Two pathways to causal control: Use and availability of information in the environment in people with and without signs of depression

N.C. Byrom a, R.M. Msetfi b,⁎, R.A. Murphy a

a Department of Experimental Psychology, University of Oxford, UK
b Centre for Social Issues Research, Department of Psychology, University of Limerick, Republic of Ireland

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Perceiving one’s causal control is important for adaptive behavior. Studying depression and other individual differences has provided insight into typical as well as pathological causal processing. We set out to study factors that have been shown to distinguish those with and without signs of depression and affect perceptions of causal control: levels of behavior, the availability of outcomes and learning about the environment or context. Two experiments were carried out in which participants, scoring low and high on the Beck Depression Inventory using established cutoffs, completed a causal control task, in which outcomes occurred with a low (.25) or high probability (.75). Behavior levels were either constrained (N1 = 73) or unconstrained (N2 = 74). Overall, findings showed that levels of behavior influenced people’s experiences of the context in which events occurred. For all participants, very high behavior levels eliminated sensitivity to levels of outcomes occurring in the environment and lead to judgments that were consistent with conditional probabilities as opposed to the experimenter programmed contingency. Thus increased behavior increased perceived control via influence on context experience. This effect was also evident for those scoring high on the BDI. Overall conclusions are that behavior and context provide two important interlinked psychological pathways to perceived control. However, situations that constrain people’s ability to respond freely can prevent people with signs of depression from taking control of a situation that would otherwise be uncontrollable.

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Perception of control over actions and their consequences is a hallmark of adaptive behavior and good mental health (Taylor & Brown, 1988). Studies have shown that people in general can discriminate between experimentally controlled situations in which they do and do not have control over events (Allan & Jenkins, 1983; Dickinson, Shanks, & Evenden, 1984). In addition, comparisons between distinct groups of people based on pre-existing individual differences, such as levels of depression, have been used as a tool to inform our understanding of the psychological processes involved in causal control for people in general (e.g., Msetfi, Murphy, Simpson, & Kornbrot, 2005). This previous work shares the implicit assumption that the participant’s causal task is simply to learn the experimenter-presented relation and that they may do so accurately or in a biased fashion (for a detailed background, see Allan, 1993).

However, causal information is dynamic and much as the uncertainty principle (Heisenberg, 1927) states that the mere action of measuring the velocity of quantum particles changes their velocity, human (or animal) action has an impact on the environment in which the action takes place; the explorer not only catalogs and measures the new territory but by her very presence changes the subject of enquiry. In the case of causal control, the participant can come to define both her experience of and perception of the contingency. Thus causal control judgments do not measure the ability to perceive a particular action-outcome contingency, like one would measure the perception of the weight of a held object, but rather the perception is a reflection of both the action-outcome relation and the environmental impact of actions over time.

Along these lines, behavioral approaches to depression (e.g., Lewinsohn, 1974) and studies looking at causal control in depression (e.g., Blanco, Matute, & Vadillo, 2012) have suggested that the extent to which people ‘do’ potentially controlling behaviors, in combination with the relative availability of events that they might wish to control, influences the control they experience and the relation between depression and perceptions of control. For example, Alloy and Abramson (1979) showed that people with mild symptoms of depression judged that they had little control over frequently occurring events in contrast to people with no signs of depression who thought that they did have some control. In fact, the experimenters had programmed the experimental task such that neither group had control and suggested that people with depression were more realistic in their perceptions of control. Both groups accurately judged their lack of control when events occurred infrequently suggesting that the availability of events is important. Further, Blanco et al., (2012) showed that the ‘depressive
realism’ effect occurs because people with a higher levels of depression symptoms produce lower levels of behavior which directly predict a low perception of control. Thus sensitivity to outcome availability and levels of behavior would seem to be critical to a healthy assessment of causal control. In order to further our understanding of these behavioral dynamics of causal control, we report two experiments, which test how levels of behavior and the availability of events influence judgments of control in mildly depressed and non-depressed participants. First we provide a brief background to this work.

Systematic efforts to understand the psychological processes underlying perceived causal control were informed by Hume’s (1789) key observation that cause cannot be observed directly but must be inferred from information available in the environment, such as the temporal, spatial and statistical relations between actions and outcomes. In particular, measuring sensitivity to causal control has involved manipulating the statistical contingency between an action and outcome and evaluating accuracy and/or bias in judgments (Shanks & Dickinson, 1987; Wasserman, Elek, Chatlosh, & Baker, 1993). One metric termed \( \Delta P \) or delta \( P \) (Allan, 1980), defines the one-way contingency between actions and outcomes as the difference between the probability of the outcome, \( p(O|A) \), and the probability when no action has taken place, \( p(O|\sim A) \). When the two probabilities are equal there is no contingency and when the difference \( \neq 0 \), then a positive or negative contingency is present. Thus the value of \( \Delta P \) can vary from \(-1\) through 0 to \(+1\), like a correlation coefficient, which is consistent with a continuum of preventative control, through no control, to complete generative control over the outcome. As illustrated in the contingency table in Fig. 1, there are four possible action-outcome conjunctions that are all equally relevant to this calculation (described as cells A, B, C and D). After being exposed to a series of such conjunctions, participants could be asked to rate their own causal control over outcome occurrence using a judgment scale which maps onto the upper and lower bounds of \( \Delta P \). Thus the determination of relative and absolute accuracy should be straightforward.

If causal control in conceptualized in terms of this contingency matrix, then key components of the \( \Delta P \) calculation can change without influencing overall causal control, allowing assessment of systematic bias. For example, levels of behavior are conceptualized as the probability of action, \( p(A) \), whereas the availability of events that people might wish to control is measured as the probability of the outcome, \( p(O) \). Fig. 1 demonstrates how \( p(A) \) and \( p(O) \) can vary while \( \Delta P \) remains constant. The four exemplar conditions shown in Fig. 1 are identical in relation to \( \Delta P \), though \( p(A) \) and \( p(O) \) are varied systematically with low and high levels of both displayed. This suggests that perceived causal control should not vary between these conditions. To the contrary, however, participants appear to be sensitive to these shifts, showing elevated judgments of control with increasing \( p(A) \) and \( p(O) \) (Blanco, Matute, & Vadillo, 2011; Msetfi et al., 2005; Murphy, Vallee-Tourangeau, Msetfi, & Baker, 2005). These patterns of effects have been interpreted as a systematic and non-normative bias towards illusory control.

