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Impaired context maintenance in mild to moderately depressed students.

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Abstract

We test the hypothesis that people with depression experience difficulties in maintaining task relevant context information over longer periods of time using the AX version of the continuous performance task (AX-CPT). The AX-CPT requires that participants maintain a context cue in an active state (A) in order to respond correctly to a target cue (X) presented after a short delay. Forty non-depressed and mild to moderately depressed students completed versions of the task with short (1-s) or long (10-s) inter-stimulus intervals (ISIs). Mildly depressed participants made significantly more context dependent (BX) errors, unlike controls who made more errors on trials where good context processing would impair performance (AY). This pattern of errors was only evident in the long ISI condition suggesting poor maintenance of contextual information.

Performance across many cognitive domains, including working memory and executive function, has been linked to an underlying 'context processing mechanism' (Cohen & Servan-Schreiber, 1992). In this framework, the term context refers to any background information required to be active to ensure appropriate behaviour (Cohen, Barch, Carter, & Servan-Schreiber, 1999). Context processing has also been linked to various psychopathologies. For instance, considerable evidence indicates that impairments in context processing accompany schizophrenia (e.g., Servan-Schreiber, Cohen, & Steingard, 1996). We have also proposed that context processing mediates distinct learning impairments in mild depression (Msetfi, Murphy, Simpson, & Kornbrot, 2005). In the present study, we test this hypothesis directly by using the AX version of the continuous performance task (AX-CPT), a standard procedure designed to distinguish context processes from other more general cognitive processes and which has previously been shown to discriminate impaired performance in schizophrenia (Servan-Schreiber et al., 1996).

Context processing is thought to be involved in experimental tasks when, (i) task instructions, (ii) environmental, spatial or temporal cues, or (iii) prior discrete stimuli determine responding to subsequent stimuli, particularly when an inappropriate response must be inhibited. Many experimental procedures have these requirements but two in particular seem to distinguish those with depression from controls.

The Stroop task and the Wisconsin Card Sort Test (WCST) both require that participants inhibit a prepotent response to follow a rule (i.e., name an ink colour incongruent with a colour word; follow a new rule rather than a previously learned one). A recent systematic review has shown that there is strong evidence of depression related impairments on both the WCST (5/6 studies) and Stroop (6/6

studies) tasks (Ottowitz, Dougherty, & Savage, 2002) which suggests the presence of context processing difficulties in depression. Evidence from learning studies is similarly suggestive. We have previously reported how people with mild depression are impervious to changes in context information and, consequently, on some occasions seem to learn better than controls (Msetfi et al., 2005). We interpreted this finding as a depression related impairment in sensitivity to the information provided by the context (See Msetfi, Murphy, & Simpson, 2007). Although this body of evidence points towards context processing effects in depression, equivocal evidence of a depression related impairment has emerged from an experimental procedure specifically designed to assess context processes.

The AX version of the continuous performance task (AX-CPT: Servan-Schreiber et al., 1996) requires participants to use previously presented stimuli to determine whether a response is appropriate or not. They are asked to observe letter pairs presented sequentially on a screen at short (1-s) or long intervals (5 to 10-s) and to respond affirmatively to a target letter X, only if the letter A appears first. If any other letter precedes X or follows A, then a 'non-target' response should be made. Correct target identification is therefore dependent upon processing the first stimulus of the pair, which might be termed the 'context' stimulus. This simple task is made even more challenging because many more target than non-target trials are programmed, meaning that participants are more likely to make errors on non-target trials. It is these non-target errors that can be examined to provide clues about participants' context processing capabilities.

