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Decreased responsiveness to reward in depression

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We have interpreted the literature showing left anterior hypoactivation in depression as reflecting a decrease in approach-related motivation and behaviour among depressed subjects. In support of this model, we have previously demonstrated a decreased responsiveness to reward in subclinically depressed dysphoric subjects. The current study was designed to replicate and extend those findings. Clinically depressed subjects who met DSM-IV criteria for major depression were compared to a group of nondepressed control subjects on a verbal memory task under three monetary payoff conditions: neutral, reward, and punishment. Although control subjects changed their pattern of responding in both the reward and punishment conditions, relative to the neutral condition, so as to maximise their earnings, depressed subjects did not do so during reward. The two groups did not differ during the punishment condition. These findings provide additional evidence of a decreased responsiveness to reward in depressed individuals, and are consistent with the hypothesis that the left prefrontal hypoactivation observed in depression reflects a deficit in approach-related behaviour.

A substantial literature now exists that shows that depression is associated with decreased activation in the left anterior regions of cerebral cortex (see Davidson & Henriques, 2000; George, Ketter, & Post, 1994 for reviews). This literature includes studies of scalp recorded brain electrical activity (e.g., Gotlib, Ranganath, & Rosenfeld, 1998; Henriques & Davidson, 1990, 1991), glucose metabolism (e.g., Baxter et al., 1989; Kato et al., 1995), and regional

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cerebral blood flow (e.g., Bench et al., 1992; Passero, Nardini, & Battistini, 1995). We have interpreted these findings as reflecting a decrease in approach-related behaviour among depressed individuals consistent with the symptoms of loss interest and anhedonia (e.g., Davidson, 1992; Davidson & Tomarken, 1989). This is congruent with a number of other research traditions that propose that depression is associated with a deficit in an approach-related positive affect system. For instance, Depue and Iacono (1989) proposed that depressives suffer from an underactivation of a reward-based behavioural facilitation system (BFS). Both Costello (1972) and Meehl (1975) have suggested that depressed individuals do not experience reward as reinforcing, and Watson, Clark, and Carey (1988) have shown that low levels of positive affect distinguish depression from other affective disorders. In the context of this model of emotion (Davidson, 1992), the prefrontal regions of the left and right cerebral hemispheres are viewed as cortical convergence zones (Damasio, 1989) that serve to organise approach- and withdrawal-related behaviour, respectively.

We have previously used a signal detection task to examine subjects' responsiveness to different pay-off conditions (Henriques, Glowacki, & Davidson, 1994). A signal detection analysis allows for the decomposition of a subject's performance into sensitivity and response bias by examining the percentage of both hits and false alarms. Sensitivity is a measure of the subject's ability to discriminate between target and nontarget stimuli. Response bias reflects a subject's willlingness to define an ambiguous stimulus as a target. Changing pay-offs for hits and false alarms produces changes in response bias (e.g., Healy & Kubovy, 1978).

In the earlier study, dysphoric and nondysphoric college students were selected on the basis of extreme and stable scores on the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, & Erbaugh, 1961). Subjects were evaluated on a verbal memory task under three monetary conditions: neutral, reward, and punishment. Pay-off contingencies were structured so as to demonstrate a differential deficit in the behaviour of dysphoric subjects: In both the reward and punishment conditions a more liberal response style (i.e., responding target) maximised the subject's earnings. There were no monetary consequences for identifying a nontarget word as a target. Thus, any differences in the response biases of dysphoric subjects between conditions could not be attributed to differences in the type of responding that maximised pay-offs. Compared to the response style in the neutral condition, normal subjects were more liberal in the reward condition, whereas dysphoric subjects were not. However, both normal and dysphoric subjects were more liberal in the punishment condition, and to a similar degree.

This present study was designed to replicate these findings in a group of clinically depressed subjects who met DSM-IV (APA, 1994) criteria for unipolar depression. We predicted that clinically depressed subjects, in contrast to nondepressed controls, would fail to change their pattern of responding during the reward condition. It was not expected that the two groups of subjects would differ during the punishment condition.