However, considering causal control only in relation to the contingency programmed by the experimenter alone may under estimate factors influencing the experience and perception of causal control (Msetfi, Murphy, & Kornbrot, 2012). Firstly, it is possible that the constant contingency assumption is incorrect; changing \( p(O) \) or \( p(A) \) may produce unintentional changes in the contingency that participants experience \( \Delta P_{exp} \) (Msetfi et al., 2012). So, as an example, increasing either \( p(A) \) or \( p(O) \) over a fixed time frame may restrict participants’ experiences to

![Fig. 1. Contingency tables showing four possible combinations of action-outcome information. The top panel shows generic information from which \( \Delta P \) is calculated, where A, B, C and D refer to the frequencies of action-outcome conjunctions. \( \Delta P = A/(A + B) - C/(C + D) \). All examples involve conditions in which \( \Delta P = 0 \), yet the \( p(O) \) and the \( p(A) \) is either low or high.](image-url)
p(O|A) only, meaning that ΔP is actually equal to p(O|A) (Matute, 1996). Thus, participants’ judgments may be consistent with the contingency they actually experience ΔP_EXP, as opposed to the contingency programmed by the experimenter and therefore not evidence of a specific bias in judgment. Moreover, Herrnstein’s (1961) matching law, along with evidence from contingency learning studies (Msetfi et al., 2012), tells us that with increases in p(O), behavior levels are also likely to increase in order to ‘match’ that level of outcomes. This suggests that in many studies, manipulations of p(O) and variation in p(A) may be confounded.

Second, more events will occur within the same time period than otherwise would be the case when there are increases of p(A) and p(O), like those displayed in Fig. 1. Changes to temporal presentation are important (Buehner & McGregor, 2006; Shanks, Pearson, & Dickinson, 1989). For instance, an increase in the temporal spacing delay between action-outcome conjunctions is conceptually equivalent increasing exposure to the context or Cell D of the contingency matrix (Msetfi, Murphy, & Simpson, 2007; Msetfi et al., 2005). Decreasing the temporal space has the opposite effect. This is because the temporal space between action-outcome conjunctions is a periods of time during which no actions and no outcomes occur. Thus, cell D, due to its unmarked status, is particularly vulnerable to changes in the temporal distribution of contingency events, especially in conditions in which p(O | A) is greater than 0. Thus, increases in the temporal space would lead to ΔP_EXP > experimentally programmed ΔP_PROG (Msetfi et al., 2005) whereas decreases in the temporal space would lead to the opposite pattern, ΔP_EXP < ΔP_PROG. It is also important to note that including only experimental events (spaces + cell D) into the contingency calculation could be thought of as controversial, as any periods of time [in an individual’s life] during which no actions or outcomes occur could be potential candidates to be cell D experience (Baker, Murphy, & Vallee-Tourangeau, 1996). It is clear, therefore, that the value of cell D itself is ambiguous and that changes to levels of behavior or the availability of outcomes over time, in conditions in which p(O | A) > 0 will exacerbate this ambiguity and render p(O | A) unknown and therefore ΔP_EXP as well (Msetfi et al., 2012). Thus while the information type (cell D) to be included in the equation is known, the extent and frequency is unknown.

Importantly studies have suggested that sensitivity to such ambiguity is a key area of causal control that distinguishes depressed and non-depressed people’s perceptions of causal control. This is because people who are mildly depressed do not tend to produce judgments of control that are sensitive to the availability of outcomes, p(O) (Alloy & Abramson, 1979), unlike healthy people who generally judge that they have more control when there are more outcomes available (e.g., Dickinson et al., 1984). In addition, factors which increase the size of such p(O) effects and increase the perception of control in the non-depressed, including increasing the duration of the empty temporal spaces in the procedure - cell D instances - do not seem to affect depressed participants similarly (Msetfi et al., 2007; Msetfi et al., 2005). Furthermore, low levels of behavioral activity in depression (Lewinsohn, Sullivan, & Grosscup, 1980), have been shown to mediate low perceptions of causal control (Blanco et al., 2011). Given that behavior has the potential to fill empty temporal spaces with control enhancing information, i.e., action outcome pairings or cell A instances (Matute, 1996), low levels of behavior would exacerbate this problem (Blanco, Matute, & Vadillo, 2009). Thus it seems that two potential pathways to an increased perception of control - levels of behavior p(A) and sensitivity to the availability of outcomes p(O) - are compromised in depression. Understanding mood related differences in the pathways to causal control will also be informative in explicating the processes underlying healthy processing.

Thus far we have discussed how changes to p(A) or p(O) may influence each other, change p(O | A) and render ΔP unknown and ambiguous. Though the availability of outcomes, p(O), levels of behavior p(A), as well as exposure to the temporal space that is the environment or context in the absence of actions or outcomes, p(–O | –A), all influence judgments of control, the effects of one on the other have not so far been studied. In addition, we have described how when people are depressed, they tend to perceive less control than healthy people, and are less likely to produce control enhancing behavior or be sensitive to control enhancing information. Thus far, these effects have not been studied together only separately. Therefore the experiments reported here were designed to explore how all three of these factors interact by manipulating levels of p(O), observing behavioral variability p(A) while comparing mildly depressed and non-depressed participant groups. Thus our goals were two-fold. First, we wanted to test the extent to which people’s levels of depression predicted their levels of behavior, and the effect of behavior on ΔP_EXP and thus their perception of control. Second, we aimed to explore dynamic changes in behavior, sensitivity to p(O) and perceptions of causal control during the learning process. In order to achieve these goals, it was necessary to use a contingency judgment procedure which allowed us to manipulate p(O) but which also allowed observation of people’s naturally occurring activity levels, p(A). Many studies have used discrete trial designs (Alloy & Abramson, 1979; Dickinson et al., 1984; Msetfi et al., 2005) in which participant behavior is constrained to fixed time windows and, as such, is not self-instigated or self-regulated. The discrete trials method is often preferred as it allows the experimenter to control and define participants’ experiences of contingency information (although see Msetfi et al., 2005 for particular areas of ambiguity in this procedure). However, discrete trials limit the extent to which the influences of temporal spacing and the availability of outcomes can be studied in relation to naturally occurring levels of behavioral activity. Thus for these particular studies we chose to use a free-operant procedure in which there are no discriminable trials, responses may be repeatedly performed at any time and naturally occurring behavioral activity may be studied (see also: Wasserman, Chatlos, & Neunaber, 1983; Wasserman et al., 1993). There are of course disadvantages to use of the free-operant procedure that we will address fully in the general discussion.