Some errors will be made because the initial context stimulus has been processed well and its representation remains strongly active. Different errors will occur because the context representation is poor in the first place or not well

maintained in an active state. Consider the three possible types of non-target trial, AY, BX and BY, where A and X are the target context and stimulus respectively but B and Y are any randomly selected non-target context and stimulus. Good context processing would produce more errors on AY than BX trials. This is because if the representation of the context stimulus is strongly active, the A of the AY trial will produce such a powerful expectation of X that an error is likely when Y is actually presented. However the B of the BX trial would still be active on presentation of X so the participant would be ready with the non-target response and few errors would occur. Conversely, a poorly processed context would result in the opposite pattern, of more BX than AY errors. The B of BX trials would not be strongly active on the presentation of X, so uncertainty and errors would result due to X's resemblance to the target. This would not be the case on AY trials where only the context stimulus resembles the target and it would not be active when the second unambiguous stimulus was presented. BY trials should not produce errors due to context processes and serve as a general difficulty control.

Therefore, good context 'processors' should always produce more AY than BX ($\leq$ AX = BY) errors. However, error patterns resulting from poor context processing will be linked to the specific type of impairment. The problem could be due to the quality of the initial context representation **or** an inability to maintain it over time. Impoverished representations would produce more BX than AY ($\leq$ AX = BY) errors with both short and long durations between stimuli. This pattern would emerge only with long durations between stimuli if the problem was to do with context maintenance only. It is clear though that the BX versus AY comparison is critical in order to distinguish generally poor performance from a specific context processing impairment (MacDonald & Carter, 2003).

Studies using the AX-CPT procedure have been inconclusive concerning depression and context processing. Cohen et al. (1999) reported that depressed patients and healthy controls made more BX than AY errors, especially with long intervals between stimuli. This error pattern was similar, albeit less extreme, to the pattern of errors made by patients with schizophrenia (although see Holmes et al., 2005; Servan-Schreiber et al., 1996). Interestingly, several other studies described similar, though perhaps non-significant, trends in healthy controls (e.g., Ceccherini-Nelli, Turpin-Crowther, & Crow, 2007; Javitt, Rabinowicz, Silipo, & Dias, 2007; MacDonald, Pogue-Geile, Johnson, & Carter, 2003). Several possible explanations exist for these findings. It might be the case that most people, whether healthy or depressed, have difficulties maintaining context stimuli over longer intervals, hence the similarity between these groups. Alternatively, in light of the evidence we laid out earlier, perhaps higher depression levels in healthy controls were responsible for their apparent difficulties. However, as depression levels and the results of BX versus AY significance tests have rarely been reported, it is hard to establish whether depression is linked to a context processing impairment as measured by the AX-CPT.

Present Study

It is presently unclear whether both healthy and depressed people have trouble maintaining context information over a longer period or whether elevated levels of depression in healthy controls could be responsible for their specific pattern of errors. In order to investigate some of these possibilities, we tested a sample of students who resembled a healthy control group but who had also been screened for depression. They were categorised as non-depressed or mildly depressed by their scores on the Beck Depression Inventory (BDI: Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) and completed either a short or long ISI version of the AX-CPT. If context processing

difficulties arise simply from being required to maintain context information actively for longer periods, then all participants, irrespective of mood, should make more BX than AY errors in long but not short ISI conditions. On the other hand, if the similarity between depressed patients and controls is due to depression levels in the latter group, then only the depressed group should make this specific pattern of errors.

Finally, when testing analogue samples of depressed participants, it is recommended that anxiety measures should be taken as higher levels of anxiety can produce elevated BDI scores (Vredenburg, Flett, & Krames, 1993) and be responsible for any between group differences as opposed to depression specifically. As high levels of stress can also produce such an effect, the Depression, Anxiety and Stress scales (DASS: Lovibond & Lovibond, 1995) were used for this purpose. Finally, depressed people often experience interfering ruminative thoughts that impact on the ability to concentrate and maintain context information actively for longer periods of time. Therefore a measure of ruminative tendencies was taken using the Ruminative Response Scale (RRS: Nolen-Hoeksema, 1991).

