The Effects of Cognitive Load during Intertrial Intervals on Judgements of Control: The Role of Working Memory and Contextual Learning

H. A. Cavus[1] and Rachel M. Msetfi[12]

University of Limerick

Author Note

[1]Centre for Social Issues Research, Department of Psychology, University of Limerick, Limerick, Republic of Ireland

[2]Health Research Institute, University of Limerick, Limerick, Republic of Ireland.

Correspondence concerning this article should be addressed to H. A. Cavus, Department of Psychology, University of Limerick, Limerick, Ireland. E-mail: halim.cavus@ul.ie

word count: 7,237

Abstract

When there is no contingency between actions and outcomes, but outcomes occur frequently, people tend to judge that they have control over those outcomes, a phenomenon known as the outcome density (OD) effect. Recent studies show that the OD effect depends on the duration of the temporal interval between action-outcome conjunctions, with longer intervals inducing stronger effects. However, under some circumstances OD effect is reduced, for example when participants are mildly depressed. We reasoned that Working Memory (WM) plays an important role in learning of context; with reduced WM capacity to process contextual information during intertrial intervals (ITIs) during contingency learning might lead to reduced OD effects (limited capacity hypothesis). To test this, we used a novel dual-task procedure that increases the WM load during the ITIs of an operant (e.g., action-outcome) contingency learning task to impact contextual learning. We tested our hypotheses in groups of students with zero (Experiments 1, *N*= 34), and positive contingencies (Experiment 2, *N*= 34). The findings indicated that WM load during the ITIs reduced the OD effects compared to no load conditions (Experiment 1 and 2). In Experiment 2, we observed reduced OD effects on action judgements under high load in zero and positive contingencies. However, the participants' judgements were still sensitive to the difference between zero and positive contingencies. We discuss the implications of our findings for the effects of depression and context in contingency learning.

Keywords: contingency learning; perceived control; working memory load; associative learning; depressive realism

Abstract

When there is no contingency between actions and outcomes, but outcomes occur frequently, people tend to judge that they have control over those outcomes, a phenomenon known as the outcome density (OD) effect. Recent studies show that the OD effect depends on the duration of the temporal interval between action-outcome conjunctions, with longer intervals inducing stronger effects. However, under some circumstances OD effect is reduced, for example when participants are mildly depressed. We reasoned that Working Memory (WM) plays an important role in learning of context; with reduced WM capacity to process contextual information during intertrial intervals (ITIs) during contingency learning might lead to reduced OD effects (limited capacity hypothesis). To test this, we used a novel dual-task procedure that increases the WM load during the ITIs of an operant (e.g., action-outcome) contingency learning task to impact contextual learning. We tested our hypotheses in groups of students with zero (Experiments 1, *N*= 34), and positive contingencies (Experiment 2, *N*= 34). The findings indicated that WM load during the ITIs reduced the OD effects compared to no load conditions (Experiment 1 and 2). In Experiment 2, we observed reduced OD effects on action judgements under high load in zero and positive contingencies. However, the participants' judgements were still sensitive to the difference between zero and positive contingencies. We discuss the implications of our findings for the effects of depression and context in contingency learning.

Keywords: contingency learning; perceived control; working memory load; associative learning; depressive realism

The Effects of Cognitive Load during the Intertrial Intervals on Judgements of Control: The Role of Working Memory and Contextual Learning

1. Introduction

Perception of control over specific events is a subjective feeling that is thought to depend on how people perceive the objective action-outcome contingencies in the environment (Langer, 1975, also see E. A. Skinner, 1996 for various terms and measures used to describe control). Experimental studies using contingency learning paradigms have shown that perception of moderate levels of control over events, even when statistically there is none, is related to mental healthiness, with extremely high and low levels of perceived control relating to psychopathology (Alloy & Abramson, 1979, 1988; Metcalfe, Snellenberg, DeRosse, Balsam, & Malhotra, 2014; Reuven-Magril, Dar, & Liberman, 2008; Taylor & Brown, 1988).

In this research, we test how changes in perceived control relate to the effects of cognitive load, which might prevent learning of important contextual information relevant to contingency learning. This is relevant, as learning is believed to occur in a limited capacity device (Wagner, 1978, 1981; Pearce & Hall, 1980), and when cognitive capacity is reduced this might interfere with the learning of contextual information. Thus, our analysis will focus on cognitive and behavioural processes such as attention and memory that might play a causal role in healthy and lower levels of perceived control (Harvey, Watkins, Mansell, & Shafran, 2004). However, first, we will discuss how perception of control has been studied and the situations where individuals differ in their levels of perceived control.