1. Experiment 1

In Experiment 1, we used a free-operant procedure in order to test our hypotheses. Free-operant procedures differ from discrete trials procedures in two important respects. They allow participants to choose both when and how frequently to respond. Therefore any differences between our findings and previous studies showing depression and p(O) effects might be due to differences in levels of behavior or because participants have the opportunity to initiate and self-regulate their own behavior. Thus, it was important that, in the first experiment, we replicate the depression and p(O) effects that have generally been reported using discrete trials designs with long intervals (approximately 15-s) in between each trial (e.g., Alloy & Abramson, 1979; Msetfi et al., 2005). We therefore introduced a novel task instruction in order to retain similar temporal constraints of previous work while allowing the behavioral variability we wished to study.

In addition, at regular intervals during the procedure, participants were asked for ratings of their own control (action rating) over the outcome and ratings of the context’s control (context rating) over the outcome. This last measure is important as it allows us to assess participants’ sensitivity both to changes in the availability of environmental information and their own perception of personal control against the occurrence of events that occur randomly in the environment. All conditions had a programmed ΔP_EXP = 0. We predicted that participants without signs of depression would rate their own control as higher in high p(O) than low p(O) conditions and higher than participants reporting signs of mild depression. We further predicted that this effect would be driven by higher levels of behavior and a greater tendency to discriminate between their own control and that of the context by non-depressed participants.
2. Method

2.1. Participants

73 university students, recruited via university email lists, volunteered to take part in this study. A priori power analysis indicated that a sample of 70 participants was required for a power of .8 to detect medium effects using the experimental design described below. Thus all volunteers were tested. However, four participants were excluded from the data set as they did not follow the task instructions, either making no key presses at all (n = 2) or engaging in a key press rate more than 1 SD above the mean (M = 19.80 key presses/block, SD = 162.67). Therefore the final sample comprised n = 69 participants.

All participants completed the Beck Depression Inventory (BDI: Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) before visiting the lab and again during their visit. On the basis of these BDI scores, non-depressed participants were categorized as a member of the low BDI group (scores of 8 or below, n = 38, with n = 23 females), and participants who showed signs of mild depression were categorized as the high BDI group (scores of 9 or above, n = 31, with n = 21 females). These cutoffs for BDI classification have been used in many previous studies (e.g., Alloy & Abramson, 1979). Table 1 shows that these groups were matched on a range of demographic and cognitive variables, including age, short term memory span (Digit span test: Lezak, 1995) or estimated IQ (Barona et al., 1984). In addition, and as expected, the high BDI group scored significantly higher than the low BDI group on the BDI and other measures of depression, anxiety and stress (Depression, Anxiety, Stress Scales DASS: Lovibond & Lovibond, 1995).

2.2. Design

This study involved two design components, a quasi-experimental design and a correlational design. In the experimental component, we used a mixed (2 × 2 × 3) × 2 fully factorial design. The within subject factors were control cue (action, context), p(O) (low .25, high .75), and time block with three levels (blocks 1, 2, 3). The between subjects variable was BDI group (low, high). In addition, the order of p(O) exposure was counterbalanced. Dependent variables were the participants’ judgments of control, the number of key presses performed and the ΔPEXP calculated by the programme on the basis of participant behavior.

The correlational component of the study explored the extent to which levels of depression were predictive of judgments of control in relation to (1) the size of p(O) effects, and (2) people’s degree of perceived personal control over and above that exerted by the context (see Fig. 2). The aim was to test whether this relationship was mediated through two key outcome variables, the number of key presses made by each participant and the resulting ΔP calculated by the programme. Therefore, the two outcome variables were ‘p(O) effect’ (high - low p(O) action rating) and personal control (action – context rating).

2.3. Materials

2.3.1. Free-operant contingency task

The presentation of experimental events was programmed using a Macintosh computer and REALbasic (2009, Release 2.1) software. The task was presented within a realistic scenario and cover story in which participants were asked to test their own control over the occurrence of a 2-s music clip (outcome) by pressing the spacebar (action or key press) on the computer keyboard. Participants were asked to leave around 15 s between their responses. Every key press recorded at any time would immediately generate an outcome at the scheduled probability, p(O|A). In low p(O) conditions, p(O|A) and p(O – A) were always .25, and .75 in high p(O) conditions. In addition, during the procedure, the computer programme would check the keyboard for a key press every 15 s. If, at that point, the key was not pressed, the programme would record the occurrence of a ‘no press’ trial and the outcome would occur at the scheduled probability [p(O – A)]. Note that the 15 s time bin was timed to ensure similarity between p(O|A) and p(O) and the timing used with discrete trials procedures (e.g., Alloy & Abramson, 1979; Msetfi et al., 2005).

Each p(O) condition was located within a distinct virtual context, represented by pictures of different rooms in a house. After each 5-minute block (3000 ms) of exposure to the context, participants were asked to rate their own control (action rating), and that of the context (context rating), over the outcome. There were three 5-minute time blocks of low p(O) conditions and 3 of high p(O) conditions. The ratings were made on the computer screen using a slider on a judgment scale, which varied from −100 (labeled totally prevent) through 0 (labeled no influence) to +100 (labeled totally control), with increments of +/−1. Other dependent variables included activity levels, as measured by the absolute number of key presses made in each 5-minute block. In addition, we also calculated ΔPEXP as p(O|A)cA–p(O – A)cA, where the conditional probabilities were calculated (hence CALC) using the 15 s time bin created by instructing participants to count 15 s between each key press and the programming loop which checked for a key press every 15 s. Probabilities were then calculated such that if the participant made 20 key presses of which 15 were reinforced, p(O|A)cA = .75, and if the programme logged 20 ‘no key press’ occasions of which 15 were reinforced, then p(O – A)cA = .75, and ΔPEXP = 0.