METHOD

Subjects

Eighteen depressed (11 female) and 15 nondepressed (9 female) subjects were recruited for this study via advertisements in local papers. A total of 883 subjects (548 female) were contacted by phone and screened to see if they met criteria. Of these, 215 subjects (124 female) were interviewed with a Structured Clinical Inventory for DSM-IIIR (SCID; Spitzer, Williams, Gibbon, & First, 1990, 1991) modified to make DSM-IV diagnoses. Diagnostic interviews were conducted by graduate students and staff members from the Laboratory for Affective Neuroscience trained in the use of the SCID. Reliability of the decision to accept or reject participants was evaluated through independent rating of 10 randomly chosen SCID audiotapes (k = .80, one participant misclassified). Depressed subjects were required to meet DSM-IV criteria for Major Depression. Any subject with a history of mania or psychosis or with a current diagnosis of Psychotic Depression, OCD, Social Phobia, Agoraphobia, Panic Disorder, GAD, Alcohol or Drug Abuse/Dependence, Bulimia Nervosa, or Anorexia Nervosa was excluded. Three of the depressed subjects had a prior history of an anxiety disorder, and another had a current phobia. Control subjects were required to have an absence of psychopathology in both themselves and their first degree relatives. Depressed subjects were required to have been medication-free for at least three weeks prior to testing, and were tested within two weeks after the completion of the SCID. All subjects were right-handed as assessed with the Chapman Handedness Inventory (Chapman & Chapman, 1987), and had normal or corrected-to-normal vision. Informed consent was obtained at the time of the diagnostic interview. Subjects were paid for their participation in this study; in addition, they were able to keep any money that they earned during the course of the experiment.

Procedure

When subjects came into the laboratory for testing, they were given an overview of the experiment and asked to complete several questionnaires consisting of the BDI (Beck et al., 1961), the Carroll Rating Scale for Depression (CRSD; Carroll, Feinberg, Smouse, Rawson, & Greden, 1981), and both the state and trait version of the Positive and Negative Affect Scale (PANAS-Now and PANAS-Gen; Watson, Clark, & Tellegen, 1988). On completion of the questionnaires, the signal detection task was explained in greater detail, and the subjects were shown an envelope containing ten dollars which they were told they could earn during the session.[1] The signal detection task was presented on computer with the aid of Neuro Stim (Neurosoft, Inc., 1990). Subjects were seated 50 to 55 cm from the computer screen.

Signal detection task

The verbal recognition task consisted of six blocks of trials which varied in pay-off contingencies: neutral, reward, or punishment, as well as one block of practice trials. The structure of the practice block was similar to the neutral block (described later). However, it contained fewer trials and the stimuli were nonoverlapping. In the neutral condition, accuracy feedback was provided visually, without monetary incentive. In the reward condition, subjects earned $0.10 each time they correctly identified a target word. In the punishment condition, subjects were initially credited $2.50, but $0.10 was deducted each time they failed to correctly identify a target word. There were two blocks with each of the three different pay-off conditions. The order of the neutral, reward, and punishment conditions was randomised across subjects.

At the start of each block, subjects were informed as to the pay-off contingencies for that block. Each block was divided into three parts: presentation of target words, colour distractor task, and discrimination trials. In the first part, 24 target words were presented consecutively for 400 ms each, with an interstimulus interval (isi) of 200 ms. All words were in lower case letters, 1.0 to 1.5 cm in height. The target words were presented in the same order for all subjects. Immediately following the presentation of the target words, the subjects completed the colour distractor task.[2] This task was included so as to increase the difficulty of the verbal recognition task by preventing subjects from rehearsing the target words. The colour discrimination task consisted of 20 trials, designed to vary in difficulty, in which subjects were asked to determine whether two consecutively displayed circles had been identical in colour. The circles had a diameter of 2.8 cm, were displayed for 100 ms, and had an isi of 2000 ms. Subjects received visual feedback on their accuracy after each trial. On completion of this task, the subjects were then immediately presented with the target and distractor words in a randomised order. In each trial, words were presented one at a time for 700 ms, at which time, the subject pressed one of two buttons on a computer mouse to indicate whether the word was previously presented (target) or new (distractor). Subjects received immediate visual feedback of ‘‘correct response’’ or ‘‘incorrect

[1] We have found that subjects need to receive immediate reinforcement. Earlier work in our lab failed to elicit the predicted changes in the behaviour of control subjects when subjects were told that their earnings would be mailed to them at the completion of the study.

