' self-reported emotional responses to happy, sad, and neutral film clips (Rottenberg et al., 2005). In that study, depressed participants, relative to controls, reported both lower levels of happiness and higher levels of sadness across conditions. Depressed participants' emotional reactivity, as indicated by the degree of variability in happiness and sadness ratings across all three conditions, was diminished, compared to controls, for sadness ratings but not for happiness ratings (Rottenberg et al., 2005).

By contrast, the results of this experiment revealed that depressed participants reported higher levels of sadness and frustration across conditions (i.e., both before and after nonreward), but reported lower levels of happiness only after the reward (not before), and their reactivity was diminished for happiness but not for sadness/frustration. Hence, the results of this experiment are more consistent with other recent studies in showing reduced reactivity in positive but not negative emotions. The results obtained by Kaviani et al. (2004) suggest that I might have found reduced sadness reactivity among currently-depressed participants if they had been more severely depressed or more severely anhedonic, as those results suggest that reactivity in negative emotions is diminished only among severely depressed and anhedonic participants. However, the results of Rottenberg et al. (2005) demonstrated reduced reactivity in negative emotions in a group that was apparently no more severely depressed than those in this study. I compared clinical characteristics between the participants in the currently-depressed subsample in this study and the depressed group in the Rottenberg et al. (2005) study and found that the two groups were highly similar in both severity and duration of depression (i.e., current BDI-II score and duration of current MDD episode).

Overall, the results of this experiment, and of most previous studies, suggest that depression is consistently characterized by diminished reactivity to reward and pleasant stimuli but not necessarily by any change in reactivity to punishment, nonreward, or unpleasant stimuli. It is somewhat difficult to couch these findings in terms of sensitivity of BAS/BIS, because the precise relationship between BAS/BIS and reactivity to various stimuli remains somewhat ambiguous. The preponderance of evidence supports a model in which reactivity to reward is closely related to (if not synonymous with) BAS sensitivity, and that this is diminished in currently-depressed individuals. However, the relationship of BAS/BIS with avoidance of unpleasant stimuli remains equivocal, and there is little work assessing whether reactivity to this condition is altered in depression. Similarly, the relationship of BAS/BIS with nonreward remains equivocal, and there has been little work assessing whether reactivity to this condition specifically (as opposed to punishment) is altered in depression. The results of this experiment did not reveal any significant differences in reactivity to either avoidance or nonreward among currently-depressed, previously-depressed, and never-depressed participants.

I also compared currently-depressed, previously-depressed, and never-depressed participants' responses to self-report scales of temperament and BAS/BIS sensitivity. Results were very similar to previous work in providing strong, consistent evidence of increased NA/excessive BIS among currently-depressed participants but limited, inconsistent evidence of decreased PA/diminished BAS among currently-depressed participants. Currently-depressed participants scored significantly higher than never-depressed participants on a measure of temperamental NA and on both of two measures of BIS sensitivity. Currently-depressed participants also scored significantly lower than never-depressed participants on a measure of temperamental PA. However, currently-depressed participants scored significantly lower than never-depressed participants on only three of six measures of BAS sensitivity. This pattern is very similar to that seen in five previous studies relating self-reported BAS/BIS to depression (Campbell-Sills et al., 2004; Johnson et al., 2003; Kasch et al., 2002; Meyer et al., 2001; Pinto-Meza et al., 2006). Depression was associated with higher self-reported BIS sensitivity in all five studies, but it was associated with lower self-reported BAS sensitivity in only three.

Two previous studies found evidence that increased self-reported BIS sensitivity in depression is mainly a state effect. The first was a longitudinal study of participants with bipolar disorder that assessed concurrent and prospective associations between self-reported BAS/BIS sensitivity and symptoms of both depression and mania (Meyer et al., 2001). Results revealed a significant association between self-reported BIS sensitivity and depressive symptoms, but this association appeared state-dependent (Meyer et al., 2001). The second was a cross-sectional study comparing depressed, recovered, and control participants on self-reported BAS/BIS sensitivity (Pinto-Meza et al., 2006). Results revealed that depressed participants scored higher on self-reported BIS sensitivity than both recovered and control participants, who did not differ significantly (Pinto-Meza et al., 2006). By contrast, the results of this experiment suggested that increased BIS sensitivity in depression has both state and trait components. On a measure of temperamental NA and one of two measures of BIS sensitivity, previously-depressed participants' scores were intermediate between currently-depressed and never-depressed participants' scores, and were significantly different from both. This suggests that increased BIS sensitivity may persist after resolution of depressive symptoms (trait component), though not to the degree observed during a depressive episode (state component).

Existing data suggest that diminished self-reported BAS sensitivity in depression, when observed, appears to be mainly a trait effect. A recent study of depressed, recovered, and control participants found that control participants scored significantly higher on self-reported BAS sensitivity than both depressed and recovered participants, who did not differ significantly (Pinto-Meza et al., 2006). Similarly, EEG studies have found increased left-sided alpha power, a putative indicator of diminished BAS, in both currently-depressed (Henriques & Davidson, 1991) and previously-depressed (Henriques & Davidson, 1990) participants compared to controls. By contrast, the limited evidence of diminished self-reported BAS sensitivity in depression that was observed in this study appeared to be a state effect. Currently-depressed participants scored significantly lower on a measure of temperamental PA and two measures of BAS sensitivity than both previously-depressed and never-depressed participants, who did not differ significantly. Furthermore, on a third measure of BAS sensitivity, currently-depressed participants scored significantly lower than previously-depressed participants, but neither group differed significantly from never-depressed participants.

Overall, the results of this experiment are consistent with the bulk of previous research assessing the role of BAS/BIS in depression. Namely, experimental data provide consistent evidence of diminished BAS in depression but provide little evidence of excessive BIS in depression, whereas self-report data provide consistent evidence of excessive BIS in depression but provide relatively inconsistent evidence of diminished BAS in depression. The fact that self-report data more consistently identify excessive BIS than diminished BAS among depressed participants may be because self-report measures of BAS/BIS are much more closely related to mood than to the neuropsychological systems they attempt to assess. In turn, depressed participants are probably much more acutely aware of their negative mood than their diminished hedonic capacity or reward reactivity. Moreover, it is not difficult for an individual to meet diagnostic criteria for depression without reporting anhedonia, whereas it is very difficult for an individual to meet diagnostic criteria for depression without reporting at least one of several symptoms of unpleasant affective states (e.g., depressed mood, worthlessness, guilt, suicidality). Hence, increases in negative mood may be the most common and salient subjective feature of depressive episodes, which makes increased BIS sensitivity the most consistently identified feature in self-report studies. However, this feature does not appear especially useful clinically, as it appears to be mainly a state effect and does not appear to have any prognostic value. By contrast, diminished responsiveness to reward among depressed participants appears to be easier to demonstrate experimentally, and appears to have prognostic value. The fact that experimental studies have more consistently shown that depressed participants exhibit decreased responsiveness to reward/pleasant stimuli but not to punishment/unpleasant stimuli may be because these studies are more fully assessing the underlying neuropsychological systems involved, and more accurately identifying the characteristic neuropsychological deficit among depressed participants.. Furthermore, prospective studies suggest that BAS deficits predict future depression.

Limitations and Future Directions

This study had several important limitations. First, it relied heavily on participants' self reports. The primary dependent variable was self-reported momentary affect, which is potentially subject to several biases, including consistency bias and demand characteristics. Furthermore, subjective affect is probably quite removed from the underlying neuropsychological systems I attempted to test. In the future, it will be important to see if similar results can be obtained from more objective measures of affect, such as an affective startle probe. Experiments that assess affect through more than one modality (e.g., self-report, observer-rated, physiological) typically find little correlation between modalities, presumably due to "loose coupling" of affective response systems (Lang & Cuthbert, 1984). Therefore, it will be important to continue to test for individual differences in BAS/BIS sensitivity using a variety of methodologies to determine which is most representative of the underlying systems being studied.

A related limitation is that this study was organized around the valence of emotions but did not take into account differences in the level of arousal that may be inherent in these various emotions (Russell, 1980). I did differentiate between the lower-arousal emotions related to sadness and the higher-arousal emotions related to frustration. I found that these were highly correlated and that results were essentially identical regardless of whether I used the lower- or higher-arousal adjectives, or both. However, reactions to the avoidance condition were measured using only lower-arousal adjectives, which may be part of the reason reactivity in serenity did not correlate strongly with reactivity in any other emotion. In the future, it will be beneficial to control for differences in arousal or to identify experimental conditions that pull for changes in emotions of equivalent arousal level.

Correlational analyses were also limited by the substantial differences between the incentives. The promise of money utilized in the reward and nonreward conditions is very different qualitatively from the threat of physical pain utilized in the punishment and avoidance conditions. Furthermore, the reward was perceived by participants as being significantly greater in magnitude than the punishment, and produced emotional reactions that were nearly twice as strong. Further pilot testing would be needed to identify amounts of cash and amounts of time holding a hand in the cold pressor that would constitute incentives of roughly equal magnitude for most participants. However, a better solution would be to identify rewards and punishments that are more similar qualitatively as well. One of the chief difficulties in doing so will be to identify incentives that lend themselves to a clear differentiation between punishment and nonreward and between reward and avoidance. The results of this experiment suggest that these distinctions are in need of further clarification. In the future, it may be necessary to restrict individual experiments to only two of the four conditions in order to increase sensitivity in the measures and minimize the effects of repetition.

The effect of order of conditions on emotional reactions to avoidance represents a limitation in both correlational analyses and group comparisons. I partially addressed this limitation by exploring correlational results separately for the subsets of participants who had and had not previously experienced the punishment. Unfortunately, the sample size was too small to make this a viable option in group comparisons. Thus, I do not know whether depressed and nondepressed participants might have differed in their reactions to avoidance if all of them (or none of them) had experienced the punishment beforehand. Furthermore, the presumed underlying cause of the order effect (i.e., the fact that participants did not experience the punishment until they had "earned" it during the punishment condition) also represents a limitation in all analyses involving reactions to punishment, because participants rated their reactions to the punishment before ever having experienced it. Future studies should ensure that both punishment and avoidance conditions involve incentives with which participants are experientially familiar. For example, future studies that utilize the cold pressor as an incentive should require all participants to experience the cold pressor early in the session, before the relevant experimental condition(s).