2.3.2. Beck Depression Inventory (BDI: Beck et al., 1961)

The BDI is a self-report measure of depression and has been used with clinical and student populations for many years. Participants were asked to choose from 21 statements that best describe them. These ranged from neutral statements (e.g., I do not feel like a failure) scored as 0, to more extreme mood related statements (e.g., I feel I am a complete failure as a person) scored as up to a value of 3. Total scores could range from 0 to 63 where higher scores indicate higher levels of depression. The BDI has been validated in student samples, correlations of .77 being reported between BDI scores and a psychiatric rating of severity of depression (Bumberry, Oliver, & McClure, 1978).

2.3.3. Depression Anxiety Stress Scales (DASS: Lovibond & Lovibond, 1995)

The DASS is a 42-item self-report questionnaire that yields three subscales, measuring the severity of depression, anxiety and stress symptoms. Participants rate each item (e.g., I found myself getting upset by quite trivial things) on a scale of 0 to 3, indicating the extent to which this had applied to them in the past week. A score of 3 would indicate that the statement had applied to the participant most of the time. There are 14 items for each of the emotional states and each subscale can yield a maximum possible score of 42.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Demographic and depression relevant characteristics of each group for Experiment 1.</th>
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<tr>
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<td>Low BDI (n = 38)</td>
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<td>High BDI (n = 31)</td>
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<td>Independent groups t-test*</td>
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<tr>
<td>X</td>
<td>SE</td>
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<tr>
<td>Age</td>
<td>21.34</td>
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<td>IQ</td>
<td>111.44</td>
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<td>DS</td>
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<td>BDI</td>
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<td>DASS</td>
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<td>(A)</td>
<td>2.37</td>
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<td>(D)</td>
<td>3.18</td>
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<td>5.29</td>
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Note: DS = Digit Span; BDI = Beck Depression Inventory; DASS = Depression, Anxiety and Stress Scales; (A) = Anxiety subscale; (D) = Depression subscale; (S) = Stress subscale. "df = 67."
2.4. Procedure

After giving written informed consent, participants provided their demographic details, completed the digit span task and then the battery of questionnaires. Then instructions for the contingency task were displayed on the computer screen. The cover story required participants to imagine that they were in a house in which there was a hidden stereo system. The music could be controlled in each of the rooms of the house (distinct contexts) using a remote control. Participants were also informed that the remote control had been working intermittently and that sometimes music switched on when no one was touching the remote. Their task was to test the remote control in each of the rooms. In addition, participants were instructed to count to 15, and leave a minimum of 15 "elephant counts" in between subsequent key presses. This instruction was included to retain a similar temporal constraint to discrete trials procedures in which \( p(O) \) and depression effects are observed (e.g., long ITIs and constrained number of presses: Mezeti et al., 2005). However, participants were actually able to press the button less and more frequently than this (i.e. leave < or > 15 s in between each key press). At the end of each 5-minute time block, a judgment window was displayed and participants were required to rate the causal relationship between their own action and the outcome, and between the context and the outcome. At the end of the final time block, participants were thanked, debriefed and received a small financial compensation for their participation (€10).

3. Results and discussion

Participants rated their own control and that of the context in a free-operant contingency learning task in low and high \( p(O) \) zero \( \Delta P \) conditions. The first set of analyses involved looking at relative differences between conditions on control ratings and levels of activity using mixed factorial analyses of variance, with the counterbalancing variable and gender included. An alpha level of .05 is used throughout unless stated otherwise.

3.1. Judgments of control

Participants rated their control higher with higher probabilities of outcome (.75 vs .25) and high BDI scores were related to lower ratings of control. These control judgments for each time block are shown in Fig. 3 as a function of control cue, \( p(O) \) and BDI group. For the low BDI group, there is clear evidence of large \( p(O) \) effects decreasing over time block and actions were rated as more controlling than the context in high \( p(O) \) conditions. Similar trends were evident for the high BDI group but with greater discrimination apparent between action and context ratings in the first time block. In addition, and as expected, in the high \( p(O) \) condition the low BDI group gave higher action ratings than the high BDI group.

The ANOVA revealed a significant four-way interaction between control cue, \( p(O) \), time block and BDI group, \( F(2, 122) = 3.57, p = \)
.031, MSE = 625.04, η² = .06, with no higher-level interactions involving gender or the counterbalancing variable. In order to explore the 4-way interaction, we carried out further analyses, in the first of which we examined action and context ratings separately to provide a clear picture of the precise location of the between groups differences. For action ratings, there was a significant main effect of p(O), F(1, 61) = 120.47, p < .001, MSE = 1333.01, η² = .66, qualified by a p(O) by BDI group interaction, F(1, 61) = 4.02, p = .04, MSE = 1333.01, η² = .06, although the three way interaction with block was not reliable, F < 1, p = .45. The focus of the significant 2-way interaction was that the low BDI group gave higher action ratings than the high BDI group in the high p(O) condition, F(1, 61) = 5.00, p = .03, MSE = 1490.39, η² = .08, with no significant difference in the low p(O) condition, F < 1, p = .69. Thus the p(O) effect was larger in the low BDI group, η² = .72, than the high BDI group, η² = .61.

Looking at context ratings, there was also a significant main effect of p(O), F(1, 61) = 24.43, p < .001, MSE = 3426.77, η² = .29, with high p(O) conditions rated higher than low p(O) conditions. The interaction between p(O) and BDI group was not reliable, F < 1, p = .57, however, the three-way interaction was significant: p(O) × BDI × block: F(2, 122) = 3.09, p = .047, MSE = 857.01, η² = .10. This was because low BDI participants’ context ratings were strongly sensitive to p(O), F(1, 34) = 18.60, p < .001, MSE = 3414.84, η² = .35, consistently through all the time blocks, p(O) × block: F < 1, p = .82. On the other hand low BDI participants’ context ratings did change in sensitivity to p(O) over time block, F(2, 54) = 3.63, p = .03, MSE = 978.14, η² = .12. In fact, in the first time block, there was no difference between high BDI context ratings attributable to p(O), p = .44, but this sensitivity was evident by blocks 2 (p = .02) and 3 (p = .02). Thus whereas low BDI group’s context ratings were strongly sensitive to p(O) from the outset, this sensitivity took time to develop in high BDI participants.