[2] The colour task was not a focus of this investigation. However, the two groups did not differ either in response bias: Control-$M = 0.60$, SD = 0.23; Depressed-$M = 0.61$, SD = 0.19; $t(31) = -0.15$, n.s. or sensitivity (Control-$M = 0.78$, SD = 0.12; Depressed-$M = 0.72$, SD = 0.14; $t(31) = 1.24$, n.s.)

response''. In the reward and punishment conditions, accuracy feedback was accompanied by the display of the amount of money the subject has earned thus far in the block. Following the experiment, subjects were paid and debriefed.

Materials

The six word lists were composed of 48 words each, 24 targets and 24 distractors. All words were chosen from Toglia and Battig (1978), and were 5–6 letters in length. Words were selected so that targets and distractors were matched on imagery, familiarity, and pleasantness across lists. Pilot work with groups of 15–20 subjects insured comparable levels of difficulty across lists. The lists were randomised across blocks.

Signal detection measures

Measures of response bias (BR) and sensitivity (PR) were computed for each subject based on their hit rate (HR) and false alarm rate (FAR) using the formulas provided by Snodgrass and Corwin (1988). In Henriques et al. (1994), we used A′ and B″ as our measures of sensitivity and bias. However, Snodgrass and Corwin (1988) in their examination of four different measures of bias and sensitivity found there was a lack of independence between these two measures. They urged the adoption of a two-high-threshold model. Response bias (BR) was computed as the FAR divided by 1 minus the difference of HR and FAR, and sensitivity (PR) is simply the difference between HR and FAR. For BR, larger numbers indicate a more liberal response bias. Larger values for PR reflect a greater sensitivity in discriminating between target and nontarget stimuli. Data were computed for each block and then collapsed within pay-off condition.

RESULTS

Self-report measures

The two groups did not differ in age, $t(31) = -0.22$, n.s. Depressed subjects reported more depression, as compared to control subjects, on both the BDI, $t(23.1) = -14.41$, $p < .0001$;[3] and the CRSD, $t(20.8) = -16.11$, $p < .0001$, at the time of testing. On the PANAS-Gen, depressed subjects reported less PA, $t(31) = 5.76$, $p < .0001$; and more NA, $t(19.5) = -6.18$, $p < .0001$, compared to control subjects. Depressed subjects also reported less state PA, $t(31) = 4.51$, $p < .0001$; and more NA $t(19.7) = -3.89$, $p < .001$ than their nondepressed counterparts (see Table 1).

[3] The degrees of freedom reflect an adjustment for unequal variances between groups.

TABLE 1
Subject characteristics by group

Measure	*Depressed*	*Controls*
Age (in years)	33.44 (9.15)	32.67 (11.58)
BDI	26.44 (5.80)	1.93 (2.56)**
CRSD	24.94 (5.79)	1.71 (1.73)**
PANAS-Now		
Positive	21.94 (5.79)	30.57 (4.77)**
Negative	17.77 (6.89)	11.21 (1.72)*
PANAS-Gen		
Positive	21.05 (5.17)	34.36 (5.53)**
Negative	26.06 (9.73)	11.64 (2.34)**

Note: For depressed, $n = 18$; for controls, $n = 15$. Standard deviations are in parentheses. BDI, Beck Depression Inventory; CRSD, Carroll Rating Scale for Depression; PANAS, Positive and Negative Affect Schedule.

* Controls vs. depressed $p < .001$; ** Controls vs. depressed $p < .0001$.

