# Effect of depression and anxiety on human schedule performance

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## Abstract

Two experiments examined the impact of depression and anxiety on the microstructure of human schedule responding. Human participants responded by pressing a computer key for points on a multiple random ratio (RR) random interval (RI) schedule. The RI schedule was yoked to the RR schedule in terms of reinforcement rate within subject. Overall response rates were higher on the RR compared to the RI schedule. In both experiments, the presence of psychometrically-measured depressive traits reduced overall levels of responding. Depressive traits also decreased within-bout responding, but increased levels of bout-initiation responding. These findings regarding the microstructure of responding were not noted for anxiety traits. These results suggest that depression impacts learning by working through a number of different mechanisms – both impacting the perceived value of the reinforcer, and possibly by creating a bias to attend and process external cues associated with reinforcement which are taken to control response-initiation rates.


**Keywords:** schedules of reinforcement; microstructure of responding; depression, anxiety; humans.

Schedules of reinforcement are an important research tool that have been used to investigate many aspects of environmental control over behaviour (e.g., Pliskoff, Hawkins, & Wright, 1964; Pliskoff, Wright, & Hawkins, 1965). They have been shown to interact with many such environmental manipulations to determine the effects of those manipulations (Morse & Kelleher, 1970), which was a major part of the investigations conducted by Wright and colleagues (see Burgess & Wright, 1985; Reed & Wright, 1988). Recently, interest has been expressed in the relationship between schedule-controlled behaviour and psychopathological traits (Chen, Osborne, & Reed, 2020; Lattal & Neef, 1996; Randell, Ranjith-Kumar, Gupta, & Reed, 2009). Such an assumption follows from demonstrations that psychopathological traits impact a wide variety of human behaviours, but often using procedures different from schedules (see Alloy & Abramson, 1979; Feldman, Zayfert, Sandoval, Dunn, & Cartreine, 2012; McCabe & Gotlibe, 1995; Nolen-Hoeksema, Desrosiers & Wilsnack, 2013).

Psychopathological traits such as depression and anxiety have been assumed to impact human schedule behaviour (Costello, 1972; Ferster, 1973; Gavalas & Briggs, 1966; Reed, 2019). Both traits have relatively high lifetime prevalence, and may be expected to impact high numbers of individuals (Avenevoli, Swendsen, He, Burstein, & Merikangas, 2015; Remes, Brayne, Van Der Linde, & Lafortune, 2016). Moreover, at a theoretical level, the manner in which individuals who display depression and anxiety traits adapt to exposure to schedules may give insight into the nature of these disorders. Despite these assumptions and potential theoretical importance, there are few studies examining the impact of these two common psychopathological traits on human schedule performance. As there is a gap in the research knowledge surrounding this issue, the current study explored the effects of depression and anxiety on human schedule behaviour.

Research into the effects of psychopathological traits using non-clinical populations has been found to be an effective way to study the effects of these traits on learning (Randell, May, Jones, & Reed, 2011; Reed, 2019). The use of a nonclinical population avoids several confounds associated with the use of patients, such as the effects of medication, symptom severity, and patient distress (Raine & Lencz, 1995; Tsakanikos & Reed 2005), which may mask or distort any effects (Kane, 2006). Given these considerations, as well as the existence of many valid tools for establishing degrees of depression and anxiety in nonclinical samples, and coupled with the exploratory nature of the study, the current experiments took this nonclinical approach.

Depression is suggested to reduce reinforcer effectiveness, and reduce sensitivity to the occurrence of reinforcers (Costello, 1972; Ferster, 1973). There is an abundance of research showing that depressive disorders are related to cognitive and decision-making deficits often characterised by impairments in neurological signals regarding expected reward-value, reward-prediction errors, and decreased learning and sensitivity to reward (Belzung, Turiault, & Griebel, 2014; Gotlib & Joormann, 2010; Must, Horvath, Nemeth, & Janka, 2013; Perreault, Hasbi, O'Dowd, & George, 2014; see McDermott & Ebmeier, 2009, for a review). Unfortunately, much of this evidence comes from procedures radically dissimilar to schedules of reinforcement, making tenuous inferences about schedule performance by those who have depressive traits. Reed (2019) noted decreased rates of responding on some schedules of reinforcement in those with high levels of sub-clinical depressive traits, and Alloy and Abramson (1979) demonstrated reduced judgements of causal efficacy in depressed individuals on random ratio (RR) schedules. Given that loss of reinforcement leads to avoidance and withdrawal behaviours, which represent core symptoms of depression (Ferster, 1973; Trew, 2011), Topic, Kroger, Vildirasova and Huston (2012) state that rodent behaviours implicated in withdrawal from positive reinforcement during

extinction could serve as a model of depressive-like states. However, as noted above, little direct evidence of the impact of depression on schedule performance is available.

Considerable evidence from neurological paradigms suggests that anxiety impacts patterns of learning (McNaughton & Gray, 2000), and anxiety has long been associated with alterations to behavioural inhibition and behavioural activation systems (Gray, 1982). The impact of anxiety on the tendency to respond to environmental stimuli has received enormous investigation in clinical settings using self-report scales (e.g., Muris, Merckelbach, Schmidt, Gadet, & Bogie, 2001), and in neurologically-related nonhuman research (e.g., Bach, 2015). It has been suggested that anxious individuals display reduced levels of reward sensitivity (Torrubia, Avila, Moltó, & Caseras, 2001), and increased behavioral inhibition (Gray, 1987). Both of these traits predict lower rates of responding. However, like depression, further evidence regarding the direct relevance of anxiety to schedule performance in humans is not available (but see Reed 2019). In view of the assignable influence of psychopathologies traits on human behaviours, and its importance for understanding psychopathologies and their treatments (Lattal & Neef, 1996), this gap in knowledge is important to address.

In addition to exploring the effects of psychopathological traits on schedule-maintained performance, the current studies also investigated whether such traits would differentially effect different types of operant responses (Killeen, Hall, Reilly, & Kettle, 2002; Reed, 2011; Reed, Smale, Owens, & Freegard, 2018; Shull, 2011). Schedule-controlled behaviour comprises both: ‘bout-initiation’ responses, controlled by rates of reinforcement and contextual conditioning (Reed et al., 2018; Shull, 2011); and ‘within-bout’ responses, controlled by the status of the reinforcing stimulus and its relationship to preceding behaviour (Killeen et al., 2002; Reed et al., 2018). Bout-initiation responses have been suggested to be stimulus-driven (Chen et al., 2020; Reed et al., 2018), and within-bout responding appears controlled by the impact of reinforcement on the preceding responses

(Shull, 2011). Due to the differential nature of the factors controlling these two types of response (Reed et al., 2018; Shull, 2011), it may be that psychopathological traits such as depression and anxiety act differentially on these forms of operant responding.