Secondly, it was important to explore the contrast between participants’ ratings of their own control versus their ratings of context control and how this differed for low and high BDI groups. This is because participants can potentially rate their own control over the outcome as low or high but similar and indistinguishable from the control of the context. In some of our previous work, high BDI participants have shown little evidence of such discrimination (Chase et al., 2011). In order to test for this we compared action and context ratings for each level of p(O) at each time block using single df contrasts and the alpha level adjusted according to the Holm procedure in order to correct for multiple comparisons (comparisons = 12). We found that for all participants it was only block 1, high p(O) conditions, in which there was any statistical evidence of actions being rated as significantly more controlling than context. For low BDI participants this difference was large and reliable at the adjusted alpha level (η² = .26, p = .001 < α_{HOLM} = .004). For high BDI participants, the difference was smaller, not significant and would only be reliable using a non-adjusted criterion (η² = .18, p = .02 ns > α_{HOLM} = .005). For all other conditions there was no evidence difference between action and context ratings, range of p values = .16–.94.

3.2. Activity levels

As instructed, participants made an average of 1 key press every 15 s during the 5-minute blocks with 19.80 (SE = 2.72) key presses in a block and this was not significantly different from the 20 presses we expected that participants would make in the time frame, t(68) < 1, p = .94. However, as shown in Fig. 4, while the low BDI group maintained a low activity rate across time blocks, the high BDI group responded more frequently early in the procedure, before settling on a similar rate by the end of the task, BDI group × block interaction: F(1, 61) = 4.67, p = .01, MSE = 1425.95, η² = .07. For low BDI participants, their key press rate remained constant over time (M = 15.67 key presses per block, SE = 1.5, p = .65) and the block effect was not reliable, F < 1, p = .65. For high BDI participants, their key press rates were significantly higher than the low BDI group in block 1, F(1, 61) = 5.98, p = .02, MSE = 2420.12, η² = .09, and their key press rates decreased over time blocks, F(2, 54) = 4.00, p = .02, MSE = 3112.52, η² = .13. There was no significant p(O) × block × BDI group interaction, F(2, 122) = 1.51, p = .22.

3.3. Mediation analysis

Two sets of mediation analyses were carried out in order to test the hypotheses described in order to test whether levels of depressive symptoms as measured by the BDI were predictive of activity levels (key presses), ΔP_{EXP} and (Analysis 1) the size of the p(O) effect as measured by the difference between low and high p(O) action judgments and (Analyses 2) personal control as measured by the difference between control ascribed to the action and context. These hypotheses were described graphically in Fig. 2 and the results are shown in Table 2, with significance examined in relation to 95% confidence limits for the beta parameters (Analysis 1 upper, Analysis 2 lower). For analysis 1, as the outcome variable constituted the difference between two conditions, the key press and ΔP_{EXP} measure were also the difference between the same conditions. This showed that BDI group was the only significant predictor of the size of the p(O) effect on action ratings, with the effect strongest in the low BDI group, c = −20.04, 95% CI [−37.13, −2.94], and this was not mediated individually or serially by either the difference in activity levels or ΔP_{EXP}.

Analysis 2 focused on personal control, where larger values indicate discrimination between action and context ratings. In this analysis, as the outcome variable was taken from one condition, key press and ΔP_{EXP} data from the same condition were used rather than difference data. This analysis showed that the high BDI group produced higher key press levels, a_1 = 57.18, 95% CI [6.51, 108.24], which indirectly predicted a greater level of discrimination between action and context control, a_2b_1 = 7.58, 95% CI [5.1, 24.13]. None of the other direct or indirect effects were reliable at the 95% confidence level.

Discrimination between action and context control was only present in block 1, high p(O) conditions. This effect seemed to be evident for all participants but was only significant for the low BDI group. The mediation analysis then provides some explanation for this effect showing that high BDI participants produced higher levels of key pressing which in turn produced greater discrimination. This useful finding
further suggests that high BDI participants may require or at the very least can use, high behavior levels, if available, to counter over time the differences in outcome sensitivity evidenced here in context ratings.

Taken together, the results of Experiment 1 were consistent with previous research and showed that p(O) effects were stronger in low than high BDI participants (Alloy & Abramson, 1979; Msetfi et al., 2005), and that low BDI participants rated their own actions as more strongly controlling in high p(O) conditions than the high BDI participants. However, there was clear evidence that produced levels of behavior contributed to greater sensitivity to the effects of behavior over context. Low BDI participants were consistently sensitive to levels of p(O) as demonstrated by a consistent p(O) effect on their context ratings. However, this sensitivity was not present initially for the high BDI group and, for them, developed later in the procedure. Note also that the BDI specific p(O) findings were not related to activity or activity based fluctuations in ΔPEXP.

4. Experiment 2

Experiment 1 was designed to include a similar constraint on behavioral activity as found in discrete trials designs in order to ensure comparability with previous research. While some variation in activity was present, this was as expected and inline with the experimental instructions. The next experiment was designed to remove that constraint, and test the same hypotheses under conditions where rates of activity are determined by the participant’s own inclination. In this experiment, the same procedure was used as in Experiment 1, but the instruction requiring 15 counts in between key presses was removed.

5. Method

The recruitment, design and procedure details were identical to Experiment 1, apart from one change in the instructions; participants were not instructed to count between key presses. Only new details are reported here.

5.1. Participants

74 university students were recruited. Five participants were removed because of atypical behavior, either making no key presses (n = 2) or responding at an extremely high rate (>1 SD above the mean; M = 230.18 key presses/block, SD = 407.27).

Participants were categorized as low BDI (n = 40, with n = 32 females) or high BDI (n = 29, with n = 24 females). Independent groups t-tests showed that there were no between group differences in age, digit span score or estimated IQ (see Table 3). As expected, the high BDI group produced significantly higher scores on the BDI and DASS than the low BDI group.

6. Results

Analyses were carried as in Experiment 1.

6.1. Judgments of control

As with Experiment 1, ratings of control were higher with higher outcome probability although this effect was not present for the context as it had been for Experiment 1. Participants’ ratings of action and context control are shown in Fig. 5. These ratings were analyzed using a mixed factorial analysis of variance, including the same variables as in Experiment 1, except for the present analysis gender was removed due to lower numbers of males in the sample (n = 13, of which n = 5 high BDI males). There were no significant effects or interactions involving BDI group, all ps > .13. There was a significant two-way interaction between cue and p(O), F (1, 64) = 24.31, p < .001, MSE = 2050.78, η² = .28. Further simple effects tests showed that participants gave higher action ratings in the high than low p(O) condition, F(1, 64) = 92.12, p < .001, η² = .56. However, this effect was much smaller for context ratings though it did reach the significance level, F(1, 64) = 6.75, p = .01, η² = .10.