This study was also limited by the lack of assessment of regulatory focus. As discussed above, some of the conceptual distinctions I attempted to make during this experiment may not be fully interpretable without accounting for participants' awareness of the self. It is possible that some of the individual differences in emotional reactivity might have been at least partially accounted for by individual differences in chronic self-regulatory focus. In future studies of emotional reactions in humans, it will be important to test not only whether BAS/BIS explains additional variance beyond the effects of general temperamental tendencies to experience PA or NA, but also whether regulatory focus explains additional variance beyond the effects of BAS/BIS.

Other researchers have called for additional studies that directly compare the behavioral correlates of the BIS/BAS scales and the SPSRQ, the most widely used self-report measures of BAS/BIS sensitivity (Cogswell et al., 2006). These measures appear to be based on different theoretical conceptualizations of BAS/BIS and have important differences in predictive utility (Cogswell et al., 2006; Smillie & Jackson, 2005), as demonstrated in this study. A significant limitation in the literature is the relative lack of studies that utilize both measures. Additional studies that include both measures will allow the field to clarify the validity and utility of each, and may provide additional direction in elucidating better strategies for assessing BAS/BIS sensitivity.

Additional studies that compare punishment with nonreward and/or compare reward with active avoidance are clearly needed. Not only are these distinctions theoretically relevant, but there is some evidence that they may account for inconsistencies in previous research. Furthermore, studies that clearly differentiate punishment from nonreward and reward from avoidance will be useful not only in clarifying the structure of BAS/BIS, but also in clarifying the range of deficits observed in depression. As noted above, several previous studies have found no differences between depressed and nondepressed participants' reactions to punishment, but other studies have found that depressed participants' reactivity to punishment may be diminished, at least when the punishment takes the form of unpleasant film clips. Additional studies are clearly needed to determine the circumstances under which depressed participants do and do not exhibit altered responsiveness to cues of punishment and nonreward.

To date, there has been little research assessing whether reactivity to successful avoidance of punishment is altered in depression. This issue is particularly important in light of the growing interest in the role of avoidance as both a defining feature of depressive episodes (Ferster, 1973; Jacobson, Martell, & Dimidjian, 2001) and a maladaptive coping strategy that serves to prolong depressive episodes (Hayes, Beevers, Feldman, Laurenceau, & Perlman, 2005) and increase risk for future episodes (Blalock & Joiner, 2000; Holahan, Moos, Holahan, Brennan, & Schutte, 2005). It is not clear whether depressed individuals' increased tendency to engage in avoidance-oriented coping strategies (Moos & Holahan, 2003; Moulds, Kandris, Starr, & Wong, 2007) is accompanied by any change in their emotional reactivity to successful avoidance of aversive stimuli. It will be interesting to see if future studies replicate the results of this experiment in showing that depressed participants exhibit diminished responsiveness to cues of obtaining a reward but not to cues of successfully avoiding a punishment.

Table 1. Demographic and Clinical Characteristics of Total Sample and Four Overlapping Subsamples.

	Total Sample (*N* = 138)	Normative Subsample (*n* = 119)[a]	Never-Depressed Subsample (*n* = 43)[b]	Previously-depressed Subsample (*n* = 19)[c]	Currently-depressed Subsample (*n* = 19)[d]
Female sex (*N* [%])	74 (53.6)	64 (53.8)	22 (51.2)	8 (42.1)	9 (47.4)
Ethnicity (*N* [%])					
Asian/Pacific Islander	35 (25.4)	33 (27.7)	12 (27.9)	3 (15.8)	3 (15.8)
African American/Black	10 (7.2)	6 (5.0)	3 (7.0)	1 (5.3)	1 (5.3)
Caucasian/White	60 (43.5)	51 (42.9)	20 (46.5)	10 (52.6)	9 (47.4)
Hispanic	21 (15.2)	20 (16.8)	7 (16.3)	3 (15.8)	3 (15.8)
Other or Mixed	12 (8.7)	9 (7.6)	1 (2.3)	2 (10.5)	3 (15.8)
Education in years (*M* [*SD*])	13.15 (0.41)	13.15 (1.32)	12.95 (1.20)	13.71 (1.34)	13.26 (1.48)
Age in years (*M* [*SD*])	20.41 (4.30)	20.51 (4.58)	20.01 (3.04)	22.85 (8.95)	19.98 (2.08)
Marital status (*N* [%])					
Never married	134 (97.1)	115 (96.6)	41 (95.3)	18 (94.7)	19 (100.0)
Married	2 (1.4)	2 (1.7)	1 (2.3)	1 (5.3)	0 (0.0)
Separated/Divorced	2 (1.4)	2 (1.7)	1 (2.3)	0 (0.0)	0 (0.0)
BDI-II Score (*M* [*SD*])	11.45 (10.63)	9.35 (9.50)	2.47 (2.65)	4.21 (2.49)	28.63 (8.80)
Lifetime history of MDD (*N* [%])	64 (46.4)	49 (41.2)	0 (0.0)	19 (100.0)	19 (100.0)
Current diagnosis of MDD (*N* [%])	20 (14.5)	9 (7.6)	0 (0.0)	0 (0.0)	18 (94.7)
Duration of current MDD episode in weeks (*M* [*SD*])	23.65 (51.06)	18.11 (24.56)	--	--	24.53 (54.52)
Number of lifetime MDD episodes (*M* [*SD*])	2.81 (3.26)	2.74 (3.56)	--	2.11 (2.45)	3.76 (2.91)
Lifetime history of DD (*N* [%])	9 (6.5)	6 (5.0)	0 (0.0)	0 (0.0)	3 (15.8)
Current diagnosis of DD (*N* [%])	2 (1.4)	1 (0.8)	0 (0.0)	0 (0.0)	2 (10.5)

Note: BDI-II = Beck Depression Inventory-II; MDD = Major Depressive Disorder; DD = Dysthymic Disorder.

[a]Includes 96 participants who scored below 16 on the BDI-II and 23 participants who scored 16 or higher.
[b]Participants scored below 10 on the BDI-II and never met criteria for MDD or DD.
[c]Participants scored below 10 on the BDI-II and met criteria for a past (but not current) diagnosis of MDD or DD.
[d]Participants scored 16 or higher on the BDI-II and met criteria for a current diagnosis of MDD or DD.

Table 2. Means, Standard Deviations, and Reliability Coefficients for Questionnaire Measures (*N* = 138).

	M (*SD*)	Alpha	Mean inter-item correlation
GTS-PT[a]	16.95 (6.58)	.90	.24
GTS-NT[a]	13.87 (8.17)	.94	.34
BAS-Drive	11.17 (2.60)	.75	.43
BAS-Fun	12.68 (2.53)	.69	.36
BAS-RR	17.18 (2.41)	.72	.33
BAS Total	41.03 (5.92)	.82	.26
BIS	21.32 (3.92)	.76	.32
SPSRQ-R[a]	12.84 (4.86)	.82	.15
SPSRQ-P[a]	11.77 (5.96)	.88	.23
AMS[a]	14.07 (3.39)	.70	.11
MASQ-Anx	29.28 (11.24)	.90	.34
MASQ-Dep	53.63 (17.38)	.94	.44
BDI-II	11.45 (10.63)	.94	.43

Note: GTS-PT = General Temperament Survey Positive Temperament subscale; GTS-NT = General Temperament Survey Negative Temperament subscale; BAS-Drive = BIS/BAS Scales Drive subscale; BAS-Fun = BIS/BAS Scales Fun Seeking subscale; BAS-RR = BIS/BAS Scales Reward Responsiveness subscale; BAS Total = sum of BAS-Drive, BAS-Fun, and BAS-RR subscales; BIS = BIS/BAS Scales BIS subscale; SPSRQ-R = Sensitivity to Punishment and Sensitivity to Reward Questionnaire Sensitivity to Reward subscale; SPSRQ-P = Sensitivity to Punishment and Sensitivity to Reward Questionnaire Sensitivity to Punishment subscale; AMS = Appetitive Motivation Scale total score; MASQ-Anx = Mood and Anxiety Symptoms Questionnaire Anxious Arousal subscale; MASQ-Dep = Mood and Anxiety Symptoms Questionnaire Anhedonic Depression subscale; BDI-II = Beck Depression Inventory-II total score.

[a]Due to missing data, *n* = 132 for GTS-PT and GTS-NT; *n* = 135 for SPSRQ-R and SPSRQ-P; *n* = 137 for AMS.

Table 3. Reliability of Composite Scores Representing Target Emotions After Target Blocks of Puzzles.

Target Composite	Target Condition	Adjectives Comprising Composite	Reliability of Composite[a]
Joviality	Reward	happy, enthusiastic	$r = .62, p < .001$
Anxiety	Punishment	tense, nervous	$r = .70, p < .001$
Sadness/Frustration	Nonreward	discouraged, sad, annoyed, frustrated	alpha = .82, mean inter-item correlation = .53
Serenity	Avoidance	relaxed, at ease	$r = .72, p < .001$

[a]Reliability statistics were computed using participants' ratings on target adjectives immediately after the target condition ($N = 138$).

Table 4. Comparison of Composite Emotion Scores Immediately Before and Immediately After Target Blocks (N = 138).

Target Composite	M (SD) Rating Immediately Before Target Block	M (SD) Rating Immediately After Target Block	Correlation Between Pre-block and Post-block Ratings	Paired-sample t-test	Effect Size (d)
Joviality	4.38 (1.91)	6.00 (1.80)	$r = .62, p < .001$	$t(137) = 11.716, p < .001$	.87
Anxiety	4.02 (1.87)	4.89 (2.19)	$r = .58, p < .001$	$t(137) = 5.47, p < .001$	.42
Sadness/Frustration	2.46 (1.37)	3.83 (1.89)	$r = .56, p < .001$	$t(137) = 10.00, p < .001$	.80
Serenity	4.35 (1.87)	5.05 (2.02)	$r = .69, p < .001$	$t(137) = 5.35, p < .001$	.36

Table 5. Comparison of Composite Emotion Scores Immediately After Target Blocks and Immediately Before the Next Block (After a Filler Task).

Target Composite	*M* (*SD*) Rating Immediately After Target Block	*M* (*SD*) Rating Immediately Before Next Block (After Filler Task)	Correlation Between Post-block and Post-filler Ratings	Paired-sample *t*-test	Effect Size (*d*)
Joviality	6.03 (1.79)	4.91 (1.87)	$r = .78, p < .001$	$t(102) = 9.41, p < .001$	.61
Anxiety	5.06 (2.12)	3.66 (1.82)	$r = .68, p < .001$	$t(103) = 8.93, p < .001$	.70
Sadness/Frustration	3.84 (1.74)	3.18 (1.78)	$r = .76, p < .001$	$t(103) = 5.45, p < .001$	.37
Serenity	4.90 (2.06)	4.43 (1.95)	$r = .77, p < .001$	$t(102) = 3.56, p = .001$	.24

Note: Mean ratings and degrees of freedom are different from those presented in Table 4 because each target block was the final block for approximately 25% of participants.