One hypothesis relating to this issue is that individuals high on depressive states attribute bad outcomes to internal, stable, and global causes (Seligman, Abramson, Semmel, & Von Baeyer, 1979). This is not necessarily true of their attributions regrading positive outcomes (Rizley, 1978), where attributions and attention tends to favour external causes of those outcomes – notably the stimuli that predict their occurrence, rather than the participant's own responses (Minor, Jackson, & Maier, 1984; Reed & Antonova, 2007). Thus, while there may be a reduction in goal-directed behaviour for those high in depressive traits due to anhedonic tendencies (Alloy & Abramson, 1979), they may be over attentive to contextual stimuli present when those outcomes are delivered. Over-attention to contextual stimuli may interfere with learning about their own responses, and reduce the level of within-bout responding controlled by the learned relationship between outcomes and responses. Paradoxically, an enhanced focus on contextual cues predicting outcomes may serve to increase bout-initiation responding that are stimulus driven.

Studies of clinical samples have made similar suggestions, in different experimental contexts, that those with higher levels of depression may have an external cue bias (Hammer, 2010; cf. Perreault et al., 2014). Similar biases in selective attentional responding differentially impacting bout-initiation and within-bout responding may also be related to anxiety (Mogg & Bradley, 1999). Although firmer predictions are hard to make given the current state of knowledge for anxiety. Given these possibilities, the current experiments examined the impact of depression and anxiety on the microstructure of human schedule performance.

A number of different procedures have been adopted to explore the microstructure of free-operant responding (Killeen et al., 2002; Mellgren & Elsmore, 1991; Reed, 2011; Shull, 2011; Sibley, Nott, & Fletcher, 1990). As these approaches tend to produce the same pattern of results (Chen & Reed, 2020; Reed et al., 2018), the log survivor method was adopted for the current set of studies. This method turns into logs the percentage of IRTs emitted in particular time-bins as a proportion of all IRTs not yet emitted. The slope of a resulting log survivor plot is an indicator of the response rate: the steeper the slope, the higher the rate of responding. The slope of log survival plots is not uniform, but comprises an initially steep slope (bout-initiations), followed by a shallow slope (within-bout), indicating the presence of two different types of responding. A double exponential equation can be fitted, where the equation fits the two distributions of IRTs (i.e. those prior to the 'break' taken to represent response initiations; and those after the break, taken to represent within-bout responses. This equation takes the form: Ppred = a*exp(-bt)+(1-a)*e(-dt), where b and d represent the rates of within-bout and bout-initiation, respectively. Thus, the experiments reported here evaluate the effects of depression and anxiety on human schedule performance.

The current study examined whether psychopathological traits impact human behaviours on schedules of reinforcement. A focus on two common traits, depression and anxiety, was thought to have some practical and theoretical significance. Given the existeing literature, precise predictions are difficult regarding the impact of depression and anxiety of schedule behaviour. It might be expected that those with higher depression would show lower overall response rates, and lower within-bout rates of responding, but might show higher bout-initiation rates (Alloy & Abramson, 1979; Hammar, 2003). The prediction for anxiety is less clear, lower overall rates of responding might be expected (Gray, 1987; Torrubia et al., 2001), but effects on the microstructure are less clear.

# Experiment 1

The aim of Experiment 1 was to investigate the effect of depression and anxiety on human schedule performance. Participants were classified as having either lower or higher depression and anxiety, as measured by a common and valid tool (Hospital Anxiety and Depression Scales; Zigmond & Snaith, 1983). Participants responded on a multiple random ratio (RR), random interval (RI) schedule, as the effects of such a schedule on human performance is well known (Chen & Reed, 2020; Reed, 2015; Reed et al., 2018). The microstructure of responding was investigated using the log survivor method (Shull, 2011).

## Method

### Participants

Forty-seven students (6 male, 41 female) were recruited via the Psychology Department subject-pool system. G-Power calculation implied that for 90% power, with a $p < .05$ criteria, and a medium effect size ($f' = .25$), that 46 participants would be required. The participants were aged between 18 to 30 years (mean = 20.00 $\pm$ 2.37 SD). Participants received credits for their participation, but no finical payment. The study was approved by the Department of Psychology Ethics Committee.

### Apparatus

The experimental task was presented on a standard desktop computer. Visual Basic (6.0) was used to programme the multiple RR, RI schedule task. The computer task was presented on a white screen, with a stimulus box placed in the centre upper portion of the screen. The box was approximately 8cm wide × 3cm high, and was blocked with a single colour (either blue or pink), to indicate the schedule type (each schedule was associated with

a particular colour for each participant). A new schedule was indicated by the colour in the box changing. Underneath the colour stimulus box, the word "POINTS" (in capital letters) was positioned, and below this, the running total of the points accumulated appeared in figures.

## Materials

***The Hospital Anxiety and Depression scale*** (HADS; Zigmond & Snaith, 1983) is a self-report rating scale of 14 items, each measured on a 4-point Likert scale (range 0–3), designed to measure anxiety and depression (with 7 items for each subscale). The score for anxiety and depression are the sum of the respective seven items (ranging from 0–21 for each trait). The internal reliability ($\alpha$) is .85 for anxiety, and .84 for depression, for a non-psychiatric population (Herrero et al., 2003).

## Procedure

Participants were tested individually in a quiet room, which contained a desk and computer, with the monitor situated approximately 60cm from them. Participants gave written consent, and read the study information and instructions for the task. Participants were required to fill in basic demographic details about themselves, and to complete the HADS questionnaire, before the schedule task was presented. Prior to the task beginning, all participants were presented with the following instructions:

"*When the task begins, use the space bar to score **as many points as possible**. There are eight games in total. The first game is identified with a large blue [pink] rectangle at the top of the screen. When the first game is over, the rectangle will change to blue [pink] to indicate the start of the next game. The rectangles alternate between blue and pink to indicate the changing games for the remainder of the task. Your goal in each game is to*

*reach the **highest score possible**. You will see that the points reduce according to the way in which you play, but will rise again every so often, according to the pattern of space bar hits that you use. All you need to do is to find the best pattern of space bar hits to score **as highly as possible** in each game. It may be a good idea to respond quickly sometimes and slowly at other times, but you need to discover this for yourself!*"

The programme first presented an RR schedule, wherein points were awarded for presses to the space bar. On this schedule, points were awarded after each space bar response with a 1/30 probability. Each reinforcer consisted of 40 points being added to the participant's points total. The points total started at 100 for all participants, and was reset to 100 at the beginning of each new trial. For this first trial (RR) the stimulus on the screen was blue for half the participants, and pink for the other half. After each RR schedule presentation, an RI schedule was presented, signalled by a change in box colour to pink for half the participants, and blue for the other half. On this schedule, 40 points were awarded following the first response after a specified amount of time had elapsed. The RI schedule was yoked to the preceding RR schedule, so that each successive reinforcement in the RI schedule was delivered after the time taken for the corresponding reinforcer to be awarded on the preceding RR trial.