6.2. Activity levels

The instructions for this experiment imposed no constraint on activity. Participants had a high rate of activity, with an average of one key

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Demographic and depression relevant characteristics of each group for Experiment 2.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low BDI (n = 29)</td>
<td>High BDI (n = 40)</td>
</tr>
<tr>
<td>Age</td>
<td>κ</td>
</tr>
<tr>
<td>21.33</td>
<td>.56</td>
</tr>
<tr>
<td>IQ</td>
<td>111.38</td>
</tr>
<tr>
<td>DS</td>
<td>7.23</td>
</tr>
<tr>
<td>BDI</td>
<td>3.99</td>
</tr>
<tr>
<td>DASS</td>
<td>(A)</td>
</tr>
<tr>
<td>(D)</td>
<td>2.80</td>
</tr>
<tr>
<td>(S)</td>
<td>6.25</td>
</tr>
</tbody>
</table>

Note. N = 69; Confidence limits refer to bias corrected bootstrap 95% confidence limits. Note that in both analyses, Gender and anxiety are included as covariates though the inclusion of these covariates does not influence the results. Bold indicates parameter values significant at the 95% confidence level.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Mediation analyses for Experiment 1 showing the relationships between BDI group, activity levels (key presses), ΔPEXP and (1) p(O) effects, and (2) control (action — context).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Path</td>
<td>β</td>
</tr>
<tr>
<td>Analysis 1*, where Y = p(O) effect (X High p(O) - X Low p(O)), Key Presses = (X High p(O) KP - X Low p(O) KP), and ΔPEXP = (X High p(O) ΔPEXP - X Low p(O) ΔPEXP).</td>
<td></td>
</tr>
<tr>
<td>a₁</td>
<td>8.44</td>
</tr>
<tr>
<td>a₂</td>
<td>-0.01</td>
</tr>
<tr>
<td>b₁</td>
<td>-0.80</td>
</tr>
<tr>
<td>b₂</td>
<td>42.06</td>
</tr>
<tr>
<td>d₁</td>
<td>-0.01</td>
</tr>
<tr>
<td>Analysis 2*, where Y = Control (Action1 — Context1), Key Presses = Key Presses block 1, and ΔPEXP = ΔPEXP block 1. Order of presentation is a covariate.</td>
<td></td>
</tr>
<tr>
<td>a₁</td>
<td>57.18</td>
</tr>
<tr>
<td>a₂</td>
<td>-0.05</td>
</tr>
<tr>
<td>b₁</td>
<td>.13</td>
</tr>
<tr>
<td>b₂</td>
<td>40.45</td>
</tr>
<tr>
<td>d₁</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

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was no direct relationship between BDI group and the size of the

Experiment 1 (see Table 4). The

6.3. Mediation analysis

Two sets of mediation analyses were carried out as described in

Experiment 1 (see Table 4). The first analysis showed that there

was no direct relationship between BDI group and the size of the

\( p(O) \) effect, \( c' = 2.04, 95\% \text{ CL } [−23.62, 19.53] \), but that the difference

in key press activity between the two \( p(O) \) conditions mediated the re-

lationship between BDI group and the \( p(O) \) effect, \( \alpha_1 \beta_1 = 9.74, 95\% \text{ CL } [2.72, 21.14] \). In order to interpret this effect, recall that the mediator

variable here is the difference between key presses in the high and

low \( p(O) \) conditions. For the low BDI group, this difference was large

and negative (see Fig. 5), because they key pressed most in low

\( p(O) \) conditions, whereas for the high BDI group the difference was

closer to zero and positive. Thus the mediation analysis shows that

difference in the size of the \( p(O) \) effect is attributable to the BDI group’s

influence on behavioral sensitivity to \( p(O) \), which then influences the

size of \( p(O) \) effects on ratings. For the high BDI group, low behavioral

sensitivity produced a 9.74 point rating increase in the size of

\( p(O) \) effect (see also Fig. 4).

Mediation analysis 2 showed that there were no reliable relation-

ships, direct or indirect, between BDI group and personal control.

Taken together, the results derived from the free-operant procedure

with no activity constraint yielded very different findings to the previ-

ous experiment. Participants’ action ratings were highly sensitive to

\( p(O) \) but their context ratings were not. Mediation analysis revealed

how BDI group influenced the size of \( p(O) \) effects through behavioral

sensitivity to \( p(O) \) in a manner not captured by standard ANOVA com-

parisons. Specifically, the high BDI group showed no behavioral sen-

sitivity to \( p(O) \), maintaining high key pressing rates throughout and

producing almost a 10-point larger \( p(O) \) effect on action ratings.

On the other hand, the low BDI group increased their levels of behavior

when there were fewer outcomes available, which counter-intuitively

reduced the size of the \( p(O) \) effect.

It is also important to note one key area of similarity in the findings

of the two experiments, while also bearing in mind an important caveat.

In both experiments \( \Delta p_{\text{exp}} \) was not predictive of ratings, either directly, or indirectly, as a step on a pathway that starts with mood effects on

behavior. This is contrary to our hypothesis which suggested that changes

in levels of behavior would modify the number of occurrences of cell A

events, and importantly impact on the availability of a key source of am-

biguity, cell D events and \( p(O| ~ A) \) thus in

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in levels of behavior would modify the number of occurrences of cell A

events, and importantly impact on the availability of a key source of am-

biguity, cell D events and \( p(O| ~ A) \) thus influencing the experienced contingency and judgments of control. These finding are similar to

Blanco et al. (2011) who also found that the experienced contingency

they calculated using a discrete trials procedure was not predictive of

ratings in spite of there being significant variability between the experi-

enced and programmed contingencies. In their study, as in this one,

behavior was a key predictor of ratings.
However, an important caveat here concerns the time frame over which cell C and D events should be counted, and thus p(\(O\mid\neg A\)) calculated, which is not clear when free-operant procedures are used. In Experiment 1, we matched the cell count time frame to the behavioral constraint introduced by the instructions (i.e. every 15-s the program checked for a cell C or D event). This programming strategy was maintained in Experiment 2 for equivalence across experiments. However, the behavioral time frame was very different with a key press recorded every 2-s on average. This means that, in Experiment 2, the cell C/D time frame was out of kilter with behavior and \(\Delta p_{EP}\) may have been inaccurate. This raises a very important point around the results.