Table 6. Correlation Matrix of Affect Composite Regressed Change Scores and Simple Difference Scores.

	Joviality Regressed Change	Anxiety Regressed Change	Sadness/ Frustration Regressed Change	Serenity Regressed Change	Joviality Simple Difference	Anxiety Simple Difference	Sadness/ Frustration Simple Difference	Serenity Simple Difference
Joviality Regressed Change	--	.27**	.39***	.13	.87***	.23*	.37***	.05
Anxiety Regressed Change	.26**	--	.30**	-.03	.22*	.95***	.26**	.01
Sadness Regressed Change	.38***	.28**	--	.05	.37***	.23*	.99***	.01
Serenity Regressed Change	.14	-.02	.11	--	.05	-.06	.05	.95***
Joviality Simple Difference	.87***	.19*	.36***	.06	--	.16	.34***	.05
Anxiety Simple Difference	.24**	.95***	.22*	-.04	.14	--	.21*	-.05
Sadness Simple Difference	.37***	.24**	.98***	.12	.34***	.21*	--	.01
Serenity Simple Difference	.04	-.02	.07	.95***	.04	-.06	.07	--

*p < .05, **p < .01, ***p < .001.

Note: Scores above the diagonal represent results obtained with the normative subsample (n = 119); scores below the diagonal represent results obtained from the full sample (N = 138).

Table 7. Correlation Matrix of Affect Composite Regressed Change Scores Among Participants Within the Normative Subsample Who Experienced Punishment Before Avoidance and Vice-versa.

	Joviality Regressed Change	Anxiety Regressed Change	Sadness/ Frustration Regressed Change	Serenity Regressed Change
Joviality Regressed Change	--	.24[a]	.47***	.34**
Anxiety Regressed Change	.30*	--	.29*	.06
Sadness/Frustration Regressed Change	.31*	.33*	--	.14
Serenity Regressed Change	-.04	-.09	-.08	--

[a]$p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$.

Note: Scores above the diagonal represent results obtained from the participants within the normative subsample who experienced punishment before avoidance (n = 59); scores below the diagonal represent results obtained from participants within the normative subsample who experienced avoidance before punishment (n = 60).

Table 8. Correlations Among Self-report Scales.

	GTS-PT	GTS-NT	BAS-Drive	BAS-Fun	BAS-RR	BAS Total	BIS	SPSRQ-R	SPSRQ-P	AMS	MASQ-Anx	MASQ-Dep	BDI-II
GTS-PT	--	.34***	.47***	.39***	.31**	.50***	-.20*	.30**	-.60***	.63***	.01	-.56***	-.43***
GTS-NT	-.38***	--	.03	.13	.01	.07	.56***	.22*	.57***	-.02	.49***	.57***	.66***
BAS-Drive	.53***	-.05	--	.43***	.43***	.82***	-.01	.36***	-.32***	.50***	.02	-.35***	-.20*
BAS-Fun	.41***	.04	.45***	--	.30**	.75***	-.07	.34***	-.22*	.59***	.19*	-.07	.01
BAS-RR	.36***	-.02	.49***	.32***	--	.74***	.31**	.23*	-.13	.22*	-.13	-.36***	-.23*
BAS Total	.55***	-.01	.83***	.76***	.76***	--	.096	.41***	-.30**	.57***	.03	-.34***	-.18*
BIS	-.22*	.60***	-.06	-.13	.25**	.02	--	.15	.54***	-.10	.32***	.23*	.34***
SPSRQ-R	.35***	.14	.39***	.40***	.28**	.45***	.09	--	.03	.31**	.22*	-.17	.11
SPSRQ-P	-.56***	.57***	-.32***	-.27**	-.12	-.31***	.56***	-.01	--	-.38***	.35***	.53***	.58***
AMS	.63***	-.08	.51***	.60***	.28**	.59***	-.14	.41***	-.39***	--	.04	-.33***	-.23*
MASQ-Anx	-.08	.54***	-.04	.11	-.13	-.02	.39***	.11	.36***	-.02	--	.35***	.59***
MASQ-Dep	-.60***	.62***	-.38***	-.14	-.36***	-.37***	.30***	-.25**	.51***	-.38***	.44***	--	.70***
BDI-II	-.49***	.70***	-.29**	-.12	-.25**	-.29**	.41***	-.02	.56***	-.28**	.63***	.75***	--

*p < .05, **p < .01, ***p < .001.

Note: Scores above the diagonal represent results obtained from the normative subsample (n = 119). Scores below the diagonal represent results obtained from the full sample (N = 138). GTS-PT = General Temperament Survey Positive Temperament subscale; GTS-NT = General Temperament Survey Negative Temperament subscale; BAS-Drive = BIS/BAS Scales Drive subscale; BAS-Fun = BIS/BAS Scales Fun Seeking subscale; BAS-RR = BIS/BAS Scales Reward Responsiveness subscale; BAS Total = sum of BAS-Drive, BAS-Fun, and BAS-RR subscales; BIS = BIS/BAS Scales BIS subscale; SPSRQ-R = Sensitivity to Punishment and Sensitivity to Reward Questionnaire Sensitivity to Reward subscale; SPSRQ-P = Sensitivity to Punishment and Sensitivity to Reward Questionnaire Sensitivity to Punishment subscale; AMS = Appetitive Motivation Scale total score; MASQ-Anx = Mood and Anxiety Symptoms Questionnaire Anxious Arousal subscale; MASQ-Dep = Mood and Anxiety Symptoms Questionnaire Anhedonic Depression subscale; BDI-II = Beck Depression Inventory-II total score.

Table 9. Bivariate Correlations of Self-report Scales With Target Emotion Composite Ratings Immediately After Target Blocks Using the Normative Subsample (n = 119).

	Joviality After Reward Block	Anxiety After Punishment Block	Sadness/ Frustration After Nonreward Block	Serenity After Avoidance Block
GTS-PT	.23*	-.11	.09	.08
GTS-NT	-.16	.01	.12	-.15
BAS-Drive	-.09	-.01	-.02	.08
BAS-Fun	.10	-.25**	-.01	.05
BAS-RR	.14	.12	-.03	.10
BAS Total	.14	-.06	-.02	.10
BIS	-.04	.18	.08	-.12
SPSRQ-R	.28**	.02	.23*	.11
SPSRQ-P	-.16	.18	.15	-.12
AMS	.08	-.17	-.03	.13
MASQ-Anx	-.09	.07	.23*	-.11
MASQ-Dep	-.35***	-.06	.08	-.28**
BDI-II	-.14	.06	.24*	-.20*

Note: GTS-PT = General Temperament Survey Positive Temperament subscale; GTS-NT = General Temperament Survey Negative Temperament subscale; BAS-Drive = BIS/BAS Scales Drive subscale; BAS-Fun = BIS/BAS Scales Fun Seeking subscale; BAS-RR = BIS/BAS Scales Reward Responsiveness subscale; BAS Total = sum of BAS-Drive, BAS-Fun, and BAS-RR subscales; BIS = BIS/BAS Scales BIS subscale; SPSRQ-R = Sensitivity to Punishment and Sensitivity to Reward Questionnaire Sensitivity to Reward subscale; SPSRQ-P = Sensitivity to Punishment and Sensitivity to Reward Questionnaire Sensitivity to Punishment subscale; AMS = Appetitive Motivation Scale total score; MASQ-Anx = Mood and Anxiety Symptoms Questionnaire Anxious Arousal subscale; MASQ-Dep = Mood and Anxiety Symptoms Questionnaire Anhedonic Depression subscale; BDI-II = Beck Depression Inventory-II total score.

*p < .05, **p < .01, ***p < .001.

Table 10. Bivariate Correlations of Self-report Scales with Regressed Change Scores of Target Emotions Using the Normative Subsample (*n* = 119).

	Joviality Regressed Change	Anxiety Regressed Change	Sadness/ Frustration Regressed Change	Serenity Regressed Change
GTS-PT	.15	-.01	-.02	.04
GTS-NT	-.10	-.01	-.03	.01
BAS Drive	.09	.08	-.02	.05
BAS-Fun	.04	-.12	.02	.07
BAS-RR	.18	.20*	-.03	.06
BAS Total	.13	.07	-.01	.08
BIS	.01	.19*	-.01	-.03
SPSRQ-R	.24**	.01	.21*	.02
SPSRQ-P	.01	.15	.03	-.05
AMS	.02	-.04	.02	.16
MASQ-Anx	-.08	.06	.09	.01
MASQ-Dep	-.31**	-.13	-.05	-.13
BDI-II	-.14	.01	.11	-.15

Note: GTS-PT = General Temperament Survey Positive Temperament subscale; GTS-NT = General Temperament Survey Negative Temperament subscale; BAS-Drive = BIS/BAS Scales Drive subscale; BAS-Fun = BIS/BAS Scales Fun Seeking subscale; BAS-RR = BIS/BAS Scales Reward Responsiveness subscale; BAS Total = sum of BAS-Drive, BAS-Fun, and BAS-RR subscales; BIS = BIS/BAS Scales BIS subscale; SPSRQ-R = Sensitivity to Punishment and Sensitivity to Reward Questionnaire Sensitivity to Reward subscale; SPSRQ-P = Sensitivity to Punishment and Sensitivity to Reward Questionnaire Sensitivity to Punishment subscale; AMS = Appetitive Motivation Scale total score; MASQ-Anx = Mood and Anxiety Symptoms Questionnaire Anxious Arousal subscale; MASQ-Dep = Mood and Anxiety Symptoms Questionnaire Anhedonic Depression subscale; BDI-II = Beck Depression Inventory-II total score.

*p < .05, **p < .01.

Table 11. Ratings on Target Emotions Before and After Target Blocks for Participants in the Never-depressed, Previously-depressed, and Currently-depressed Subsamples.