In each trial, participants lost one point for each space bar response, regardless of whether the response was reinforced. This procedure was adopted, as it has previously been established that the presence of such a response cost generates schedule performance by humans that is similar to that observed in nonhumans (Raia, Shillingford, Miller, & Baier, 2000). It has been argued that the absence of a response cost for a simple computer keypress creates little reason to regulate performance in line with the contingency of the schedule, especially in contrast to effort needed for nonhumans to make a response in a conditioning chamber (Bradshaw & Reed, 2012).

Each schedule presentation (trial) was 4min long, and a RR schedule trial was always presented immediately prior to the yoked RI schedule trial. There were four such presentations of the yoked RR–RI pairs (i.e. eight trials in total, 4 RR presentations, and 4 RI presentations). The procedure of yoking RI trials to preceding RR trials ensured that reinforcement in the RI schedule was delivered after a similar elapsed time that it had taken for the corresponding reinforcers to be awarded on the RR trial.

## Results and Discussion

### *Overall rates of responding*

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Figure 1 about here

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Figure 1 shows the mean overall rates of response, for the last trial of training, on the two schedules for the sample as a whole, and also for participants who scored lower or higher in terms of depression (HADS-D) and anxiety (HADS-A). Inspection of the overall rates of response reveals a higher response rate for the RR compared to the RI schedule. A repeated-measures analysis of variance (ANOVA) conducted on these data was significant, $F(1,46) = 70.85$, $p < .001$, $\eta^2_p = .606$[95%CI: .411-.716], $H_1/D = .999$. This schedule-induced difference in overall response rates replicates that noted in many previous studies with humans (Bradshaw & Reed, 2012; Raia et al., 2000; Reed et al., 2018).

To explore whether depression impacted schedule-maintained responding, the participants were split into two groups according to the mean HADS-D score (4.00 $\pm$ 2.61): creating a lower-depression group ($N = 28$; mean = 2.21 $\pm$ 1.23); and a higher-depression group ($N = 19$; mean = 6.63 $\pm$ 1.71). Inspection of the overall rates, when analysed according to lower or higher depression, shows rates were higher to the RR than the RI schedule, but

with little difference according to depression group. A two-factor mixed-model ANOVA (group x schedule) revealed a significant main effect of schedule, $F(1,45) = 65.24$, $p < .001$, $\eta^2_p = .592[.389\text{-}.706]$, $H_1/D = .999$, but no main effect of depression, $F < 1$, $\eta^2_p = .010[.000\text{-}.131]$, $H_0/D = .999$, and no interaction between the two factors, $F(1,45) = 1.84$, $p = .182$, $\eta^2_p = .039[.000\text{-}.191]$ $H_0/D = .727$. These data do not corroborate the suggested reduced overall rate for those with higher levels of depression (Alloy & Abramson, 1979; Reed, 2020).

Participants were also split into two groups according to the mean HADS-A scores (9.40 $\pm$ 3.77): creating a lower-anxiety group ($N = 24$; mean = 6.45 $\pm$ 2.30); and a higher-anxiety group ($N = 23$; mean = 12.47 $\pm$ 2.19). There was the usual RR versus RI schedule difference, but little difference depending on anxiety group. A two-factor mixed-model ANOVA (group x schedule) revealed a significant main effect of schedule, $F(1,45) = 69.27$, $p < .001$, $\eta^2_p = .606[.408\text{-}.717]$, $H_1/D = .999$, but no main effect of anxiety, $F < 1$, $\eta^2_p = .001[.000\text{-}.001]$, $H_0/D = .999$, or interaction, $F < 1$, $\eta^2_p = .002[.000\text{-}.007]$, $H_0/D = .999$. These data also suggest no effect of anxiety-traits on schedule-maintained responding.

The mean rates of bout-initiation responding, as determined by the log survivor method, for the sample as a whole, on the last block of training, were: 3.37 ($\pm$ 2.69) for the RR schedule; and 6.41 ($\pm$ 8.53) for the RI schedule. A repeated-measures ANOVA found a significantly higher rate of bout-initiation responding for the RI schedule, $F(1,46) = 7.67$, $p = .008$, $\eta^2_p = .143[.010\text{-}.324]$, ], $H_1/D = .844$. This difference is relatively unusual, as, typically, this rate is similar between RR and RI schedules (Reed, 2011; Shull, 2011). However, there are some studies which have noted this tendency for higher rates of responding to the RI schedule in human responding (Chen & Reed, 2020; Reed, 2020), and it is often when the reinforcer is not a strong one (i.e. points not exchangeable for tangible

goods), and the contingency becomes a schedule of outcome presentation, rather than a schedule of reinforcer presentation (Reed, 2001).

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Figure 2 about here

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Figure 2 shows the bout-initiation rates on the last block of training for the two schedules, for both lower and higher depression groups (left panels), and lower and higher anxiety groups (right panels), using the survivor method. Inspection of the data for the depression groups shows that the bout-initiation rates for the RR and RI schedules were similar for the lower-depression groups, but were higher for the RI schedule for the higher-depression group. A two-factor mixed-model ANOVA (group x schedule) conducted for the depression groups revealed significant main effects of schedule, $F(1,45) = 11.32$, $p = .002$, $\eta^2_p = .201[.033\text{-}.385]$, $H_1/D = .966$, and depression, $F(1,45) = 6.67$, $p = .013$, $\eta^2_p = .129[.006\text{-}.311]$, and a significant interaction, $F(1,45) = 6.52$, $p = .014$, $\eta^2_p = .127[.005\text{-}.308]$, $H_1/D = .777$. Simple effect analyses revealed that there was no significant difference in bout-initiation rates between the schedules for the low-depression groups, $F < 1$, $\eta^2_p = .001[.000\text{-}.005]$, $H_0/D = .999$, but a significantly higher rate of bout-initiation rate for RI schedule for the high-depression group, $F(1,45) = 5.95$, $p = .022$, $\eta^2_p = .009[.000\text{-}.126]$, $H_0/D = .845$. These data are in line with the prediction that those with higher levels of depression may emit greater numbers of bout-initiation responses due to the greater attention paid to stimuli predicting reinforcement (Minor et al., 1987; Reed & Antonova, 2007). These contextual stimuli may gain greater strength in the higher depression group by virtue of the greater attention paid to them, relative to the lower-depression group.

Inspection of these data for the lower and higher anxiety groups (right panel), reveals a numerically similar, but very less pronounced pattern of results to that described for the

depression groups. A two-factor mixed-model ANOVA (group x schedule) conducted for the anxiety groups revealed a significant main effect of schedule, $F(1,45) = 7.81$, $p = .008$, $\eta^2_p = .148[.012-.331]$, $H_1/D = .862$, but not of anxiety, $F(1,45) = 1.81$, $p = .185$, $\eta^2_p = .039[.000-.190]$, $H_0/D = .731$, and no interaction, $F(1,45) = 1.16$, $p = .288$, $\eta^2_p = .025[.000-.164]$, $H_0/D = .793$. It is difficult to draw firm conclusions from these data, but they suggest anxiety is not impacting bout-initiation responding.