Response bias: BR

A two-way repeated measures analysis of variance (ANOVA; SAS Institute, Inc., 1989) was computed on subjects' response bias, using Group (depressed/nondepressed) and Condition (neutral/reward/punishment) as variables. There was a significant Group $\times$ Condition interaction, $F(2, 62) = 3.36$, $p < .05$. This was a result of control subjects showing a more liberal response bias during both the reward and punishment conditions relative to the neutral condition. In contrast to the controls, depressed subjects actually were somewhat more conservative during the reward and punishment conditions relative to the neutral condition, although these differences from the neutral condition were not significant, $t(17) = -1.38$ and -1.13 for reward and punishment, respectively, n.s. (see Table 2). For control subjects, the difference in bias between the neutral and reward conditions was significant, $t(14) = 2.18$, $p < .05$, but the difference

TABLE 2
Response bias by group

Condition	*Depressed*	*Controls*
Neutral	.63 (0.17)	.54 (0.19)
Reward	.58 (0.16)	.60 (0.17)
Punishment	.61 (0.18)	.59 (0.19)

Note: For depressed, $n = 18$; for controls, $n = 15$. Standard deviations are in parentheses.

between neutral and punishment conditions was not, $t(14) = 1.47$, n.s. The two groups did not significantly differ in response bias during any individual condition: neutral, $t(31) = -1.41$, $p > .15$; reward, $t(31) = 0.35$, $p > .50$; punishment, $t(31) = -0.31$, $p > .75$. Rather it was the relative change between the pay-off and neutral conditions that differentiated the depressed and nondepressed subjects.

When the depressed and control subjects were compared on their differences in response bias between the neutral condition and the pay-off conditions (computed as a payoff-neutral change score), the difference between the neutral and reward conditions differed significantly between the depressed and nondepressed groups, $t(31) = 2.38$, $p < .03$. The difference in bias between the neutral and punishment conditions was not significantly different between the two groups, $t(20.5) = 1.82$, $p > .05$ (see Figure 1).

Three of the subjects in the depressed group had a past anxiety disorder and a fourth had a current phobia. A comparison between anxious and nonanxious depressives found that while the two groups had similar differences in response bias between the neutral and reward conditions, $t(16) = -0.16$, n.s., the groups

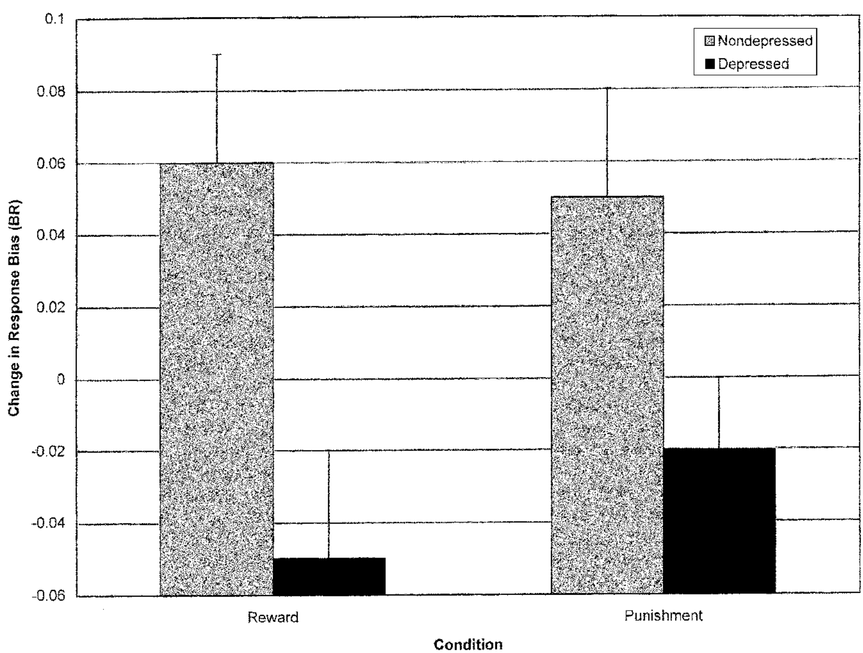

Figure 1. Mean change in response biases (Payoff-Neutral) and standard errors of depressed ($n = 18$) and control ($n = 15$) subjects during differing payoff conditions. Higher numbers reflect a more liberal response bias.