Method

Participants. Participants were recruited using a mass screening method. They were required to fill in the Beck Depression Inventory before being invited to participate and then, again, on arrival to take part in the experiment. Only those who scored high or low at both time points were included in the sample. Forty participants were assigned to the depressed (n = 20, female: n = 10, male: n = 10) or non-depressed (n = 20, female: n = 10, male: n = 10) groups, where scores of 9 or above indicated mildly depressed mood and scores of 8 or below indicated no depression. There was no difference between average BDI scores in the total population of volunteers (M =

9.773, *SE* = .575) and the final selected sample (*M* = 9.725, *SE* = 1.238), *t*(39) = -.039, *p* = .969. Half of the participants in each mood group were then assigned to the short ISI condition (1-s) and half to the long ISI condition (10-s) with the constraint that there should be equal numbers of males and females in each group. One non-depressed male participant's data was excluded from all analyses due to an overall random error rate (probability of error on all trials > .5). All groups were successfully matched on a range of relevant demographic variables, including age, years of education, digit span and National Adult Reading Test (NART) scores which provide a measure of pre-morbid IQ (see Table 1). As expected, scores on the BDI, DASS anxiety, depression and stress scales, and Ruminative Response Scale were higher in the depressed than in the non-depressed groups but did not differ across ISI groups.

(Table 1 about here)

Materials. A version of the AX-CPT was used and programmed using REALBasic Version 3 software.

Design. A mixed fully factorial design was employed with mood (non-depressed, depressed) and ISI (short, long) as between subjects factors. Error type (AX, AY, BX, BY) was a repeated measures factor. The dependent variable was whether participants made an error (error present) or not (error absent) on each trial.

Data analysis. The error present / absent data constitute a binary response variable and were entered into a logistic regression model with the frequency of errors as a weighting factor. As there was more than one observation for each participant, the variable 'participant' was included in the analysis in order to control for the effect of this factor. This analytical method is recommended for situations with a binary

response variable (e.g., absent, present) and where observations occur for several strata (e.g., several combinations of control variables, see Agresti & Hartzel, 2000).

Procedure. Participants gave background information about age, number of years in full time education and completed the digit span test, the NART and the BDI. Participants were then informed that they would see letters appear sequentially on the computer screen and that they were required to press the target button – the return key on the computer keyboard – whenever they saw the letter "X" preceded by the letter "A", or press the non-target button – the tab key on the computer keyboard - on trials when any other letter sequence was observed. Participants were further instructed that on each trial they would have 1-s to make their response and that they should make the response as quickly and accurately as possible. If the response occurred after the 1-s interval had elapsed, a beep would sound indicating a 'miss', and they should try again on the next trial (see Appendix 1 for the exact text of the instructions shown over two screens). The letter pairs were presented on a computer display sequentially over 150 trials separated by a 1-s ITI. The delay between each pair of letters (ISI) was 1-s in the short condition and 10-s in the long condition. Each stimulus remained on the screen for 300-ms and after the presentation of the second stimulus in the pair, participants had 1-s to make their response. If participants did not respond during the allowed interval or gave an incorrect response, this was scored as an error trial. Seventy per cent of trials (105) were AX trials and the remaining 30% were equally divided between AY, BX and BY trial types (15 each). Trials were arranged in a pseudo-random order such that there would be an equal number of each trial type in each 50 trial block. After this, participants completed the Ruminative Response Scale and the DASS and were debriefed.

Results

The probability of error predicted by the logistic regression model for each error type in both short and long ISI conditions is shown in Figure 1. Participants appeared to make more errors in long ISI conditions than short ISI conditions although this appeared to depend on mood and error type.

(Figure 1 about here)

Experimental variables were entered simultaneously into a binary logistic regression model resulting in a significant model, $\chi^2(50) = 244.58, p < .001$, Nagelkerke $R^2 = .11$. The effect of error type was significant, $\chi^2(1) = 18.71, p < .001$, and the effect of ISI also approached the level of significance, $\chi^2(1) = 3.75, p = .053$. The interactions between error type and ISI, $\chi^2(3) = 10.69, p = .014$, and error type, ISI and mood, $\chi^2(3) = 11.94, p = .008$, were also significant. None of the other effects or interactions, except participant, $\chi^2(35) = 170.39, p < .001$, were reliable predictors.