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Figure 3 about here

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The mean rates of within-bout-responding, as determined by the log survivor method, for the sample as a whole, on the last block of training, were: 565.24 (± 171.03) for the RR schedule; and 388.37 (± 264.18) for the RI schedule. A repeated-measures ANOVA revealed a significant difference between these rates of response, $F(1,46) = 7.66$, $p = .008$, $\eta^2_p = .143[.013-.324]$, $H_1/D = .844$. This corroborates the findings from previous investigations that have demonstrated this effect in nonhumans (Shull, 2011) and humans (Chen & Reed, 2020; Reed et al., 2018).

The left panel of Figure 3 shows the within-bout rates on the last block of training for the two schedules, for both lower and higher depression groups (left panels), and lower and higher anxiety groups (right panels), using the survivor method. For the depression groups (left panels), there were higher rates of within-bout responding for the RR compared to the RI schedule, and slightly higher rates for both schedules the lower depression group. A two-factor mixed-model ANOVA (group x schedule) revealed main effects of schedule, $F(1,45) = 11.32$, $p < .002$, $\eta^2_p = .201[.033-.385]$, $H_1/D = .966$, and depression, $F(1,45) = 6.68$, $p = .013$, $\eta^2_p = .129[.006-.311]$, $H_1/D = .788$, and an interaction between the factors, $F(1,45) = 6.54$, $p = .014$, $\eta^2_p = .127[.005-.308]$, $H_1/D = .777$. Simple effect analyses revealed no significant

difference between the schedules for the lower-depression group, $F < 1$, $\eta^2_p$ = .009[.000-.126], $H_0/D$ = .845, but a significant effect of schedule for the higher depression group, $F(1,45) = 16.21$, $p < .001$, $\eta^2_p$ = .264[.070-.445], $H_1/D$ = .995. This difference between the degree to which the schedules control differential performance across the groups is, in part, due to the lower variance seen in the higher-depression group, so caution needs to be applied when interpreting these data.

The right panel of Figure 3 shows the within-bout rates for the anxiety groups. There were higher rates of within-bout responding for the RR compared to the RI schedule. A two-factor mixed-model ANOVA (group x schedule) revealed a main effect of schedule, $F(1,45) = 23.78$, $p < .001$, $\eta^2_p$ = .346[.130-.515], $H_1/D$ = .999, but no main effect of anxiety, $F < 1$, $\eta^2_p$ = .002[.000-.081], $H_0/D$ = .999, and no interaction $F < 1$, $\eta^2_p$ = .001[.000-.033], $H_0/D$ = .999.

The current results replicate several aspects of previous reports studying human schedule performance. Overall rates were higher on RR than RI schedules, and within-bout rates also demonstrated this pattern (Reed et al., 2018; Shull, 2011). A difference from previous studies was that rates of bout-initiation responding were higher for the RI compared to the RR schedule. That RI responding was higher for both higher-depression participants (and, numerically, for higher-anxiety participants), and that such participants are often excluded from analyses of human schedule behaviour on the bases of the existence of psychopathologies (Reed et al., 2018), might explain the slightly different effect of schedules on bout-initiation for the overall sample, described above, when compared to some previous studies. There was little impact of anxiety traits on overall, bout-initiation, or within-bout, responding. However, the results with respect to depression suggested higher rates of bout-initiation responding, and a decrease in within-bout responding – but mainly on the RI schedule. This pattern of responding needs to be replicated prior to extensive discussion, but

it suggests one possibility consistent with previous theorising; those with higher levels of depression tend to have increased attention for external cues (Minor et al., 1987; Reed & Antonova, 2007), and such participants may give greater weight to factors external to their own responding. If bout-initiation responding is determined by the value of the context (Reed et al., 2018), and there is a relatively greater salience placed on such external cues, then it might be that those with higher depression/anxiety would display greater rates of such responding than those with lower levels of psychopathological traits. Of course, why this should be true of the RI schedule to a greater degree than the RR schedule is unclear. Moreover, it should be noted that the levels of depression and anxiety noted in the current study using the HADS were not great, and comparisons of lower and higher levels in the groups is really between very low and low levels of these traits.

## Experiment 2

As the findings presented in Experiment 1 were novel, and suggested a pattern of results that has some theoretical significance, it was felt important to replicate these results prior to further theoretical speculation. It was also felt important to determine whether the findings were specific to the use of one particular scale measuring depression and anxiety. To this end, Experiment 2 study represented a systematic replication of Experiment 1, but depression was measured by the Beck's Depression Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961), and anxiety was measured by the Spielberger State Trait Anxiety Inventory (Trait; Spielberger, 1983). It was also hoped to increase the range of psychopathological scores by recruiting a more diverse set of participants than were engaged in Experiment 1.

## Method

### Participants and Apparatus

A sample of 85 participants (24 males and 61 females) were recruited: 37 undergraduate students via the Psychology Department subject-pool system, who received credits for their participation, but no finical payment; and 48 were volunteer adult Chinese participants who received finical payment (50 RMB per hour). The sample were aged between 18 to 54 years (mean= 29.80 $\pm$ 11.37). The experimental task was as described in Experiment 1, with the exception that instructions for the Chinese participants were presented in the appropriate Chinese language (and the Chinese translations of the scales were employed.

### Materials

***Beck's Depression Inventory*** (BDI; Beck et al., 1961) is a 21-item questionnaire that measure the clinical symptoms of depression through asking about feelings during past few weeks. The score ranges from 0 to 63, with an internal reliability ($\alpha$) between .73 and .92 for a non-psychiatric population (Beck, Steer, & Garbin, 1988).

***Spielberger Trait Anxiety Inventory*** (STAI-T; Spieberger, 1983) assesses long-standing patterns of anxiety (i.e., trait anxiety) by examining the affective and physiological manifestations of anxiety. Total score of range from 20 to 100. The internal reliability (Cronbach a) of this scale is .93, and a concurrent validity is from .52 to .80 (Spielberger, Gorsuch, & Lushene, 1970).

### Procedure

The procedure was as described in Experiment 1, with the exception that participants completed the BDI and STAI-T scales.

## Results and Discussion

### *Overall rates of responding*

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Figure 4 about here

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Figure 4 shows the mean overall rates of response, for the last trial of training, on the two schedules for the sample as a whole, and also for participants who scored lower or higher in terms of depression (BDI) and anxiety (STAI-T). Inspection of the overall rates of response reveals a higher rate for the RR compared to the RI schedule. A repeated-measures ANOVA revealed this difference was significant, $F(1,84) = 12.77$, $p < .001$, $\eta^2_p = .132$[.027-.267], $H_1/D = .978$. This schedule-induced difference replicates that noted in Experiment 1, and in previous studies (Bradshaw & Reed, 2012; Raia et al., 2000).