	Rating Before Target Block			Rating After Target Block		
Target Emotion	Never-depressed (*n* = 43)	Previously-depressed (*n* = 19)	Currently-depressed (*n* = 19)	Never-depressed (*n* = 43)	Previously-depressed (*n* = 19)	Currently-depressed (*n* = 19)
Joviality *M* (*SD*)	$4.76 (2.36)_{a}$	$4.08 (1.83)_{a}$	$4.21 (1.56)_{a}$	$6.53 (1.76)_{a}$	$6.11 (1.83)_{a,b}$	$5.26 (1.75)_{b}$
Anxiety *M* (*SD*)	$3.84 (1.94)_{a,b}$	$3.13 (1.55)_{a}$	$4.79 (1.61)_{b}$	$4.78 (2.35)_{a}$	$4.26 (1.97)_{a}$	$4.89 (2.34)_{a}$
Sadness/Frustration *M* (*SD*)	$2.00 (1.83)_{a}$	$1.74 (0.76)_{a}$	$3.54 (1.83)_{b}$	$3.33 (2.02)_{a}$	$3.32 (1.65)_{a,b}$	$4.64 (2.07)_{b}$
Serenity *M* (*SD*)	$4.94 (2.12)_{a}$	$4.47 (1.67)_{a,b}$	$3.66 (1.39)_{b}$	$5.63 (2.18)_{a}$	$5.55 (1.96)_{a,b}$	$4.21 (1.58)_{b}$

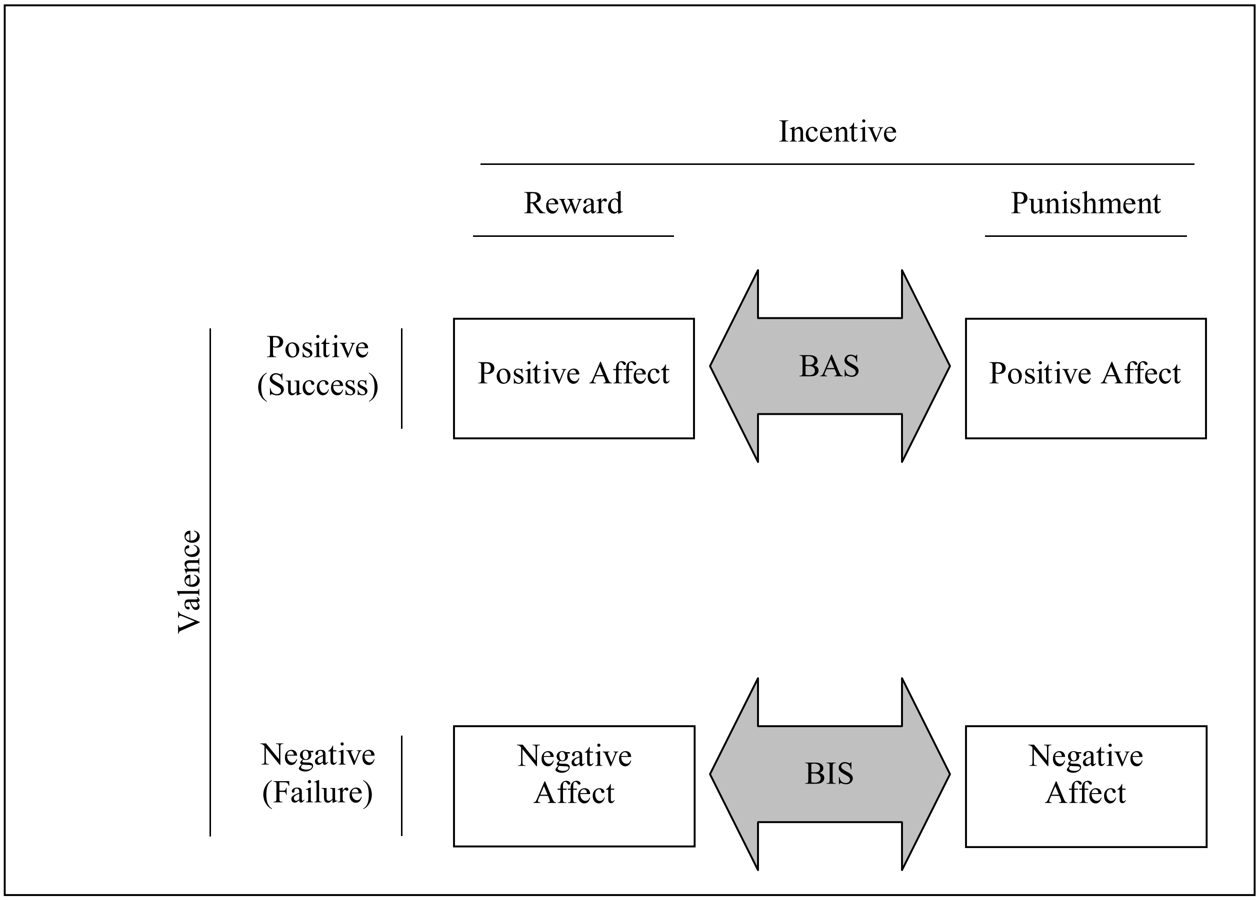
Note: Means with different subscripts are significantly different ($p < .05$) between groups based on ANOVA with post-hoc Tukey's honestly significant difference comparisons.

Table 12. Self-report Scales for Never-depressed, Previously-depressed, and Currently-depressed Participants.

	Never-depressed (n = 43)	Previously-depressed (n = 19)	Currently-depressed (n = 19)	Effect of Group (ANOVA)
GTS-PT	20.30 $(4.52)_a$	19.53 $(6.33)_a$	10.39 $(5.74)_b$	$F(2, 74) = 23.05, p < .001$
GTS-NT	5.58 $(5.23)_a$	12.58 $(5.63)_b$	22.00 $(4.77)_c$	$F(2, 74) = 62.16, p < .001$
BAS-Drive	11.26 $(2.16)_a$	11.47 $(2.50)_a$	9.42 $(3.04)_b$	$F(2, 78) = 4.36, p = .016$
BAS-Fun	12.53 $(2.66)_a$	12.89 $(2.11)_a$	11.53 $(2.86)_a$	$F(2, 78) = 1.47, p = .24$
BAS-RR	16.95 $(2.24)_{a,b}$	17.68 $(2.36)_a$	15.42 $(3.31)_b$	$F(2, 78) = 3.98, p = .023$
BAS Total	40.74 $(5.13)_a$	42.05 $(5.88)_a$	36.37 $(7.41)_b$	$F(2, 78) = 5.09, p = .008$
BIS	19.02 $(3.58)_a$	20.89 $(3.89)_a$	23.63 $(2.97)_b$	$F(2, 78) = 11.41, p < .001$
SPSRQ-R	12.33 $(4.67)_a$	12.84 $(5.23)_a$	11.56 $(6.08)_a$	$F(2, 76) = .29, p = .746$
SPSRQ-P	7.52 $(4.86)_a$	10.95 $(5.56)_b$	16.06 $(3.65)_c$	$F(2, 76) = 20.15, p < .001$
AMS	14.84 $(2.79)_a$	14.89 $(2.60)_a$	11.53 $(3.96)_b$	$F(2, 78) = 8.61, p < .001$
MASQ-Anx	23.19 $(5.91)_a$	25.21 $(6.62)_a$	40.68 $(14.28)_b$	$F(2, 78) = 27.63, p < .001$
MASQ-Dep	41.63 $(10.16)_a$	45.68 $(12.88)_a$	78.32 $(10.06)_b$	$F(2, 78) = 78.83, p < .001$
BDI-II	2.47 $(2.65)_a$	4.21 $(2.49)_a$	28.63 $(8.80)_b$	$F(2, 78) = 208.09, p < .001$

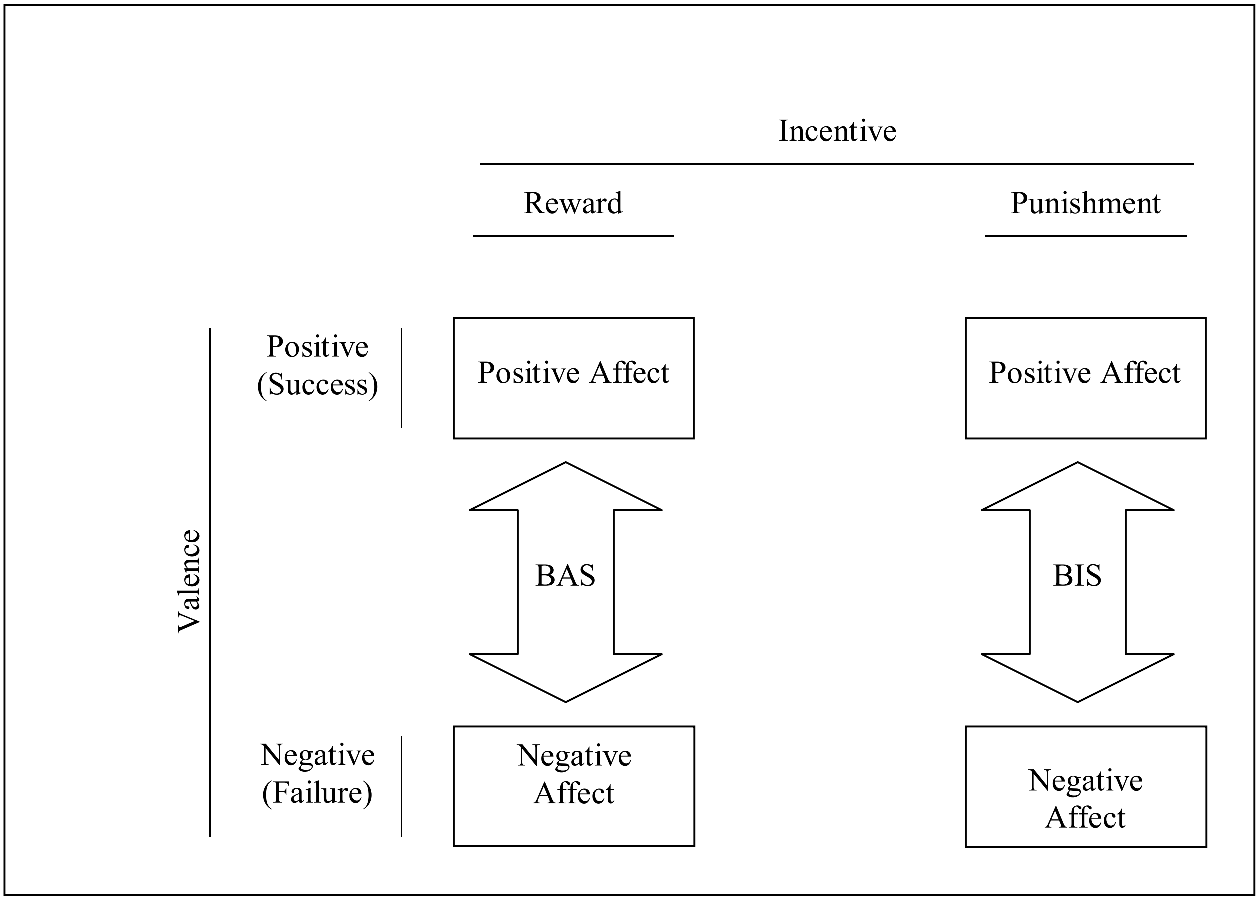
Note: Means with different subscripts are significantly different ($p < .05$) between groups based on post-hoc Tukey comparisons. GTS-PT = General Temperament Survey Positive Temperament subscale; GTS-NT = General Temperament Survey Negative Temperament subscale; BAS-Drive = BIS/BAS Scales Drive subscale; BAS-Fun = BIS/BAS Scales Fun Seeking subscale; BAS-RR = BIS/BAS Scales Reward Responsiveness subscale; BAS Total = sum of BAS-Drive, BAS-Fun, and BAS-RR subscales; BIS = BIS/BAS Scales BIS subscale; SPSRQ-R = Sensitivity to Punishment and Sensitivity to Reward Questionnaire Sensitivity to Reward subscale; SPSRQ-P = Sensitivity to Punishment and Sensitivity to Reward Questionnaire Sensitivity to Punishment subscale; AMS = Appetitive Motivation Scale total score; MASQ-Anx = Mood and Anxiety Symptoms Questionnaire Anxious Arousal subscale; MASQ-Dep = Mood and Anxiety Symptoms Questionnaire Anhedonic Depression subscale; BDI-II = Beck Depression Inventory-II total score.