The significant three-way interaction between error type, ISI and mood, was explored further by testing the ISI by error type interactions for each mood group and both were found to be significant (Depressed: $\chi^2(3) = 9.30, p = .026$; Non-depressed: $\chi^2(3) = 8.39, p = .039$). Theoretically motivated planned Helmert's contrasts were then carried out on the raw data and tested whether one specified error type in each condition was significantly more likely than all the other error types combined in that group. As predicted, in long ISI conditions, depressed people made more BX errors than any other error type, $\chi^2(1) = 12.40, p < .001$, while the non-depressed made more AY errors than any other error type, $\chi^2(1) = 6.49, p = .011$. Although an alpha

level of .05 was used for these planned contrasts, significant effects would have also met a more conservative rejection criterion. This pattern of errors, which is consistent with poor context maintenance in the depressed group and efficient context maintenance in the non-depressed, was not observed in short ISI conditions. The depressed group made more errors in the BY general difficulty control condition, χ^2 (1) = 7.64, p = .006, whereas the non-depressed made very few errors on AY trials in comparison to other trials, χ^2 (1) = 5.19, p = .023.

In order to examine the possibility that the pattern of errors observed in long ISI conditions was due to longer procedure times and consequential fatigue rather than context maintenance specifically, data from the theoretically important AY and BX trials was subjected to further scrutiny. The probability of error on each block of 50 trials is shown in Table 2.

(Table 2 about here)

Table 2 provides no evidence for an increase in errors due to increased procedure time. Moreover, the analysis showed that the interaction between ISI, error type, mood and trial block was not significant, χ^2 (2) = .03, p = .866.

A further possibility was that levels of anxiety, stress or rumination could account for differences in AX-CPT error patterns between the mood groups. In order to explore this possibility, correlations were computed between the predicted probabilities of errors made in each condition (i.e., depressed, long ISI, BX error) and anxiety, stress and rumination scores individually. None of these correlations were reliable (anxiety: all p's > .331; stress: all p's > .279; rumination: all p's > .180) and

this remained the case if short and long ISI groups or depressed and non-depressed groups were combined to increase power.

Discussion

The purpose of the present study was to investigate the relationship between context processing capabilities and depressed mood using the AX-CPT. We found that although non-depressed participants were able to maintain context representations strongly over time, errors made by the depressed group were consistent with impaired context maintenance. On the other hand, errors made by both mood groups in short ISI conditions were neither consistent with good or with inadequate context representation. We will discuss all these findings in light of previous studies examining context processing and the implications for other cognitive impairments in depression.

Although data from long ISI conditions clearly fits the profiles of good or poor context maintenance as predicted by Cohen and colleagues' theory, data from short ISI conditions does not fit predictions. The non-depressed made fewer AY errors than any other error type, which were all at a similarly low level. As short AY trials are likely to produce more errors with strong context representation, this improved performance seems inconsistent. However, Braver, Satpute, Rush, Racine and Barch's (2005) explanation for a similar facilitation of AY performance in their older adult sample might provide a useful insight. They invoked the notion of proactive cognitive control, defined as the ability to sustain context information in order to prepare attentional mechanisms for the appearance of the target. The suggestion was that impaired proactive control would result in an improvement in AY performance because A was less likely to be used as a predictive context for X. One

suggestion is that our non-depressed sample tended not to use A in this way in short ISI conditions, simply because they found the task so easy. In other words, the facilitation of AY performance we observed was due to the lack of need to use proactive cognitive control in this task, as opposed to inability. This may be because we used a version of the AX-CPT that was possibly shorter than that used in most other studies, as short and long ISI trials were not intermixed. The fact that depressed groups' errors peaked in the general difficulty BY condition supports the view that errors made in short conditions were reflective of task difficulty or vice versa rather than the context processing aspect of the task.