To explore whether depression impacts schedule-maintained responding, the participants were split into two groups according to the mean BDI score (8.92 $\pm$ 7.05): creating a lower-depression group ($N = 44$; mean = 3.48 $\pm$ 2.63); and a higher-depression group ($N = 41$; mean = 14.75 $\pm$ 5.43). Inspection of these rates when analysed according to lower or higher depression shows rates were higher to the RR than the RI schedule, but with little difference according to depression group. A two-factor mixed-model ANOVA (group x schedule) revealed a significant main effect of schedule, $F(1,83) = 13.63$, $p < .001$, $\eta^2_p = .141$[.031-.278], $H_1/D = .985$, no main effect of depression, $F < 1$, $\eta^2_p = .001$[.000-.015], $H_0/D = .901$, and no interaction between the two factors, $F(1,83) = 3.65$, $p = .063$, $\eta^2_p = .039$[.000-.191] $H_0/D = .608$. As with Experiment 1, these data do not corroborate the suggested reduced overall rate for those with higher levels of depression (Alloy & Abramson, 1979; Reed, 2020).

Participants were also split into two groups according to the mean STAI-T scores (77.55 $\pm$ 17.55): creating a lower-anxiety group ($N$ = 54; mean = 64.04 $\pm$ 8.85); and a higher-anxiety group ($N$ = 40; mean = 92.98 $\pm$ 10.98). Inspection of the right hand panel for Figure 4 shows the typical RR versus RI schedule difference. A two-factor mixed-model ANOVA (group x schedule) revealed a significant main effect of schedule, $F(1,83) = 13.16$, $p < .001$, $\eta^2_p = .140$[.029-.273], $H_1/D = .982$, but no main effect of anxiety, $F(1,83) = 2.68$, $p = .105$, $\eta^2_p = .031$[.000-.132], $H_0/D = .705$, or interaction, $F(1,83) = 1.03$, $p > .30$ $\eta^2_p = .012$[.000-.094], $H_0/D = .845$. These data, like those from Experiment 1, suggest no effect of anxiety-traits on overall schedule-maintained responding rates.

The mean rates of bout-initiation, as determined by the log survivor method, for the sample as a whole, on the last block of training, were: 9.62 ($\pm$ 7.65) for the RR schedule; and 8.10 ($\pm$ 4.34) for the RI schedule. A repeated-measures ANOVA found a significantly higher rate of bout-initiation responding for the RR schedule, $F(1,84) = 4.38$, $p = .039$, $\eta^2_p = .049$[.000-.162], $H_1/D = .517$. This did not corroborate the findings from Experiment 1, and suggests that any difference in the rates of bout-initiation responding on RR and RI are unreliable across studies. This would fit with the general view that this rate of responding is similar on both schedules when they are matched for rate of reinforcement (Shull, 2011)

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Figure 5 about here

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Figure 5 shows the bout-initiation rates on the last block of training for the two schedules, for both lower and higher depression groups (left panels), and lower and higher anxiety groups (right panels), using the survivor method. Inspection of the data for the depression groups (left panel), shows that the bout-initiation rates for higher-depression groups were greater than for the lower-depression groups, irrespective of the schedule. A

two-factor mixed-model ANOVA (group x schedule) conducted for the depression groups revealed significant main effects of schedule, $F(1,83) = 4.29$, $p = .041$, $\eta^2_p = .049[.000\text{-}.162]$, $H_1/D = .523$, and depression, $F(1,83) = 5.22$, $p = .025$, $\eta^2_p = .059[.000\text{-}.177]$, $H_1/D = .591$. but there was no interaction, $F < 1$, $\eta^2_p = .001[.000\text{-}.015]$, $H_0/D = .999$. As with Experiment 1, those with higher levels of depression emitted greater numbers of bout-initiation responses.

Inspection of these data for the lower and higher anxiety groups (right panel Figure 5), reveals a slightly higher rate of bout-initiation for the RR schedule, which was not affected by anxiety. A two-factor mixed-model ANOVA (group x schedule) conducted for the anxiety groups, similarly, revealed a significant main effect of schedule, $F(1,83) = 4.35$, $p = .040$, $\eta^2_p = .049[.000\text{-}.163]$, $H_1/D = .518$, but not anxiety, $F < 1$, $\eta^2_p = .004[.000\text{-}.070]$, $H_0/D = .999$, and no interaction, $F < 1$, $\eta^2_p = .001[.000\text{-}.010]$, $H_0/D = .999$.

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Figure 6 about here

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The mean rates of within-bout-responding, as determined by the log survivor method, for the sample as a whole on the last block of training were: 385.08 ($\pm$ 221.09) for the RR schedule; and a lower mean of 3286.21 ($\pm$ 240.79) for the RI schedule. A repeated-measures ANOVA revealed a significant difference between these rates of response, $F(1,84) = 23.46$, $p < .001$, $\eta^2_p = .218[.082\text{-}.358]$, $H_1/D = .999$.

The left panel of Figure 6 shows the within-bout rates on the last block of training for the two schedules for both lower and higher depression groups (left panels), and lower and higher anxiety groups (right panels), using the survivor method. For the depression groups (left panels), there were higher rates of within-bout responding for the RR compared to the RI schedule, and numerically higher rates for both schedules the lower depression group. A two-factor mixed-model ANOVA (group x schedule) revealed main effects of schedule,

$F(1,83) = 23.99$, $p < .001$, $\eta^2_p = .224[.084\text{-}.364]$, $H_1/D = .999$, and a marginal effect of depression, $F(1,83) = 3.54$, $p = .060$, $\eta^2_p = .041[.000\text{-}.149]$, $H0/D = .620$, but no interaction between the factors, $F(1,83) = 1.50$, $p = .224$, $\eta^2_p = .018[.000\text{-}.107]$, $H_0/D = .811$.

The right panel of Figure 6 shows the within-bout rates for the anxiety groups. There were higher rates of within-bout responding for the RR compared to the RI schedule, with little effect of anxiety. A two-factor mixed-model ANOVA (group x schedule) revealed a main effect of schedule, $F(1,83) = 24.39$, $p < .001$, $\eta^2_p = .227[.086\text{-}.367]$, $H_1/D = .999$, but no main effect of anxiety, $F < 1$, $\eta^2_p = .001[.000\text{-}.025]$, $H_0/D = .999$, and no interaction $F(1,83) = 1.83$, $p = .180$, $\eta^2_p = .022[.000\text{-}.115]$, $H_0/D = .784$.