Figure 1. Relationships Among Individual Differences in Emotional Reactions Predicted by the Valence Model of BAS/BIS.



Note: BAS = Behavioral Activation/Approach System; BIS = Behavioral Inhibition System.

Figure 2. Relationships Among Individual Differences in Emotional Reactions Predicted by the Incentive Model of BAS/BIS.



Note: BAS = Behavioral Activation/Approach System; BIS = Behavioral Inhibition System.

Figure 3. Schematic Representation of Overlapping Subsamples.

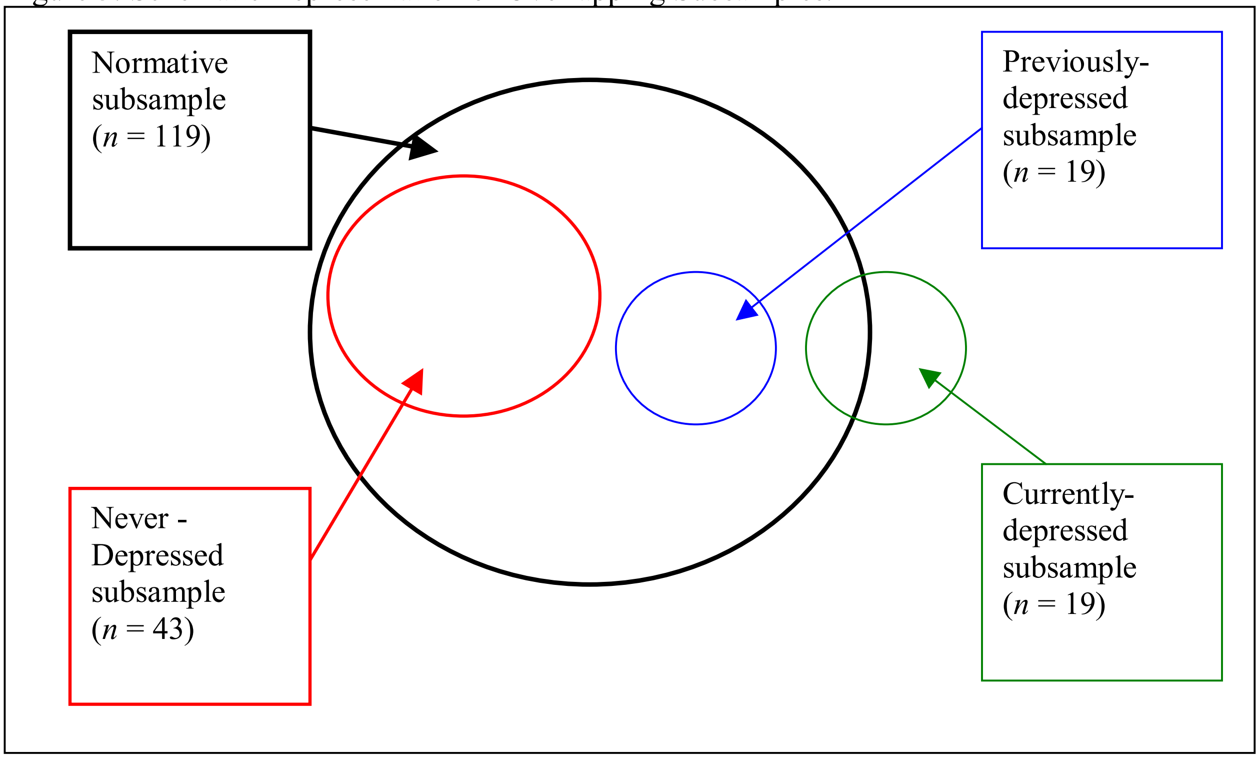


Figure 4. Example of Anagram Trial.

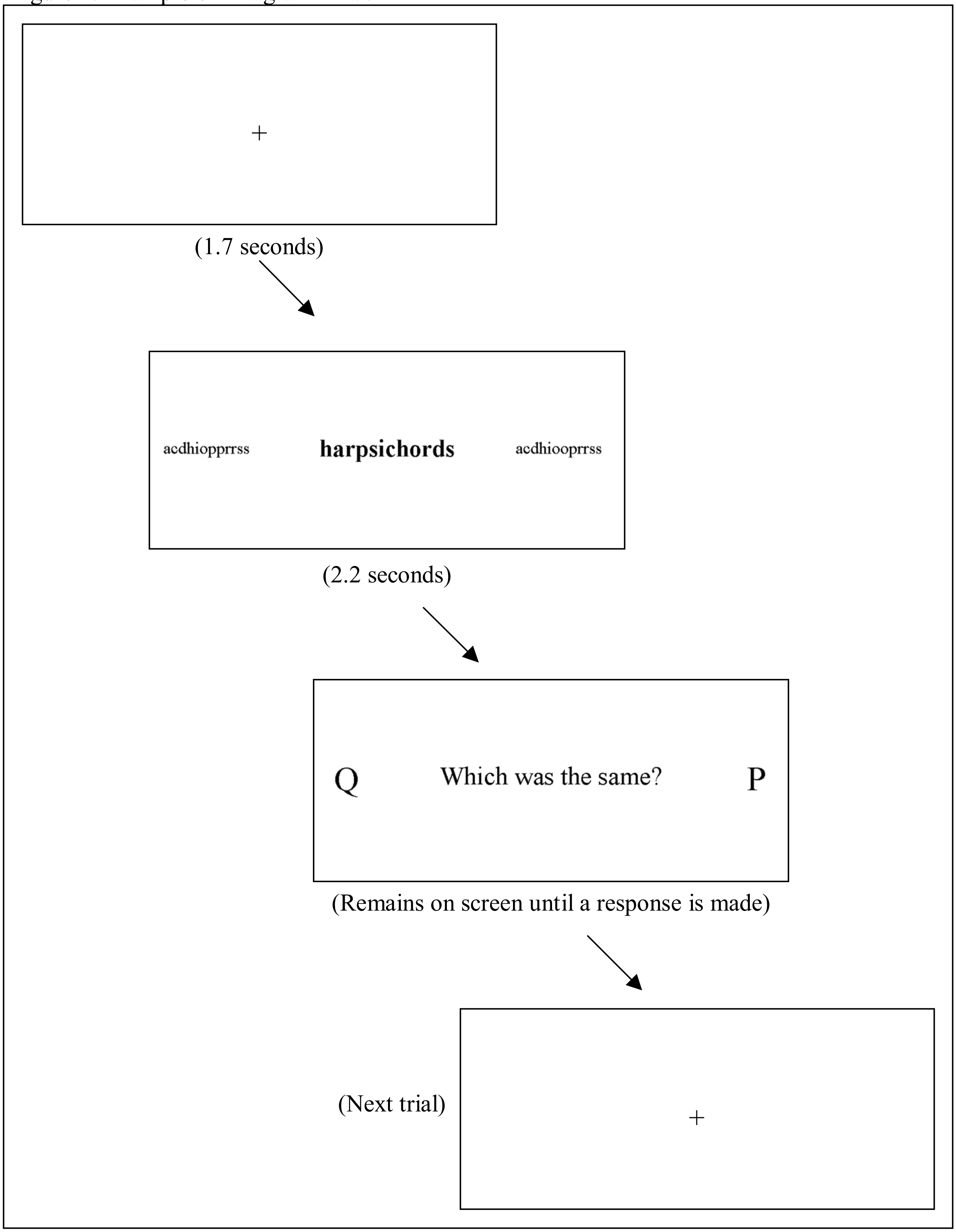


Figure 5. Example of Figure Rotation Trial.