Previous studies using the AX-CPT yielded no evidence of differences between depressed patients and healthy controls. However, error patterns observed in AX-CPT data were sometimes suggestive of context maintenance difficulties in both depressed groups and healthy controls (e.g., Ceccherini-Nelli et al., 2007; Cohen et al., 1999), though this has rarely been the focus of any meaningful discussion. Our findings provide some clarification to this confusion. Our sample, which resembled a healthy control group, was categorised on the basis of depressed mood and a very distinct pattern of errors emerged from the depressed groups. The error pattern in long ISI conditions is consistent with context maintenance difficulties in mild depression. This further suggests that unassessed levels of depression in healthy control groups could be responsible for the similarity between their data and that of depressed patients, potentially concealing the effect of any impairment in that group. This emphasises the importance of measuring and controlling for relevant confounding variables, especially depression in healthy control groups, when the patient control group also have diagnoses of depression.

In this study data was also collected on levels of stress, anxiety and the tendency to ruminate. Levels of stress and anxiety, as opposed to depression specifically, could produce erroneous between group differences when analogue samples are used (e.g., Vredenburg et al., 1993). We also reasoned that the tendency to ruminate during experimental procedures could cause depressed people to perform poorly on tasks such as the AX-CPT. However, anxiety, stress and rumination measures were not related to errors and the specific error pattern observed in the long ISI condition was consistent with an impairment of context maintenance, rather than overall difficulties in maintaining attention to the procedure.

Studies which have concluded no differences between depressed patients and healthy controls have been seen as support for the view that impaired context processing is a hallmark of schizophrenia specifically (e.g., Cohen et al., 1999; Holmes et al., 2005). Our findings cast doubt upon this view because they suggest that if depression levels had been measured and controlled in such experiments, differences between the groups may have been revealed. As depression levels were not measured in healthy control groups, a depression - linked context impairment could not be discounted. Thus, our findings add to the growing body of evidence on the effects of depressive states on context processing.

The general conclusion, then, is that people who are depressed have difficulties maintaining context information over time. Given the methodology in the present study, we cannot conclude a causal role for depression in the genesis of such difficulties. In fact, on the basis of the present findings, it is equally possible that context processing difficulties could predate depression and contribute to its onset and maintenance. For example, people with depression make context independent contingency judgements (e.g., Msetfi et al., 2005), report contextually impoverished

autobiographical memories (e.g., Williams & Scott, 1988) and display an emotional or expressive insensitivity to changes in contextual information (e.g., Rottenberg, Gross, & Gotlib, 2005). These findings are consistent with depression both as a cause and a consequence of context processing difficulties. On the other hand, it has been suggested that disrupted context regulation of affect in depression might stem from functional hippocampal impairment related to the effect of stressful early experiences (for a discussion see Davidson, Jackson, & Kalin, 2000). Thus contextual processing difficulties may well precede the onset of depression.

If one accepted the concept of context processing being causally related to the onset and maintenance of depression then it would be possible to incorporate this finding into current dominant theoretical accounts of the genesis of depression. For example, depressive schema contain generalised, negative self knowledge (I am an angry person) and are postulated to have a causal role in the onset of depression (e.g., Beck, 1967). Although the process through which specific episodic knowledge (I was angry during a particular event) becomes decontextualised and generalised is unclear (e.g., Squire, 1992), it is possible that, if contextual processing becomes impaired early on, such generalisations would become difficult to modify and could contribute to the initial development, as well as the maintenance of pervasive, inflexible depressive schema.

It could also be argued, then, that this area of research sheds light on the 'active ingredients' of therapeutic approaches to depression that emphasise the importance of contextual awareness. One example is mindfulness (Kabat-Zinn, 1994) which emphasises, among other activities, participants gaining an increasing awareness of the present moment. This would include the capturing of contextual information which might otherwise be lost and which might be important in allowing

a richer stream of information to be accessible and processed. This richer stream of information then allows for more rounded judgements of the self, the world and others to develop and allows the availability of counter examples to be readily available. We argue then that the findings of this paper are not only theoretically and conceptually coherent but can also provide an explanation for the effectiveness of emerging approaches to the successful treatment of depression.