7. General discussion

The findings of two experiments on judgments of causal control made after exposure to a free-operant contingency procedure showed that behavior and context are critical aspects of people’s experiences and perceptions of causal control which are affected by the symptoms of depression. Although both can be manipulated by an experimenter (Matute, 1996; Msetfi et al., 2005), these findings show that both can also be influenced by the participant themselves thereby increasing their sense of agency with potential implications for alleviating feelings of helplessness in depression. Specifically, within the constrained procedure, which preserves temporal spacing as in previous studies, low BDI participants were more sensitive than high BDI participants to levels of outcomes available, both in relation to action and context ratings. High BDI participants were sensitive to p(\(O\)), but less so than others. For context ratings, which are a measure of sensitivity to outcomes available in the environment, p(\(O\)) sensitivity took longer to develop in the high BDI group and this was concurrent with their high levels of behavioral activity. This points towards activity levels, and the ability to withhold activity, as being crucial in allowing people to develop outcome rate sensitivity and personal control as demonstrated by behaviorally mediated BDI effects on perceived control. When the behavioral constraint was removed, activity levels increased dramatically and consequently temporal spacing was reduced. As might have been predicted, all participants’ action ratings were sensitive to p(\(O\)) but their context ratings were not, presumably because they had almost no experience of the outcome rate in the absence of activity. However, low BDI participants’ behavior was highly sensitive to outcome levels, with much higher rates of behavior evident in low p(\(O\)) conditions when fewer outcomes were available. Counter intuitively, the high BDI group pressed consistently across all conditions, and this increased the size of the p(\(O\)) effect on their action ratings. This again demonstrates that when the ambiguity of p(\(O\)) – A experience is removed from the equation, here because of behavioral increase, perceived and experienced causal control is enhanced. Thus, a key outcome of this study is the finding that, together, behavior and context provide two linked pathways to perceived causal control, and that by creating fixed immutable experimental procedures we are ignoring important aspects of behavior that humans use in order to assert, determine or respond to causal control. Although we discuss these separately below, the interactivity between context and behavior must be emphasized.

7.1. Behavioral pathway to causal control

In these experiments, we observed shifts in behavioral activity, though not exactly as expected. We certainly expected that people would produce high rates of behavior in these naturalistic free-operant conditions (Matute, 1996) and this is what we found. However, we also expected that those scoring higher on the BDI would show less activity than others and that this tendency would be linked to a smaller p(\(O\)) effect (Blanco et al., 2012). In fact, we found no evidence of a general trend towards lower levels of behavior in high BDI participants. When constraints were imposed on behavior, at least initially, high BDI participants engaged in twice as much key pressing as low BDI participants, before their activities normalized to the same level as others. This effect was concurrent with reduced p(\(O\)) sensitivity on context ratings and a between (BDI) group difference on action ratings. This mood difference in action control ratings has been observed on many occasions (Blanco et al., 2012; Msetfi et al., 2005), and has been explained via low levels of behavior in depression or an inability to process context information. The findings of the current study suggest that higher behavior levels reduce ability to be sensitive to outcome rates in the environment, with a knock on effect on perceived action control.

We had also anticipated that that higher levels of activity would be evident in high p(\(O\)) conditions where activity is reinforced on the majority of trials, increasing motivation to respond on the next trial (Matute, 1996). When, activity was unconstrained by the task instructions, we did observe a p(\(O\)) effect on behavior, but it was low p(\(O\)) conditions that produced the highest levels of behavior in low BDI participants, with no difference present for high BDI participants. Not only is this finding inconsistent with assumptions made about the relation between key pressing and reinforcement (Matute, 1996), it is also inconsistent with Herrnstein’s (1961) matching law which states that behavior tends to ‘match’ the reinforcement contingencies. In the unconstrained procedure reported here, behavior was more consistent with a ‘maximization’ strategy (Msetfi et al., 2012) in which behavior increased in spite of a low outcome probability in order to maximize the absolute levels of outcomes received.

However, considering the contrasting findings of the two experiments, an important observation emerges. When participants were...
allowed to engage in as much or as little behavioral activity as they chose, activity levels increased dramatically. This increase was important to causal control in two ways. First, it resulted in no sensitivity to outcome rates in the environment as relevant experience was limited. Second, ambiguity was removed from the control situation as the participant gained almost no experience of not responding and noting whether or not the outcome occurred. In other words, cell C and D occurrences were almost eliminated from the contingency meaning that $Δp = p(O|A)$. We will return to this issue later, however an important point, not addressed by our data, is whether or not behavior was used strategically to create these effects or whether it was a reflex response to environmental contingencies.

7.2. Contextual pathway to causal control

Theoretical approaches to contingency learning involving the development of associations have proposed context as a key moderator variable in learning about causal control. There are different mechanisms proposed for how context exerts its influence. For example, the Rescorla–Wagner model (RWM: Rescorla & Wagner, 1972), when applied to contingency learning, describes perceived control as being dependent on the strength of action-outcome associations, though all stimuli present in a learning situation including the context will also acquire associative strength (Dickinson et al., 1984). RWM assumes that outcomes can only support a limited amount of associative strength and thus actions and context compete for association with the outcome. This notion of associative competition means that an action will gain associative strength to the extent that the context (or indeed other relevant stimuli) does not have it, and vice versa. The Comparator Hypothesis (Miller & Matzel, 1988) proposes an alternative mechanism to explain the influence of context (amongst other effects). According to this view both context and action gain associative strength independently but the response depends on the comparison between the two, rather than the absolute strength of the individual associations. Our findings do not explicitly distinguish between these two approaches. However, whichever approach is taken, the implications are that if the process of context-outcome association acquisition or extinction is impaired, compromised or affected in anyway, there will be a knock on effect on perceived control. Thus these findings are consistent with the idea that context is a key moderator of learning about causal control and mood differences provide insight into the mechanisms involved.