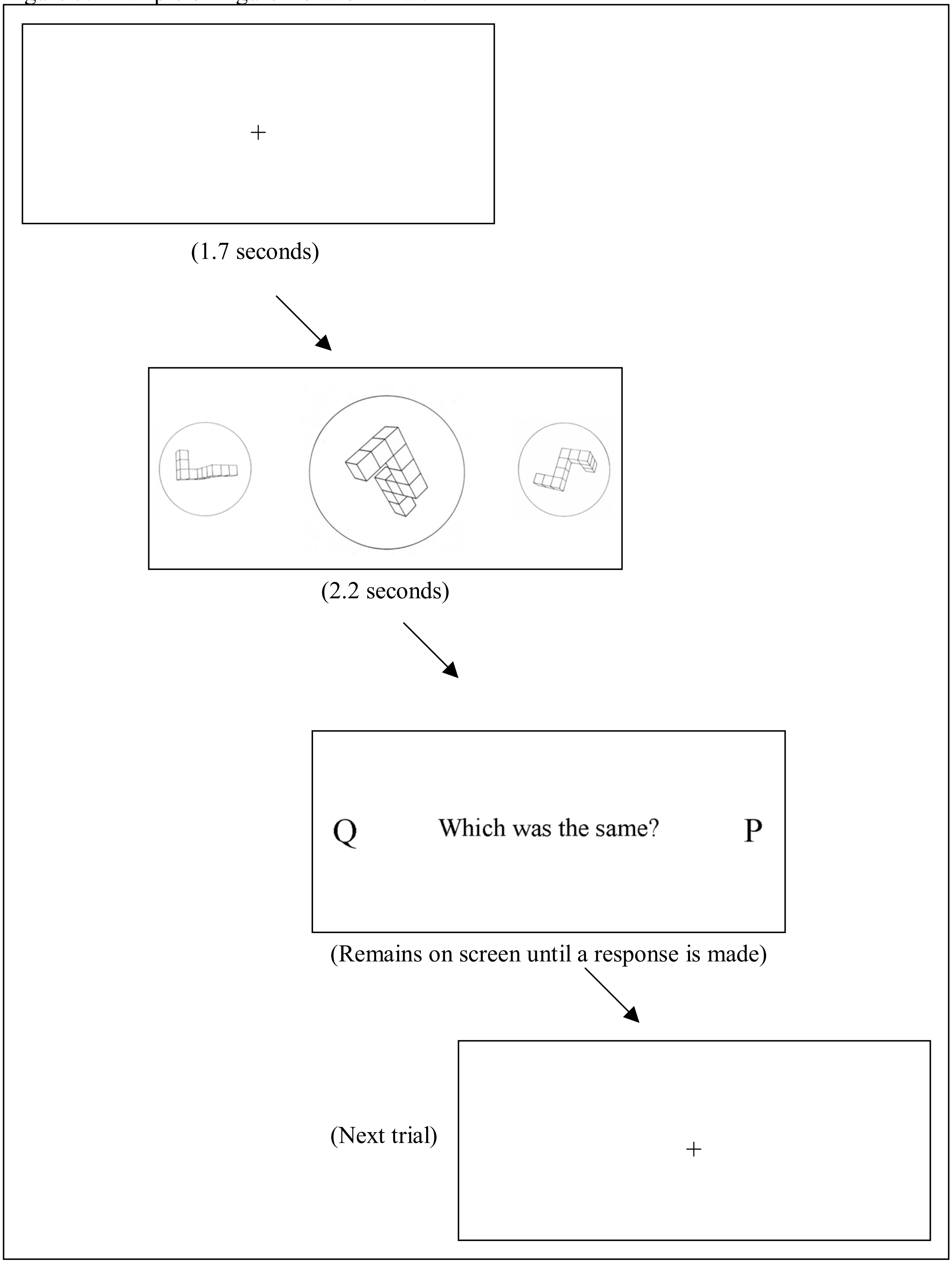
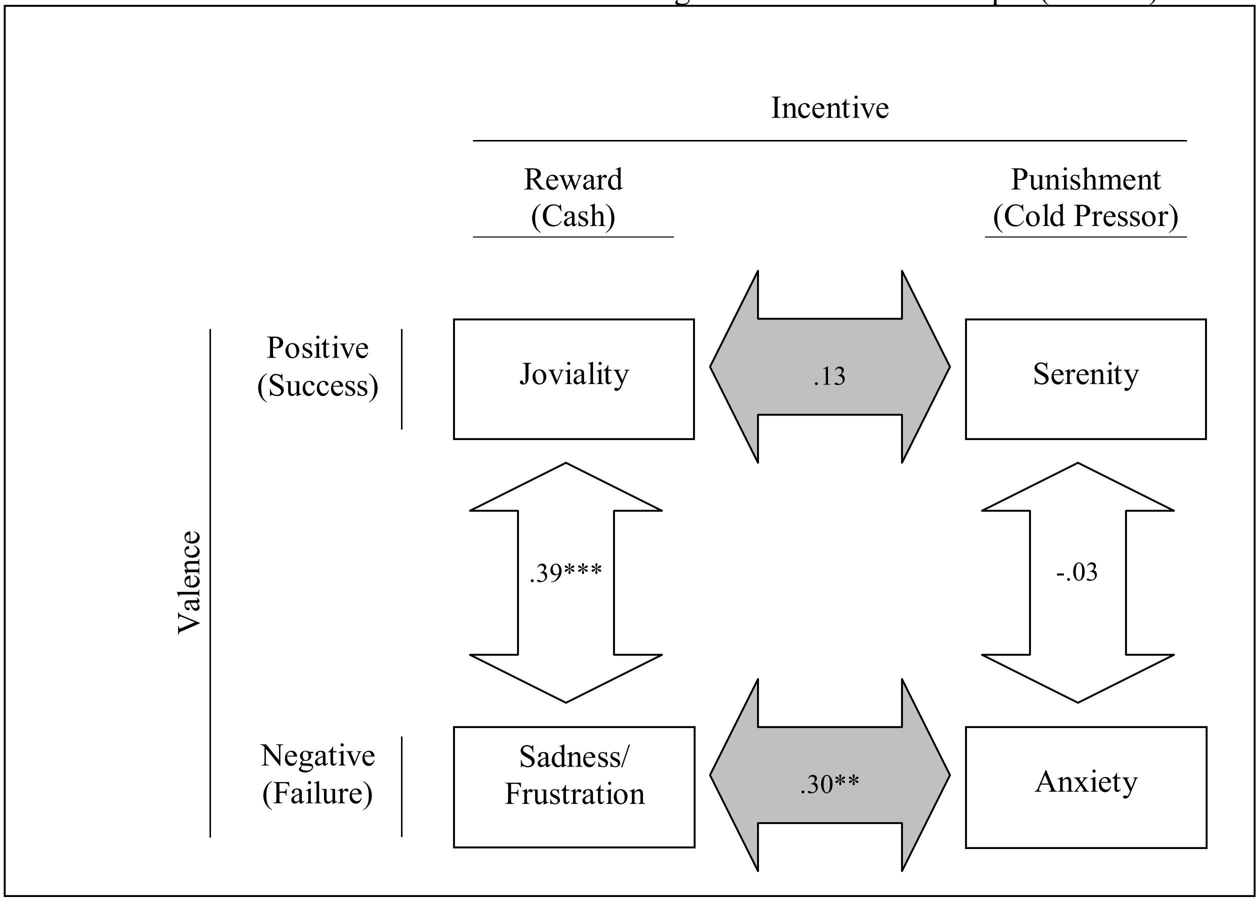
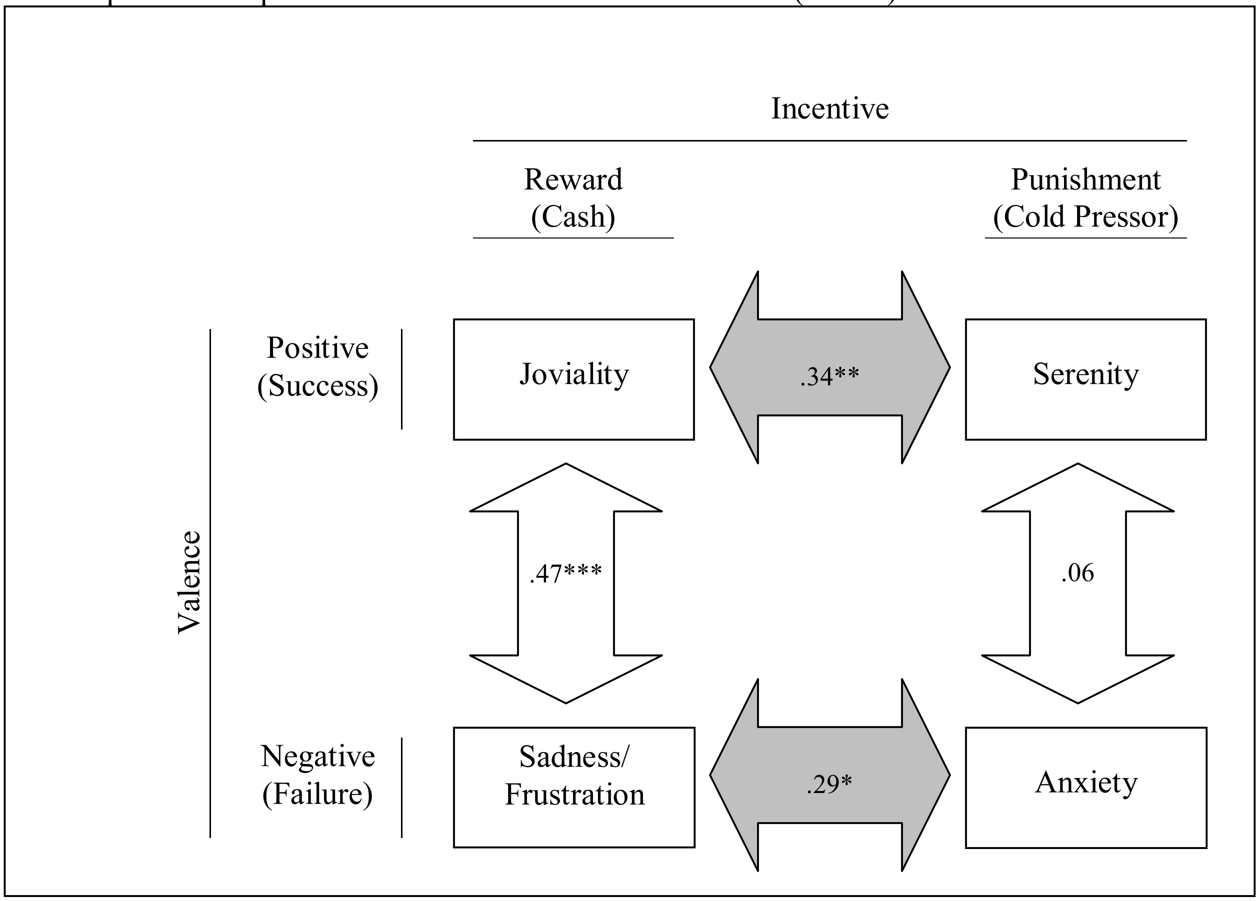


Figure 6. Correlations Among Regressed Change Scores on Target Emotions Predicted by the Valence and the Incentive Models of BAS/BIS Using the Normative Subsample (n = 119).



Note: Gray arrows represent correlations predicted by the valence model; white arrows represent correlations predicted by the incentive model.
**p < .01. ***p < .001.

Figure 7. Correlations Among Regressed Change Scores on Target Emotions Predicted by the Valence and the Incentive Models of BAS/BIS Using the Participants Within the Normative Subsample Who Experienced Punishment Before Avoidance (*n* = 59).