The current results replicate several important aspects of the data noted in Experiment 1. Overall response rates followed the typical pattern, with RR schedule responding being faster than RI schedule responding, even though reinforcement rates were matched. Within-bout rates also demonstrated this pattern (Reed et al., 2018; Shull, 2011). In this study, bout-initiation response rates were higher for the RR compared to the RI schedule. This does not follow the pattern seen in Experiment 1, and suggests that these differences are not reliable between studies. As with Experiment 1, rates of bout-initiation responding were higher for the higher-depression group, and within-bout responding was numerically lower. Again, this pattern is consistent with the view that higher levels of depression may promote focus on external cues (Minor et al., 1987; Reed & Antonova, 2007), and, given that bout-initiation responding is driven by such cues (Reed et al., 2018), then higher-depressed participants may give greater weight to factors external to their own responding. There was little impact of anxiety on these patterns.

## General Discussion

The current studies examined the impact of depression and anxiety traits on the microstructure of human schedule responding. The main findings were that the presence of depressive traits tended to reduce overall levels of responding on such schedules. However, depressive traits also both decreased within-bout responding, but increased levels of bout-initiation responding. This finding was not noted for anxiety traits. These results suggest that depression impacts learning by working through a number of different mechanisms – both impacting the perceived value of the reinforcer, and creating a bias to attend and process external cues associated with reinforcement.

The current results replicated several aspects of previous studies. Rates of responding on RR schedules were higher than those on RI schedules, despite the schedules having equal rates of reinforcement (Ferster & Skinner, 1957; Reed et al., 2018). Within-bout rates of responding were higher on the RR than the RI schedule (Reed et al., 2018; Shull, 2011); but there was no consistent difference between the rates of bout-initiation responding across experiments (Shull, 2011). These findings are consistent with 'bout-initiation' responses being controlled by overall rates of reinforcement and contextual conditioning (Reed, 2020; Shull, 2011), and being stimulus-driven responses (Reed, 2020). In contrast, 'within-bout' responses being controlled by the status of the reinforcing stimulus (Killeen et al., 2002; Reed et al., 2018), and being controlled by the impact of reinforcement on the preceding responses (Shull, 2011).

Those with higher levels of depression tended to emit less within-bout responding than those with lower levels of depression (in contrast to the effect on overall response rates). This finding is consistent with the reduced effectiveness of, or reduced sensitivity to, reinforcers in those with higher depressive traits (Alloy & Abramson, 1979; Ferster, 1973; Reed 2020). In contrast, rates of bout-initiation responding were increased for those with

higher levels of depressive traits. It may be that this reflects an attention bias in this population to external causes of reinforcing events – such as stimuli predicting their occurrence (Minor et al., 1984; Reed & Antonova, 2007). This increased attention and possibly processing of external cues which are taken to drive bout-initiation responding may offset the reduction in context conditioning associated with the reduced effectiveness of reinforcers (Ferster, 1973). This result is consistent with that from clinical samples of those with depression in other experimental contexts (Hammer, 2010). These data also add to the cognitive literature that depression impacts abilities to learn (Belzung et al., 2014; Gotlib & Joormann, 2010). The current findings about differential sensitivity to aspects of the environment may be illuminating something important about the factors responsible for depression, and the ways in which depression adapts people to the environment; however, clearly, further experimentation is needed to verify this suggestion.

In contrast to the findings relating to depression, there were few effects of anxiety traits on performance. Although there is evidence that anxiety is associated with altered learning (McNaughton & Gray, 2000), and behavioural inhibition and behavioural activation (Gray, 1982; Muris et al., 2001), this was not reflected in schedule performance in the current experiments. This possibly replicates a failure to find an effect of anxiety on schedule performance by Reed (2020), and mirrors the often contradictory findings emerging in the field (cf. Ciucurel, 2012), suggesting that anxiety may be a very diffuse construct.

Apart from the need to replicate and extend these findings to a wider range of schedules, there are a number limitations with the current studies. Although using a nonclinical population avoids several confounds associated with the use of patients (Raine & Lencz, 1995; Randell et al., 2011), it does limit generality when considering a clinical population. Moreover, the level of depression and anxiety was not particularly high, even in the higher depression and anxiety groups. The current results were also generated by use of

the of survivor method for analysing the microstructure of schedule performance (Killeen et al., 2002; Shull, 2011). There are other methods of assessing such microstructure, and the outcomes may depend on the manner in which this micro-structure is assessed. The cut-off method designates short IRTs as within-bout responses, and long IRTs as bout-initiation responses (Mellgren & Elsmore, 1991). In the context of human schedule studies, an IRT of 1000ms has proved a good index of this distinction (Reed, 2015; Reed et al., 2018). However, this approach makes assumptions about which responses should be regarded as bout-initiating and within-bout, making this approach somewhat arbitrary (Shull et al., 2001). Moreover, results using the two procedures have often been qualitatively very similar to one another (Reed, 2015).

In summary, the current findings demonstrated that overall response rates were higher on RR than RI schedules, and within-bout rates also demonstrated this pattern. There was little impact of anxiety traits on overall, bout-initiation, or within-bout, responding. However, the results with respect to depression suggested an increase the rates of bout-initiation responding, and a decrease in within-bout responding. This pattern of responding suggests one possibility consistent with previous theorising; those with higher levels of depression tend to have increased attention for external cues as well as a decreased sensitivity to reinforcement.

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**Figure 1: Experiment 1: Group-mean overall response rates for RR and RI schedules, for the whole sample, and lower and higher depression and anxiety groups. Error bars = 95% confidence intervals.**