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Table 1: Demographic and depression relevant characteristic of each experimental group. *Abbreviations: NART = National Adult Reading Test; BDI = Beck Depression Inventory; DASS = Depression, Anxiety and Stress Scales; RRS = Ruminative Response Scale. Standard errors are shown in parentheses.*

Measure	Non-depressed		Depressed		*F*	*p*
	Short	Long	Short	Long		
Age	23.80 (2.52)	26.25 (2.82)	26.20 (2.52)	21.10 (2.52)	<1[a] 2.11[b]	*ns* 0.160
Years of education	15.40 (0.85)	15.63 (0.95)	16.80 (0.85)	15.20 (0.85)	<1[a] 1.08[b]	*ns* 0.310
Digit span	6.60 (0.34)	7.00 (0.38)	7.00 (0.34)	6.70 (0.34)	<1[a] 1.02[b]	*ns* 0.320
NART	30.20 (2.50)	32.00 (2.79)	33.30 (2.50)	32.60 (2.50)	<1[a] <1[b]	*ns* *ns*
BDI	3.00 (1.38)	3.75 (1.54)	17.00 (1.38)	15.60 (1.38)	83.02[a] <1[b]	<.001 *ns*
Anxiety - DASS	2.30 (1.90)	3.00 (2.13)	9.80 (1.90)	8.00 (1.90)	10.18[a] <1[b]	0.003 *ns*
Depression - DASS	1.80 (2.23)	6.13 (2.50)	11.90 (2.23)	8.50 (2.23)	7.37[a] 2.83[b]	0.010 0.100
Stress - DASS	6.40 (2.04)	8.75 (2.28)	13.20 (2.04)	13.20 (2.04)	7.19[a] <1[b]	0.011 *ns*
RRS	44.30 (4.72)	49.00 (5.28)	53.30 (4.72)	55.20 (4.72)	2.44[a] <1[b]	0.128 *ns*

Table note: Differences between groups on measures were analysed using a Multivariate ANOVA with *df* of 1, 34. [a]Main effect of mood. [b]Interaction between Mood and ISI. *F* and *p*-values for main effect of ISI were not included as all *F*s<1.

Table 2: Predicted probability of error on AY and BX trials in each experimental group and block of 50 trials. *Standard errors of the mean are shown in parentheses*.

Mood	ISI	Error	Blocks of 50 trials		
			1	2	3
Non-depressed	Short	AY	0.018 (0.006)	0.002 (0.001)	0.002 (0.001)
		BX	0.143 (0.042)	0.059 (0.019)	0.079 (0.025)
	Long	AY	0.114 (0.035)	0.177 (0.047)	0.002 (0.001)
		BX	0.02 (0.008)	0.157 (0.044)	0.158 (0.044)
Depressed	Short	AY	0.065 (0.029)	0.105 (0.043)	0.052 (0.024)
		BX	0.076 (0.033)	0.096 (0.04)	0.009 (0.005)
	Long	AY	0.056 (0.023)	0.056 (0.023)	0.149 (0.052)
		BX	0.205 (0.064)	0.165 (0.056)	0.112 (0.042)

Figure caption.

Figure 1: Mean predicted probability of error as a function of mood, length of inter-stimulus interval and error-type.