Note: Gray arrows represent correlations predicted by the valence model; white arrows represent correlations predicted by the incentive model.
$^{*}p < .05$, $^{**}p < .01$. $^{***}p < .001$.

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Appendix

Complete instructions given to participants during computerized puzzle task.

(Solid horizontal lines indicate advancement to the next screen.)

During this part of the experiment, you will work on puzzles designed to tap your unconscious processing ability. Unconscious processing refers to your ability to understand and make decisions about things without being consciously aware of all the details. (This is believed to be the basis for acting on "hunches" or "gut feelings", or "following your instincts".)

In this experiment, your unconscious processing ability will be tested by having you solve puzzles very quickly (before you become consciously aware of all the details). In other words, you will solve puzzles by "following your instincts".

You will work on two types of puzzles: anagrams and figure rotations. You will now learn how to work each type of puzzle.

(Press N to continue.)

For anagrams, you will see an ordinary word in the center of the screen, a string of letters on the left, and a string of letters on the right, like this:

deinoooprrt **proportioned** deinnoopprtt

You will have to decide which string of letters would form the word in the center if it were rearranged. In other words, which string of letters is made of the exact same letters as the word in the middle? (In this example, the string of letters on the left is the same as the word in the center.)

(Press V to continue.)

Most people take at least 10-20 seconds to solve this type of anagram puzzle consciously. During this experiment, you will see each puzzle for only 2 seconds before you must decide which string of letters is the same as the word in the center. This gives you enough time to look briefly at both strings of letters and the word in the center, but not enough time to consciously decide which string of letters is the same as the word in the center. Instead, you must rely on your "gut feeling" about which string of letters is the same as the word in the center.

You will now do a few examples for practice. The examples are designed to be easier than the ones you will do later on, and they will stay on the screen longer. This is so you can become familiar with how to solve the puzzles.

(Press N to continue.)

Before each anagram puzzle, a cross (+) will appear in the center of the screen for 2 seconds. Next, the anagram puzzle will appear for 5 seconds. Then, a screen will appear prompting you to choose which string of letters was the same as the word in the center. (The keyboard will not respond until you see the prompt. This is to ensure that everyone sees each puzzle for exactly the same amount of time.)

To choose the string on the left, press Q.

To choose the string on the right, press P.

Before you continue, please put your left index finger over the Q and your right index finger over the P.

(Press Q or P to continue.)

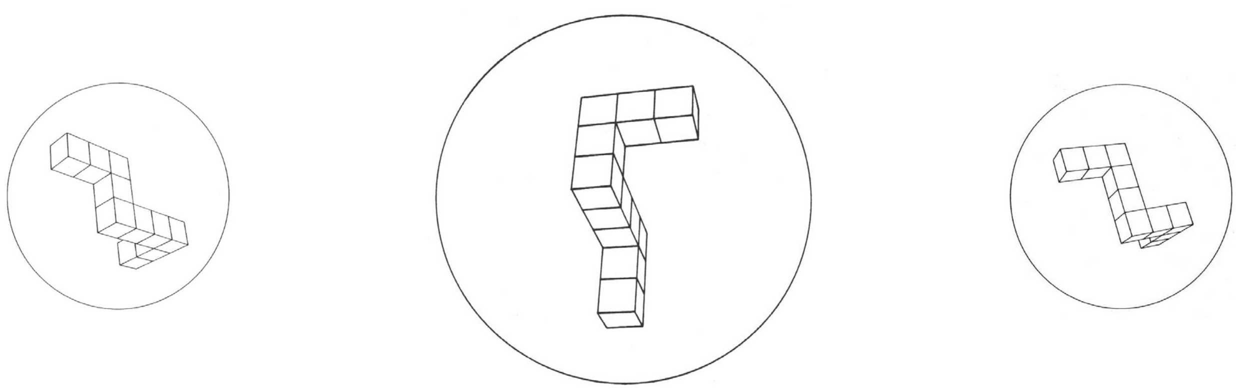
+

---

dddeeefffggg **hierarchical** aaccehhiilrr

Q	Which was the same?	P
	+	
acdiinorssyy	**idiosyncrasy**	aabbbcccddde
Q	Which was the same?	P
	+	
gghhiiilllnn	**indisputable**	abdeiilnpstu
Q	Which was the same?	P
	+	
hhhjjjkkknnn	**reiterations**	aeeiinorrstt
Q	Which was the same?	P
	+	
aabeeilmmrsu	**immeasurable**	bbbdddlllnnn
Q	Which was the same?	P

For figure rotation puzzles, you will see a larger figure in the center of the screen with smaller figures on the left and right, like this:



You will have to decide which of the smaller figures would be the same as the one in the center if it were rotated to the same position. (In this example, the figure on the right is the same as the one in the center.)

(Press N to continue.)

As with the anagram puzzles, most people take at least 10-20 seconds to solve this type of figure rotation puzzle consciously. During this experiment, you will see each puzzle for only 2 seconds before you must decide which figure is the same as the one in the center. This gives you enough time to look briefly at all three figures, but not enough time to consciously decide which is the same as the one in the center. Instead, you must rely on your “gut feeling” about which one is the same as the one in the center.

You will now do a few examples for practice. The examples are designed to be easier than the ones you will do later on, and they will stay on the screen longer. This is so you can become familiar with how to solve the puzzles.

(Press V to continue.)

Before each figure rotation puzzle, a cross (+) will appear in the center of the screen for 2 seconds. Next, the puzzle will appear for 5 seconds. Then, a screen will appear prompting you to choose which figure was the same as the one in the center. (The keyboard will not respond until you see the prompt. This is to ensure that everyone sees each puzzle for exactly the same amount of time.)

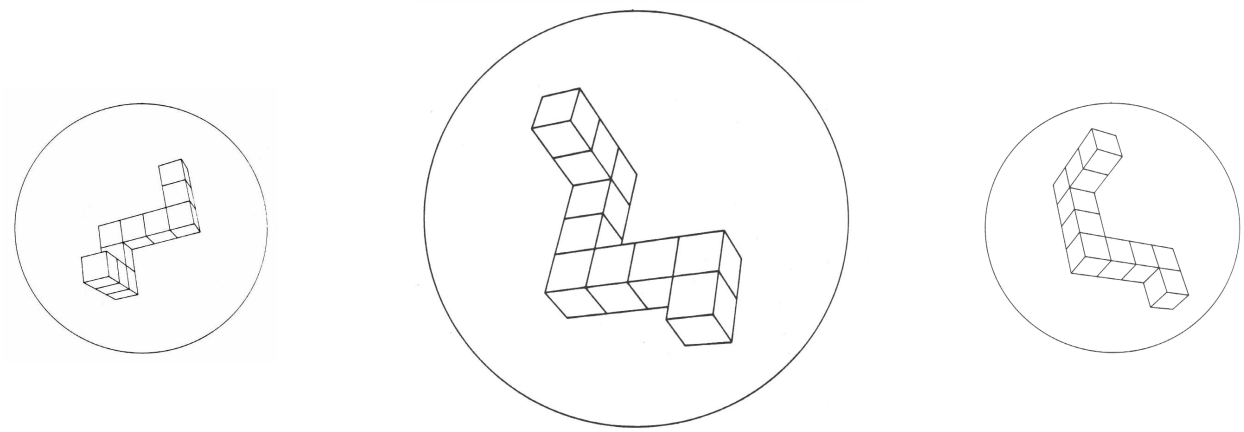
To choose the figure on the left, press Q.

To choose the figure on the right, press P.

Before you continue, please put your left index finger over the Q and your right index finger over the P.

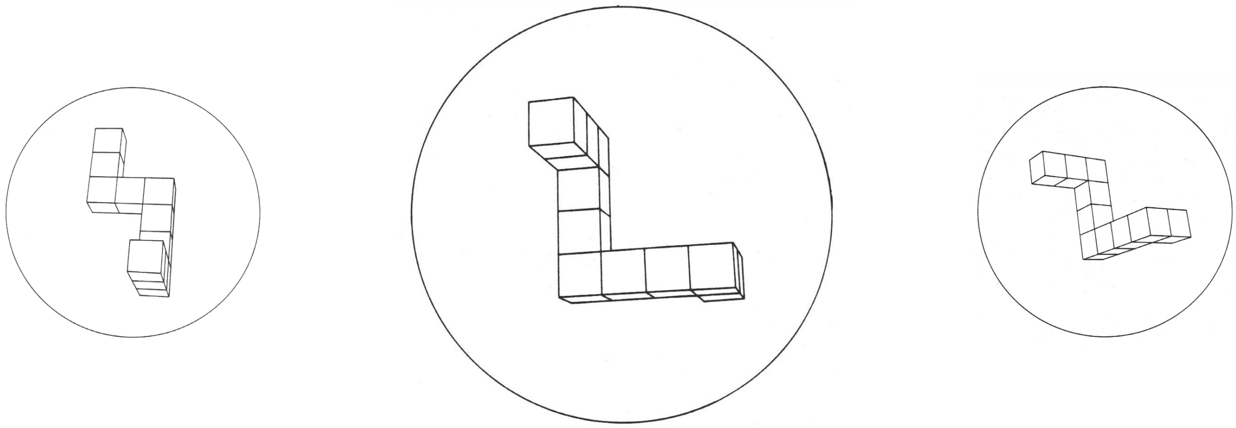
(Press Q or P to continue.)