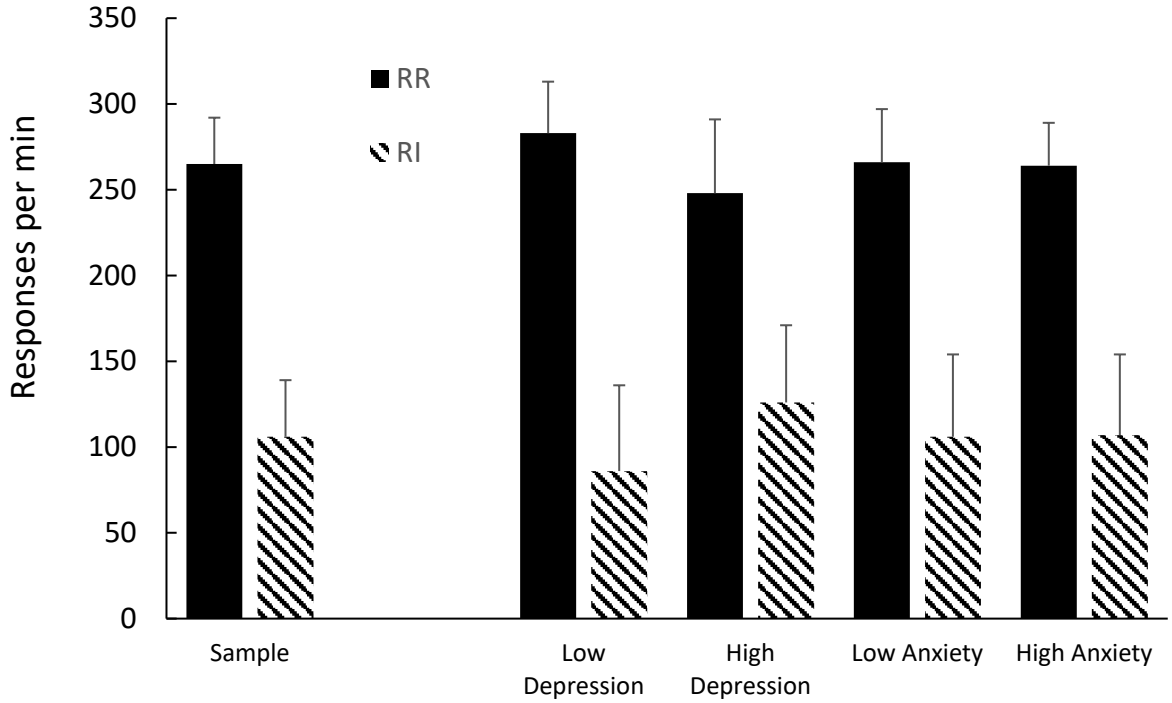

**Figure 2: Experiment 1: Group-mean bout-initiation rates for RR and RI schedules, for lower and higher depression and anxiety groups. Error bars = 95% confidence intervals.**

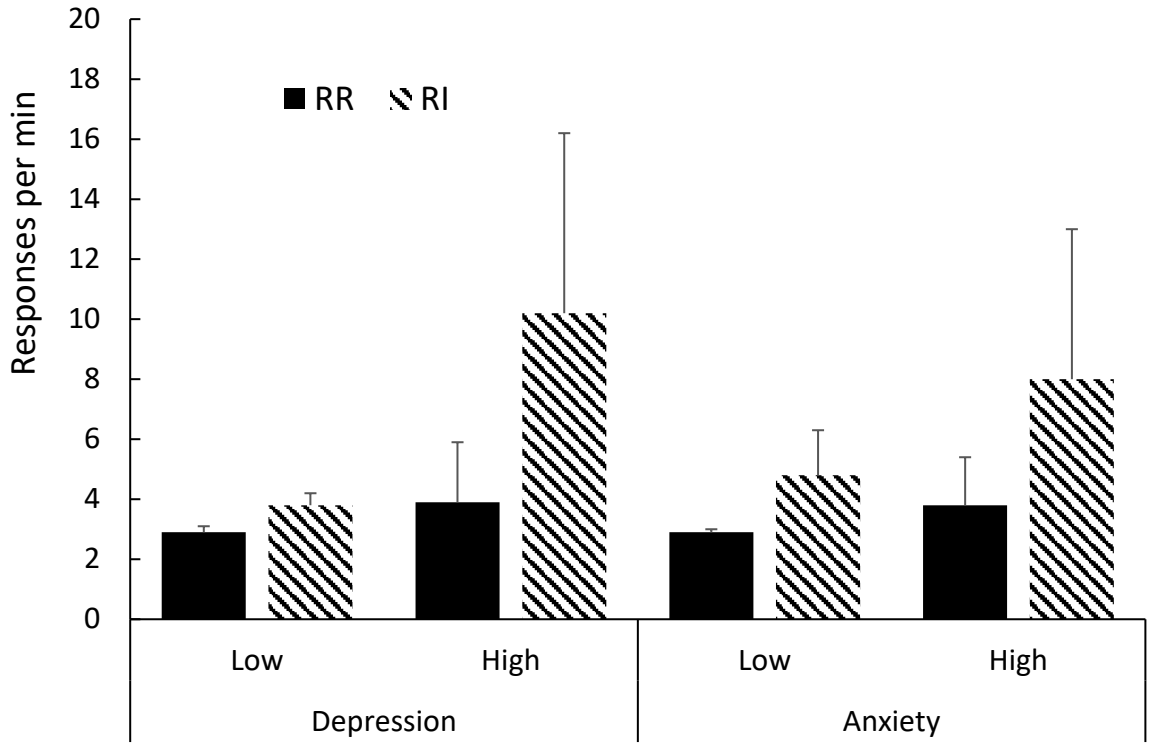

**Figure 3: Experiment 1: Group-mean within-bout rates for RR and RI schedules, for lower and higher depression and anxiety groups. Error bars = 95% confidence intervals.**

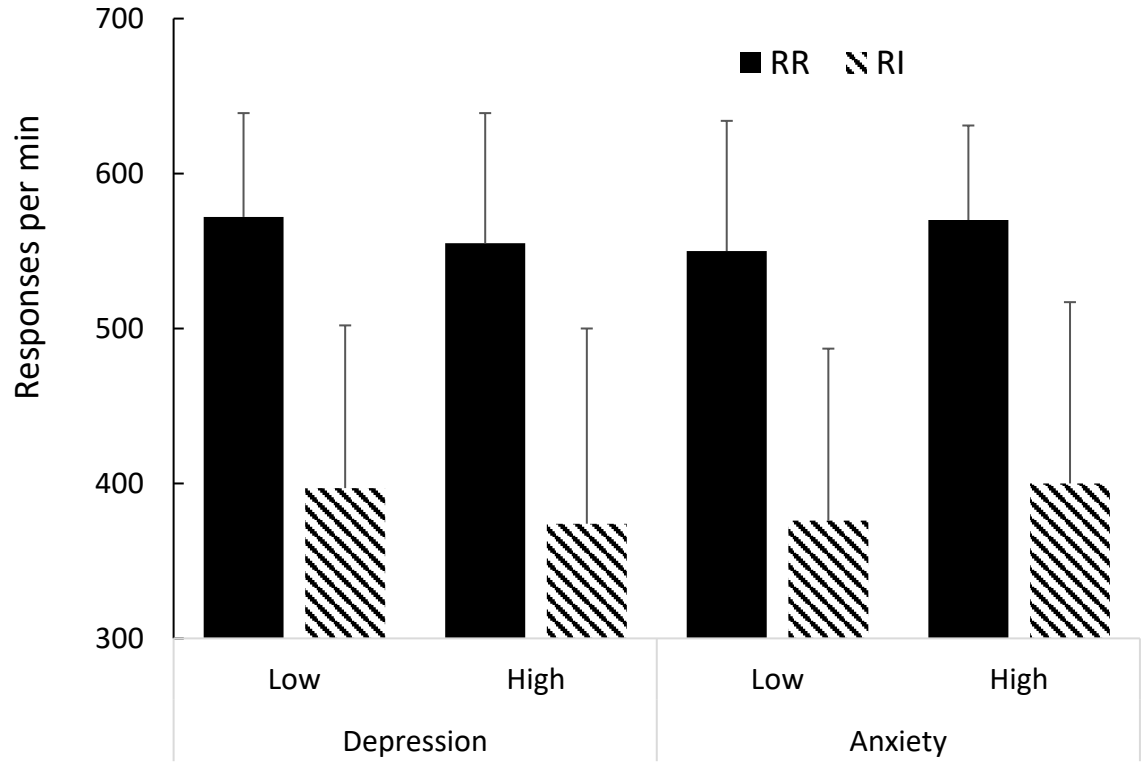

**Figure 4: Experiment 2: Group-mean overall response rates for RR and RI schedules, for the whole sample, and lower and higher depression and anxiety groups. Error bars = 95% confidence intervals.**