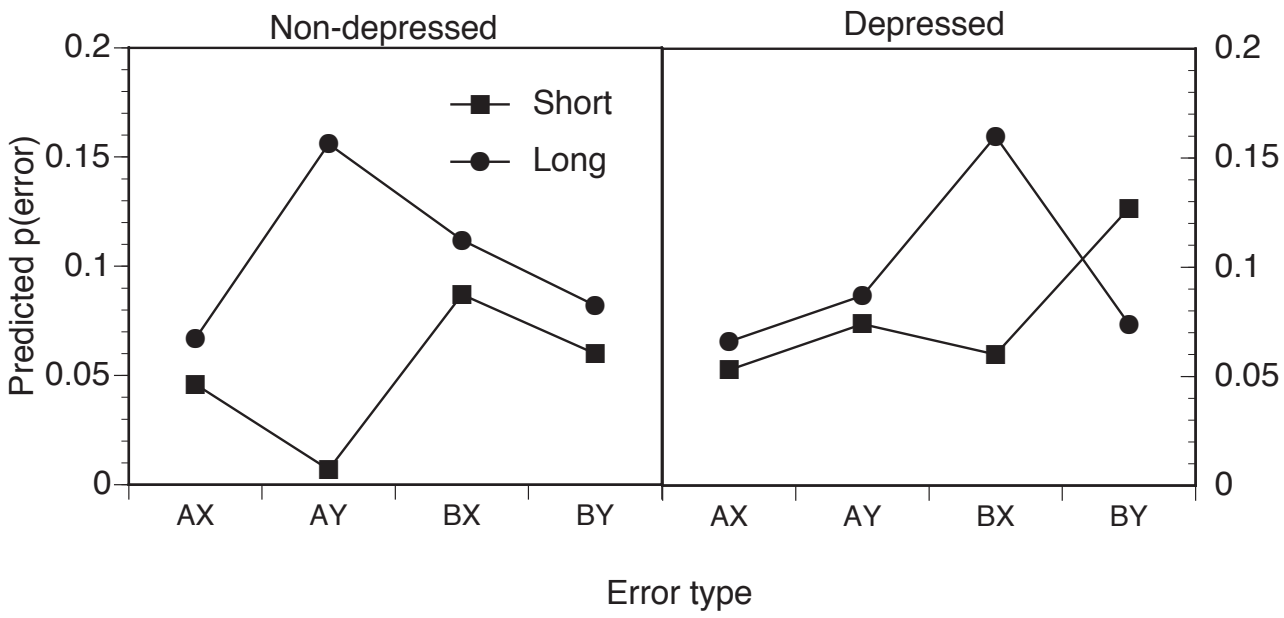
Non-depressed
Depressed
Short
Long
Predicted p(error)
0.2
0.15
0.1
0.05
0
AX
AY
BX
BY
Error type

Figure 1

Appendix 1

Screen 1:

In this task, you will see lots of different letters appear one at a time on the screen. Each letter will only stay on the screen for a brief period of time, before the screen goes blank. After a short period of time, the next letter will appear and so on. You will also see two buttons appear on the screen - the "Target" button on the right, and the "No Target" button on the left. We want you to press the "Target" button when you see the letter "X" appear on the screen - BUT ONLY IF the letter "A" appeared immediately before it.

So if you see this sequence of letters

--- A ---- X --

Press the "Target" button as quickly as possible. You can press the "Target" button using the return key.

On the other hand if you see "X" with any other letters of the alphabet immediately before it, we want you to press the "No Target" button. You can press the "No Target" button, using the TAB key on the key board.

So for example, if your saw this sequence of letters

--- B --- X--- or --- X ---- B --- or --- A --- B ---

you would press the "No Target" button.

Screen 2:

In order that you know when is the appropriate time to make your response, the following message will appear on the screen for one second.

"GIVE YOUR ANSWER QUICKLY"

This shows that it is the end of one trial and you can make your response while the message is on the screen. Therefore you will have only ONE SECOND to press EITHER the target or no target button. DO NOT press both and only press once. If you press the button after the one second interval - when the 'give your answer' message is not on the screen - the computer will make a 'beep' sound to show that you have missed.

We would like you to try to make your response as quickly and accurately as possible. However, if you do miss a response, don't worry, try again on the next trial. The whole task will last for about 10 minutes. Please ask if you have any questions and press the 'carry on' button to continue.