+



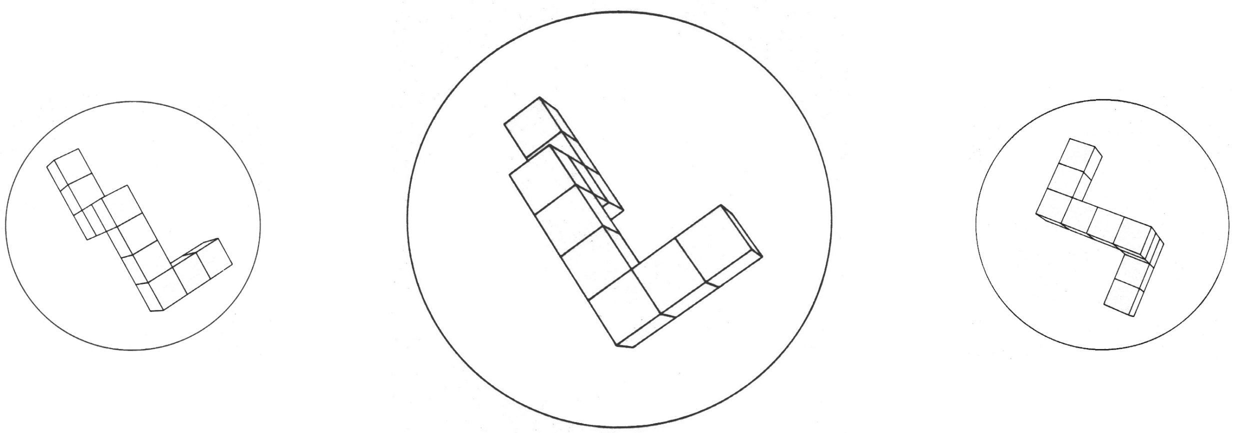
Q Which was the same? P

+



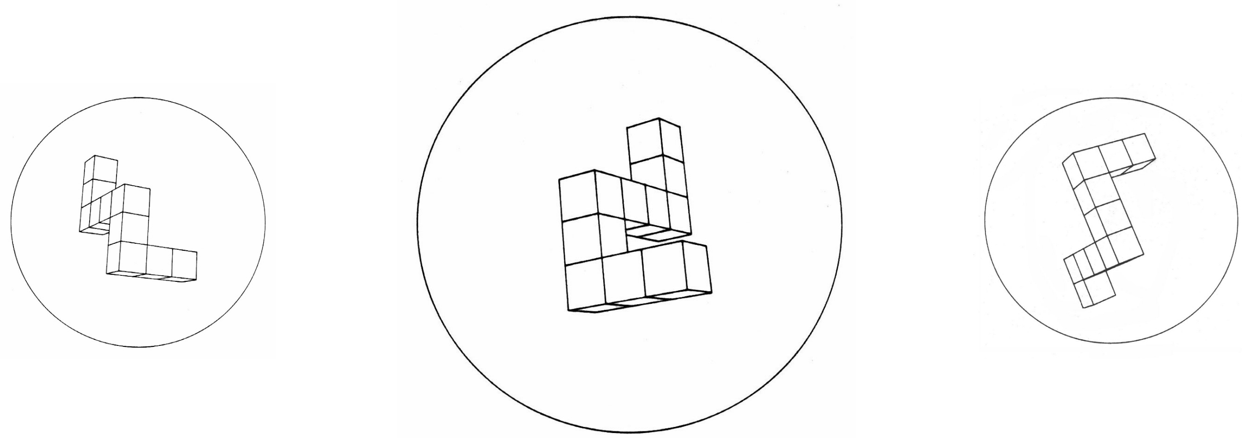
Q Which was the same? P

+



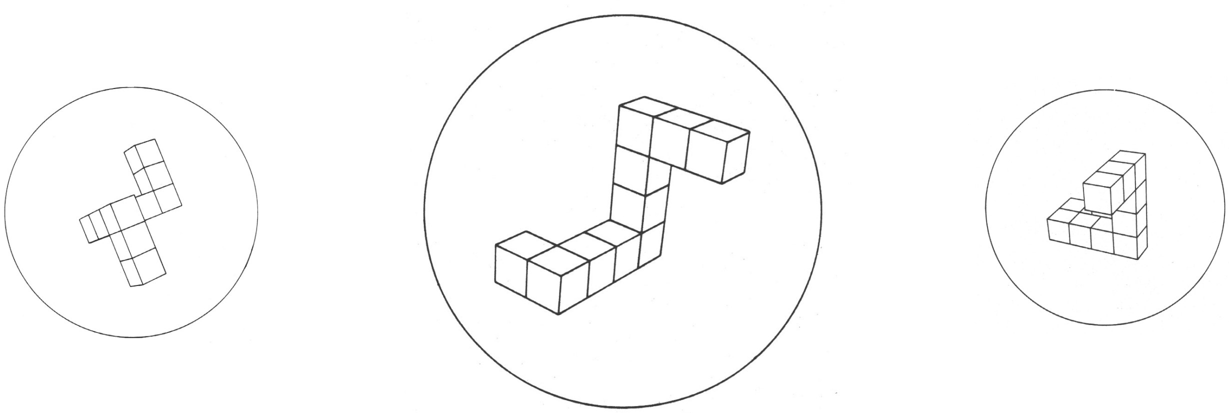
Q Which was the same? P

+



Q Which was the same? P

+



Q Which was the same? P

Several factors may be related to unconscious processing ability. This experiment is designed to examine the impact of each of these factors.

Several aspects of personality may be related to unconscious processing ability, so the experiment includes some personality questionnaires.

Emotions and mood states may also be related to unconscious processing ability, so the experiment also includes questions about how you are feeling. Because emotions and mood states often change over short periods, you will answer these questions several times.

(Press N to continue.)

Different kinds of incentives may have different effects on unconscious processing ability. For example, your unconscious processing ability may be better or worse depending on whether you are trying to earn a reward or trying to avoid a punishment.

Also, the impact of different incentives on your unconscious processing ability may depend on your personality and/or your mood state.

During this experiment, you will work on different unconscious processing puzzles under different kinds of incentives. You will work on the puzzles in sets, or blocks, of 40 puzzles each.

(Press V to continue.)

During some blocks, you will solve puzzles in order to earn a reward ($5.00 in cash). During reward blocks, you will receive $5.00 in cash if you solve at least 65% of the puzzles correctly.

(You would be expected to solve about 50% correctly simply by chance, so a cutoff of 65% is used to show your performance is better than chance.)

During reward blocks, there is no penalty or punishment if you solve less than 65% of the puzzles correctly, you simply do not earn a reward . In other words, during reward blocks, your incentive is to earn a reward by solving at least 65% of the puzzles correctly.

(Press N to continue.)

During some blocks, you will be solving puzzles in order to avoid a punishment (60 seconds in the cold pressor test of pain tolerance). During punishment blocks, you will be required to perform the cold pressor test for 60 seconds if you solve less than 65% of the puzzles correctly.

During punishment blocks, there is no reward if you solve at least 65% of the puzzles correctly, you simply do not receive a punishment. In other words, during punishment blocks, your incentive is to avoid a punishment by solving at least 65% of the puzzles correctly.

(Press V to continue.)

The computer will keep track of how many puzzles you have solved correctly and give you feedback at several points during each block. In this way, you will know what percent of the puzzles you have solved correctly (out of the ones you have done at that point in the block).

As mentioned earlier, your mood state may have an impact on the relationship between different types of incentives and different types of unconscious processing, so your mood state will be assessed before and after each block of puzzles.

You are about to begin the first block of puzzles, so it necessary to assess your mood state at this time.

(Press N to continue.)

Before you begin the next block of puzzles, please indicate how you are feeling right now.

On each of the next few screens, you will see a word describing a particular emotion. Please rate how much you are feeling that emotion right now, using the following scale:

1	2	3	4	5	6	7	8	9
Very slightly or not at all		A little		Moderately		Quite a bit		Extremely

Please note that you must use the numbers above the letters. (The numbers on the right will not work.)
(Press any number to continue.)

Right now, how much are you feeling...

---

tense

1	2	3	4	5	6	7	8	9
Very slightly or not at all		A little		Moderately		Quite a bit		Extremely

---

Right now, how much are you feeling...

---

discouraged

1	2	3	4	5	6	7	8	9

Very slightly or not at all	A little	Moderately	Quite a bit	Extremely

Right now, how much are you feeling...

relaxed

1	2	3	4	5	6	7	8	9
Very slightly or not at all		A little		Moderately		Quite a bit		Extremely

Right now, how much are you feeling...

happy

1	2	3	4	5	6	7	8	9
Very slightly or not at all		A little		Moderately		Quite a bit		Extremely

Right now, how much are you feeling...

annoyed

1	2	3	4	5	6	7	8	9
Very slightly or not at all		A little		Moderately		Quite a bit		Extremely

Right now, how much are you feeling...

nervous

1	2	3	4	5	6	7	8	9
Very slightly or not at all		A little		Moderately		Quite a bit		Extremely

Right now, how much are you feeling...

sad

1	2	3	4	5	6	7	8	9
Very slightly or not at all		A little		Moderately		Quite a bit		Extremely

Right now, how much are you feeling...

at ease

1	2	3	4	5	6	7	8	9

Very slightly or not at all		A little		Moderately		Quite a bit		Extremely

Right now, how much are you feeling...

enthusiastic

1	2	3	4	5	6	7	8	9
Very slightly or not at all		A little		Moderately		Quite a bit		Extremely

Right now, how much are you feeling...

frustrated

1	2	3	4	5	6	7	8	9
Very slightly or not at all		A little		Moderately		Quite a bit		Extremely

[The following instructions preceded the reward and nonreward blocks:]

You are about to begin a block of puzzles.

During this block, you will solve puzzles in order to earn a reward ($5.00 in cash). If you solve at least 65% of the puzzles correctly, you will receive $5.00 in cash. If you solve less than 65% of the puzzles correctly, you will not receive any cash.

Remember to look briefly at the entire puzzle and choose the answer you think is right based on your “gut feeling”.

(Press N to continue.)

[The following instructions preceded the punishment and avoidance blocks:]

You are about to begin a block of puzzles.

During this block, you will solve puzzles in order to avoid a punishment (60 seconds in the cold pressor test of pain tolerance). If you solve less than 65% of the puzzles correctly, you will be required to perform the cold pressor test for 60 seconds. If you solve at least 65% of the puzzles correctly, you will not be required to perform the cold pressor test.

Remember to look briefly at the entire puzzle and choose the answer you think is right based on your “gut feeling”.

(Press N to continue.)

[Following the instruction screen specifying the incentive, a screen specifying the type of puzzle then appeared. The following instructions preceded anagram puzzles:]

This block will consist of anagram puzzles. Before each anagram puzzle, a cross (+) will appear in the center of the screen for 2 seconds. Next, the anagram puzzle will appear for 2 seconds. Then, a screen will appear prompting you to choose which string of letters was the same as the word in the center.

To choose the string on the left, press Q.

To choose the string on the right, press P.

Before you continue, please put your left index finger over the Q and your right index finger over the P.

(Press Q or P to continue.)

[The following instructions preceded figure rotation puzzles:]

This block will consist of figure rotation puzzles. Before each figure rotation puzzle, a cross (+) will appear in the center of the screen for 2 seconds. Next, the figure rotation puzzle will appear for 2 seconds. Then, a screen will appear prompting you to choose which figure was the same as the one in the center.

To choose the figure on the left, press Q.

To choose the figure on the right, press P.

Before you continue, please put your left index finger over the Q and your right index finger over the P.

(Press Q or P to continue.)