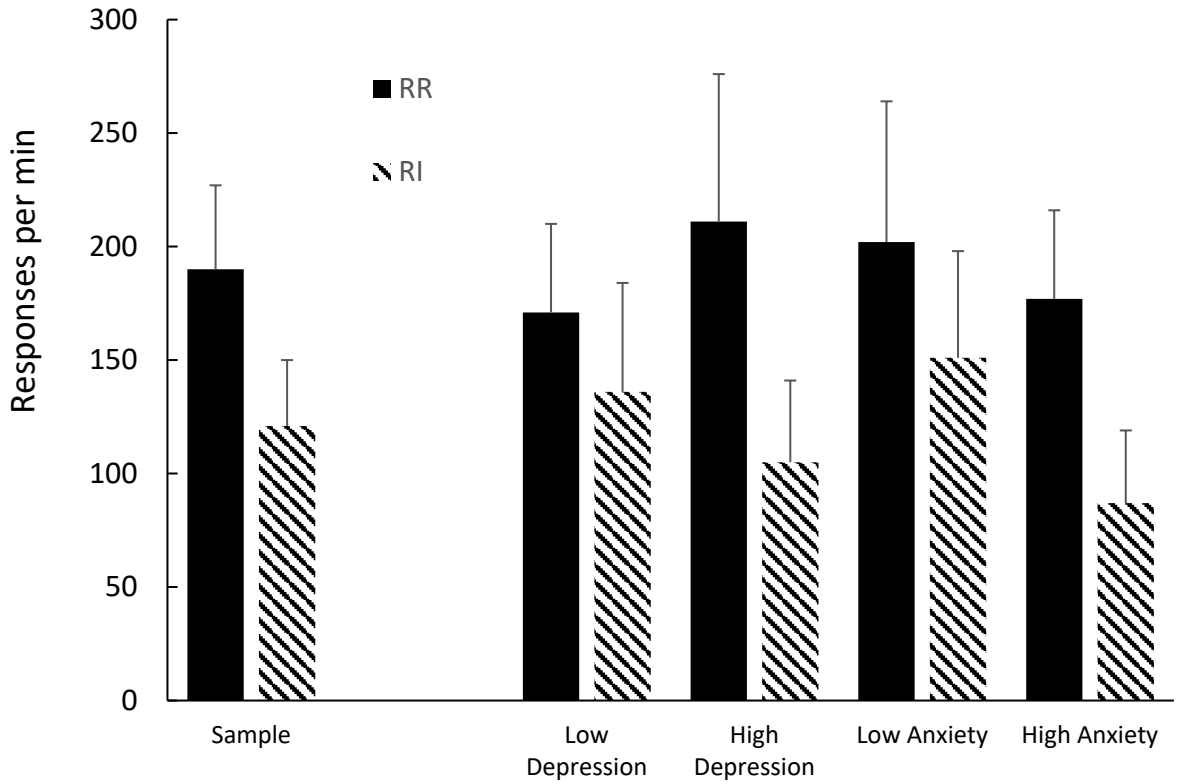

**Figure 5: Experiment 2: Group-mean bout-initiation rates for RR and RI schedules, for lower and higher depression and anxiety groups. Error bars = 95% confidence intervals.**

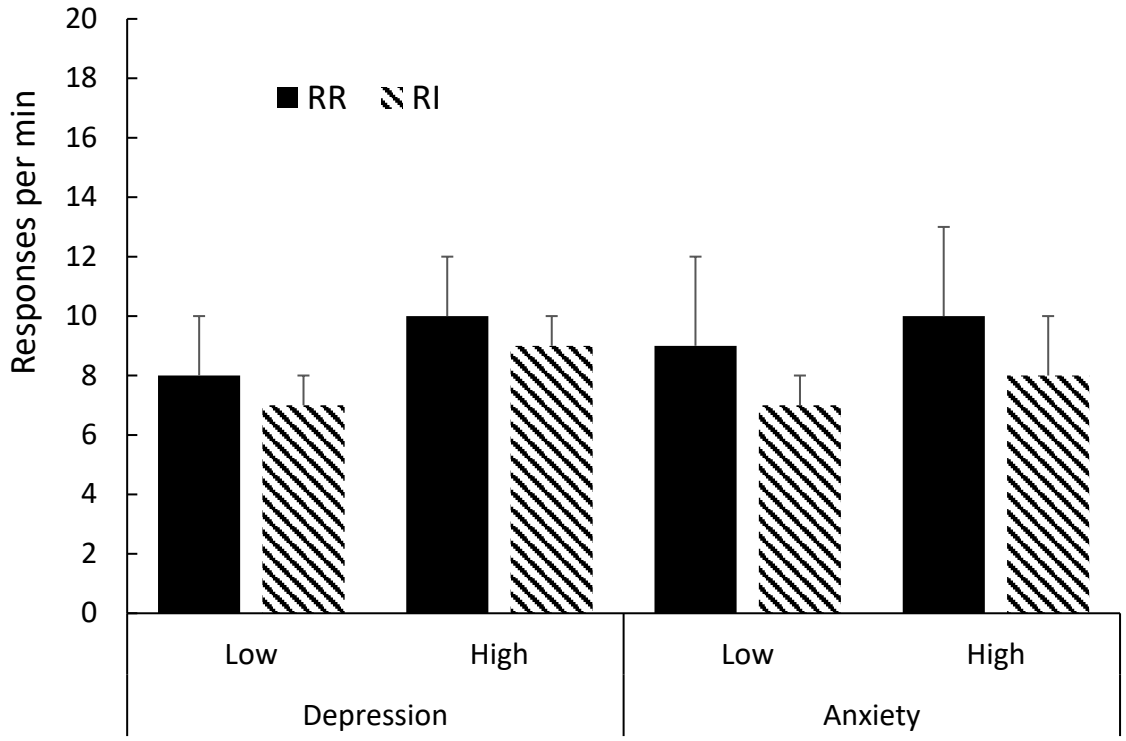

**Figure 6: Experiment 2: Group-mean within-bout rates for RR and RI schedules, for lower and higher depression and anxiety groups. Error bars = 95% confidence intervals.**