Along these lines, our previous work also suggested that context may be the key feature of contingency learning which distinguishes those who score low and high on the BDI (Msetfi, Wade, & Murphy, 2013). Manipulations of periods of context exposure with zero contingencies had no effect on high BDI groups’ judgments of low and high $p(O)$ conditions of which there was no difference, whereas low BDIs were affected such that $p(O)$ effects were only strongly evident with long periods of contextual exposure (Msetfi et al., 2005). Our interpretation of this was that contextual exposure acts as an instance of cell D in the contingency matrix, or a non-reinforced context only trial, allowing low BDIs to extinguish context associations and thus strengthen action associations, with high BDIs impervious to this manipulation. The findings of Experiment 1 here, in which the long temporal space was preserved, were consistent with those previous findings made using discrete trials procedures. Low BDI participants evidenced stronger $p(O)$ effects on their action ratings than high BDI participants. However, in this experiment, in which we took explicit ratings of context, we saw no evidence in low BDI participants of weak context ratings caused by the long cell D spaces. In fact, context ratings were relatively high for these participants. Moreover, higher levels of depressed mood predicted higher levels of key presses, which then produced a larger difference between action and context ratings. If this last metric, levels of discrimination between action and context, represents a more accurate measure of perceived control than action or context ratings individually, this might imply that irrespective of the absolute level of ratings, those who were mildly depressed experienced an enhanced sense of control. Furthermore, as specified by the Comparator Hypothesis (Miller & Matzel, 1988), action and context associations may develop independently, and the contrast between them at the time of judgment may determine perceived control, as opposed to the strength of the action association.

7.3. Temporal constraints and ambiguous information

We have discussed thus far how these data suggest that behavior and context influence each other to provide two linked pathways to causal control. However, the contrast in the data collected between these two experiments demonstrates the importance of the temporal and behavioral constraint present in the control scenario. This could be an instructional manipulation in a lab task like this one, or it could involve real world constraints that limit or induce activity thus influencing the extent to which the context is exposed. It is clear in these data that patterns of control ratings, which are thought of as characteristic of depression, are evident in constrained situations and that removal of the constraint provided a behaviorally mediated shift in ratings. This suggests that circumstances, which constrain people’s natural tendencies to respond to the contingencies around them, could constitute a block in an important pathway to causal control.

In fact, when constraints were removed in our study, high levels of behavior eliminated the all-important ambiguity inherent in contextual information. In our introduction we stated that this ambiguity is because cell D experience, which is composed of instances of no actions and no outcomes, could reside in extra-trial as well as intra-trial experience (Msetfi et al., 2005) but could also potentially include other experiences from an individual’s life (Baker et al., 1996). While the experimental context serves as an important marker for a focal set of relevant events (Cheng & Novick, 1990) and it seems likely that only those in the experiment are processed as relevant to causal control, a further area of ambiguity and complexity remains. It is not clear whether one period of contextual exposure, marked for example at the beginning and end by an occurrence of a cell A or cell B event, would count as one cell D event or many (Msetfi et al., 2005), or whether the duration of the exposure could be segmented into multiple cell D experiences. In other words the temporal frame, over which cell D accumulates, or indeed context associations develop, is unclear. Similarly, for experimenters programming no action, cell C and D experience within a free-operant procedure, the temporal frame chosen is arbitrary and may not be consistent with temporal frame used in everyday information processing. Indeed, if a temporal window were adopted that would allow ongoing experience to be ‘parsed’ into individual events, its size could be dynamic and based on pre-existing knowledge about the situation or many other factors (Buehner, 2005; Greville & Buehner, 2010). However, while in our study participants were able to remove this ambiguity from the causal control problem via their behavior, temporal dynamics and event parsing remain another important known-unknown of causal control learning.

7.4. Implications for depression

The implications of these findings for our understanding of depression cannot be discussed without first acknowledging the limitations of this work. First of all, participants were not patients diagnosed by a clinician as experiencing depression. They were university students scoring above or below the cut-off for mild depression on the Beck Depression Inventory. Although such cutoffs have been validated on psychiatric (Beck et al., 1961) as well as student samples (Bumberry et al., 1978), any implications for more severe levels of depression must be treated with caution. Secondly, data and findings were clearly derived from laboratory tasks, which, although constructed for this
study to facilitate behavioral flexibility, can be thought of as artificial and thus generalizability to the real world could be questioned (Haaga & Beck, 1995). Moreover, given the uncertainty that we have identified, both here and elsewhere (Msetfi et al., 2005), as to the true contingency relation that participants experienced and even the correct measure of control, it would be foolhardy to relate findings to judgment bias or accuracy in either group of participants. Whilst acknowledging all of these limitations, however, there are implications of these findings for mild depression which are not predicated on assumptions of a known experienced contingency.

In this study, all participants engaged in relatively high levels of behavior with no evidence of a general trend towards behavioral passivity amongst those who were mildly depressed. However, although those with signs of mild depression were certainly capable of high behavior levels, these did not shift, whether strategically or automatically, as a function of outcome availability. This suggests that any behavioral impairment associated with depression is not an absolute but may be specifically related to outcome sensitivity and the extent to which reinforcing outcomes drive behavior. Irrespective of this, mildly depressed participants benefited from high levels of behavior in unconstrained conditions, eliminating the moderating role of context and producing action control judgments that were high and similar to those with low BDI scores.

This is important given that many successful therapeutic approaches to depression include a behavioral activation component (including various types of cognitive therapy), which involves increasing levels of activity and opportunities for positive reinforcement (see Dimidjian, Barrera, Martell, Muñoz, & Lewinsohn, 2011 for a detailed discussion), but may not adequately recognize the relation between behavior and context as interlinked pathways to control.

8. Conclusion

In this paper, we set out to study the roles of behavior and the availability of outcomes in the environment, and their interactive effects, on causal control learning in people who scored low and high on a depression scale. Initially, we had identified the moderating effect of context as a key area of ambiguity in control learning, which seems to separate people with and without signs of depression. This was the case in the present study. Key findings are that behavior, via its effect on exposure to the context, provided a powerful pathway to resolve this particular ambiguity, though others remain in relation to the temporal parsing of events. Temporal and behavioral constraints on control learning, as a product of the situation or an individual difference, such as depression, may act as a block to people’s ability to enhance their sense of control.

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References


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