had different patterns of responses to the punishment condition, relative to the neutral condition, that approached statistical significance, $t(16) = 2.09$, $p < .06$. Depressed subjects who had a current or past anxiety disorder responded to the punishment condition by adopting a more liberal response bias, whereas non-anxious depressives became more conservative (see Figure 2).

When the depressed group was limited to only those subjects who had no past or current anxiety diagnosis ($n = 14$), the pattern of group differences between depressed and nondepressed subjects was still the same as that seen for the entire sample. The change in response bias from the neutral condition to the reward condition was still significantly different for the two groups, $t(27) = 2.07$, $p < .05$. In addition, the difference in bias between the neutral and punishment conditions was also significantly different between the two groups, $t(20.9) = 2.24$, $p < .05$. In both pay-off conditions, the control subjects were more liberal relative to the neutral condition, while the depressed subjects were more conservative.

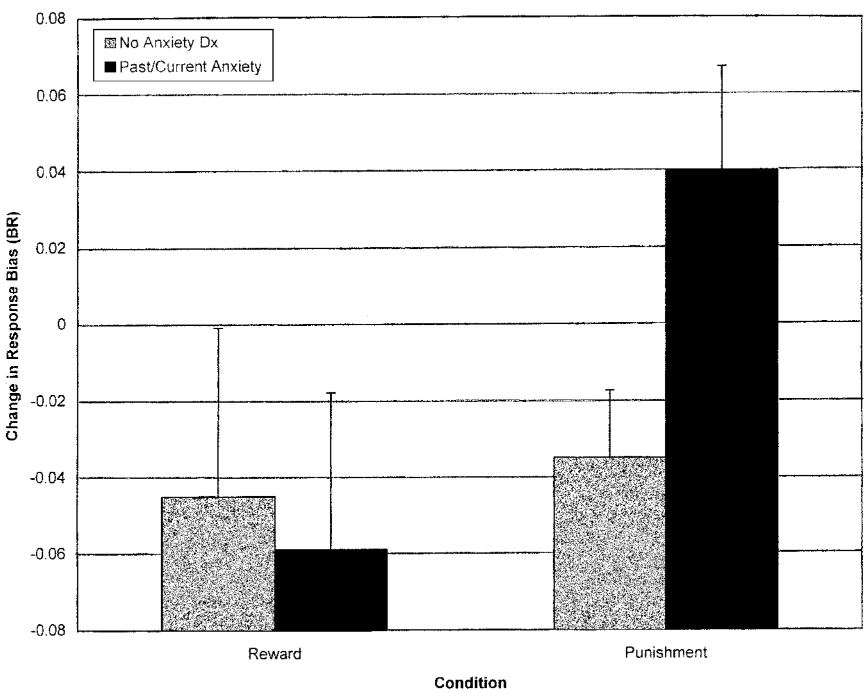

Figure 2. Mean change in response biases (Payoff-Neutral) and standard errors of depressed subjects with ($n = 4$) and without ($n = 14$) a past or current anxiety disorder. Higher numbers reflect a more liberal response bias relative to the neutral condition.

Sensitivity: PR

A two-way repeated-measures ANOVA was computed using Group (depressed/nondepressed) and Condition (neutral/reward/punishment) as variables. There was a significant Group difference in sensitivity, $F(1, 31) = 5.65$, $p < .03$, as control subjects were more accurate than depressed subjects at discriminating between target and nontarget stimuli. The Group $\times$ Condition interaction was nonsignificant, $F(2, 62) = 1.12$, $p > .30$, Control-neutral, $M = 0.50$, SD = 0.12; reward, $M = 0.48$, SD = 0.14; punishment, $M = 0.51$, SD = 0.14; Depressed-neutral, $M = 0.42$, SD = 0.17; reward, $M = 0.41$, SD = 0.13; punishment, $M =$ 0.36; SD = 0.19).[4]

Correlations between sensitivity and response bias

In the light of the group difference in sensitivity, relations between sensitivity and response bias were examined both across groups and within groups. All of these correlations were negative (range $-.23$ to $-.36$), indicating that a more liberal response bias was associated with decreased sensitivity. The only correlation that achieved statistical significance was the correlation between bias and sensitivity during the neutral condition for data collapsed across groups, $r = -.36$, $p < .04$.

DISCUSSION

In contrast to control subjects, depressed subjects failed to adopt a more liberal response bias during the reward condition. This is consistent with our earlier findings with subclinical dysphoric subjects (Henriques et al., 1994). This decrease in approach-related behaviour is consistent with models of depression that emphasise symptoms of anhedonia and lack of responsiveness to pleasurable stimuli (e.g., Costello, 1972; Davidson, 1992; Depue & Iacono, 1989; Meehl, 1975).

It was specifically this change in responding between the neutral and reward conditions that we expected to differentiate between depressed and nondepressed subjects. We did not expect to find differences between groups during the neutral condition. In fact, our results highlight the importance of examining the difference in response bias between pay-off and neutral conditions so as to eliminate individual differences in response bias not related to pay-off conditions. There were differences between the two groups during the neutral con-

[4] Using the accuracy data as a measure of performance (percentage of targets and nontargets correctly classified) resulted in similar group differences, i.e., there was a main effect for Group $F(1, 31) = 5.65$, $p < .03$ and the Group $\times$ Condition interaction was nonsignificant, $F(2, 62) = 1.12$, $p > .30$ (Neutral: Control-$M = 0.75$, SD = 0.06; Depressed-$M = 0.71$, SD = 0.08; Reward: Control-$M = 0.74$, SD = 0.06; Depressed-$M = 0.70$, SD = 0.07; Punishment: Control-$M = 0.76$, SD = 0.07; Depressed-$M = 0.68$, SD = 0.09).

dition, although these differences were not statistically significant, and the failure to examine responding during the neutral condition would have led us to incorrectly conclude that depressed and nondepressed subjects did not differ in how they responded to rewarding stimuli. It was the relative differences between the neutral and reward conditions that differed between the two groups, and it was this difference in bias that accounted for the observed Group × Condition interaction. Although these results are in line with our theoretical model, they do not directly address the issue of whether or not decreased responsiveness to reward is specific to depression. We have shown that a decreased responsiveness to reward is found among subjects who only have a diagnosis of major depression. We do not, however, know if this diminished responding to reward would be found in other diagnostic groups.

In our earlier study, we found that during the punishment condition dysphoric subjects had a more liberal response bias than the nondepressed control subjects. In the current study, we did not find this pattern of responding during the punishment condition: Depressed subjects did not change their pattern of responding for either the reward or punishment conditions. It is not clear what accounts for these differences. It may be that subjects with major depression exhibit both diminished approach *and* avoidance responding, and it is only the presence of a comorbid anxiety disorder that results in a pattern of responding during punishment that resembles that seen in controls. In fact, the comparison of depressed subjects with and without a past or current anxiety disorder suggest just such an explanation. It was those depressives who had a past or current anxiety disorder that responded with a more liberal response bias during the punishment condition. This explanation would also fit with our previous study (Henriques et al., 1994). It is quite possible that the dysphoric subjects in our earlier study had a more mixed symptom profile than our current group of depressed subjects, with a greater representation of anxiety symptoms. This might have led those subjects to be more responsive to the punishment condition. Studies have shown that high BDI scores are indicative of increased anxiety as well as increased depression (Kendall, Hollon, Beck, Hammen, & Ingram, 1987), and the dysphoric subjects in our earlier study did report more negative affect compared to our current depressed subjects.[5]

Although there were group differences in the ability to discriminate between target and nontarget stimuli, these differences do not account for the group differences in response bias. In fact, among both depressed and control subjects, those subjects who were high in sensitivity had more conservative response biases in each of the three pay-off conditions, and this correlation actually worked against our finding significant differences between groups in the pay-off

[5]The 23 dysphoric subjects examined in Henriques et al. (1994) had an average PANAS-Gen Negative score of 28.17 (SD = 7.23) and the 14 depressed subjects with no past or current anxiety disorder had an average PANAS-Gen Negative score of 24.5 (SD = 9.57).

conditions. This relation between sensitivity and bias was statistically significant in the neutral condition, and probably accounts for some of the observed, but not significant, group differences in BR observed in the neutral condition.

These results suggest a number of areas for future research. First, it is necessary to examine response bias and patterns of cerebral activation in the same group of subjects. Although the decreased responsiveness of depressed subjects to rewarding stimuli is consistent with our previous suggestion that left prefrontal hypoactivation in depression is associated with a deficit in approach-related behaviour and incentive-driven reward, it is necessary to directly test the model that we have put forth regarding left anterior activation and approach-related behaviour. Second, as noted earlier, these data do not directly address the issue of specificity to depression. Although the differences among the depressed subjects with and without a current anxiety disorder are intriguing, a study that compares depressed and anxious groups of subjects is necessary. Based on the preliminary results here, we would expect that the two groups of subjects would differ in both conditions with the anxious subjects responding more liberally during both reward and punishment conditions. Third, these data do not address the question of whether the observed deficits in approach-related behaviour are state- or trait-related. It would be useful to examine a group of depressed subjects during an acute episode and after symptom remission. If decreased responsiveness to reward is trait-related to depression, we would not expect to see changes in response bias on recovery. Finally, it would be interesting to examine the behaviour of depressed subjects across a range of reward levels in order to construct a dose-response curve. Costello (1972) suggested that depression produces a decrease in the effectiveness of reinforcers This suggests that increasing the value of the rewarding stimuli for depressives should eventually produce changes in response bias comparable to controls seen at lower levels of reward. Such an approach could also be used in examining the effects of treatment. If the observed decreased responsiveness to reward is state-related, recovery should be expected to shift depressed subjects' response curves such that they no longer differ from normal controls.

The neurotransmitter dopamine plays a central role in the maintenance of reward-motivated behaviours (Wise, 1978). Depue and Iacono (1989) believe that dopaminergic projections from the ventral tegmental area (VTA) to the prefrontal cortex underlie the BFS. They argue that decreases in dopamine result in hypoactivation of the BFS and this decrease in engagement with the environment produces depression. There is substantial evidence to support the view that depression is associated with decreases in dopamine, although this hypothesis is not the only pharmacological explanation of depression that is supported in the literature (see Willner, 1985). Thus, depression, as conceptualised by Depue and Iacono, is associated with decreased reward-seeking behaviours. In line with this, animal work has shown that chronic unpredictable stressors produce decreases in consumption of sucrose solutions (e.g., Muscat, Sampson, & Willner, 1990;

Sampson, Willner, & Muscat, 1991). This reduction in approach-related behaviour can be reversed by antidepressant medications. The administration of specific dopamine antagonists will reinstate this decrease in approach-related behaviour (Muscat et al., 1990; Sampson et al., 1991). It would be interesting to examine the effects of dopamine agonists and antagonists on this task.

To date, we have only used the task to look for deficits in approach-related behaviour in depressed individuals. Future work could use this paradigm with other populations, for example, to examine sensitivity to punishment in anxious individuals, a population that is hypothesised to be overly responsive to withdrawal-related stimuli (Gray & McNaughton, 1995), or to examine issues of hyporesponsivity to punishment and/or hyperresponsivity to reward in psychopaths (e.g., Newman & Kosson, 1986). We believe this and other similar signal detection paradigms can be useful in examining the role of both reward and punishment in a variety of clinical populations.

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