1.1. Operant contingency

In operant contingency learning tasks, individuals learn the relations between their actions and the outcomes. There are two versions of the operant learning paradigms: free-operant and discrete-trial procedures. In free-operant procedures, the task is divided into time-bins, and the participants are free to act at times they would like whereas in discrete-trial procedures, the learning task is divided into trials and participant may only perform the action during this period. In discrete-trial procedures, trials are separated by a time period known as the intertrial interval (ITI) of varying durations. Experiments have tested people's perception of control over outcomes using both kinds of paradigms (e.g., Allan & Jenkins, 1983; Alloy & Abramson, 1979; Byrom, Msetfi, & Murphy, 2015; Jenkins & Ward, 1965; Msetfi, Murphy, Simpson & Kornbrot, 2005; Msetfi, Murphy & Simpson, 2007; Msetfi, Wade & Murphy, 2013; Wasserman, Elek, Chatlosh, & Baker, 1993; Vázquez, 1987). However, the advantage of discrete-trial procedures over free-operant procedures is that they include a clearly defined event structure with an objective measure of control with which judgements of control made by people can be compared to (Ackermann & DeRubeis, 1991; Clark, Beck, & Alford, 1999; Dobson & Franche, 1989). This is a measure of action-outcome contingency, denoted by the ΔP metric (Allan, 1980), which quantifies a statistical, one-way relation between binary events.

The ΔP metric is simply equivalent to the difference between the probability of an outcome occurring in the presence of an action, $P(O|A)$, and the probability of an outcome occurring in the absence of an action, $P(O|{\sim}A)$. This metric can vary from −1 (negative or preventative contingency) to 0 (zero contingency) to +1 (positive or generative contingency). For example, in a positive contingency schedule, outcomes are more likely to occur in the presence of action than in its absence, whereas in negative contingency schedule, outcomes are less likely to occur in the presence of action. From this perspective, there are four possible action-outcome conjunctions relevant to contingency all of which are given equal weighting in the ΔP calculation, and are shown in Table 1 along with exemplar conditions.

PLEASE INSERT TABLE 1 AROUND HERE

1.2. Outcome density effects and the context hypothesis

As can be seen in Table 1, in the zero contingency schedules, outcomes are equally likely to occur irrespective of the presence and absence of action. However, most studies using discrete-trial operant contingency learning paradigms indicated that healthy individuals overestimate the degree of control they have over the outcomes when the outcome density (OD) or the probability of outcome to occur, *P*(O), is high, whereas people with mild depression tend to be less sensitive to such differences (see Moore & Fresco, 2012 for a meta-analysis). The effect that healthy people overestimate the degree of control in high OD condition is named OD bias or illusion of control, and is considered to be a deviation from ΔP. On the other hand, depressed people tend not to show this illusion, an effect known as depressive realism (Alloy & Abramson, 1979).

There are many behavioural- and cognitive-level explanations of OD and depressive realism effects, such as the response probability (Blanco, Matute, & Vadillo, 2012; Matute, 1996), response criterion (Allan, Hannah, Crump, & Siegel, 2008; Allan, Siegel, & Hannah, 2007), and context hypotheses (Msetfi, Brosnan, & Cavus, 2016; Msetfi, Murphy, Simpson, & Kornbrot, 2005; Msetfi, Murphy, & Simpson, 2007; Msetfi, Wade & Murphy, 2013). It is not possible to review all these theories in detail here. Briefly, however, Matute and colleagues suggested that illusory control might stem from high response probability, leading to more reinforced trials during the contingency learning task (Blanco, Matute, & Vadillo, 2012; Matute, 1996). On the other hand, in their psychophysical analysis of contingency, Allan and colleagues (Allan, Hannah, Crump, & Siegel, 2008; Allan, Siegel, & Hannah, 2007) suggested that people perceive the normative ΔP within the constraints of memory and attention limits. However, depressed people might have a lower response criterion (e.g., a tendency to say “nay”). Given the centrally defining role of context in learning, we will particularly focus on contextual learning here.

Learning occurs in an environmental and associative context, and contextual effects have been studied and conceptualised in numerous ways in animal learning (e.g., Balsam & Tomie, 2014; Bouton & King, 1983; Estes, 1976; Maren, Phan, & Liberzon, 2013). Although environment represents a context, there are many other forms of contexts that define experience. Our contingency manipulations here deal with action-outcome relations that occur in a particular context, and we study how individuals learn these relations .

One of the simplest methods of testing context effects on learning is via temporal manipulations because context and time are interdependent (Msetfi, Wade, & Murphy, 2013). Along these lines, Msetfi and colleagues (2005; 2007) noted that most studies reporting OD effects involved long ITIs. To test the hypothesis that the ITI duration might influence judgements of control, Msetfi et al. (2005, 2007) varied ITI duration (3s vs. 15s), along with a standard OD manipulation (low vs. high) in two groups (depressed and non-depressed) in a zero contingency task. Msetfi and colleagues' findings indicated an OD effect in the non-depressed group when ITIs were longer (e.g., 15s), and reduced OD effects in people with depressed mood in the same condition. On the other hand, both non-depressed and depressed groups' judgements of control did not significantly change due to OD manipulation when the ITIs were shorter (e.g., 3s).

At the computational level, Msetfi et al. (2005) explained these findings in the light of their ITI integration hypothesis. This hypothesis adjusts the experimental contingency by accounting for extra contextual information due to long ITIs. When ITIs are integrated into the ΔP calculation as discrete events (cell 'd'), this has the effect of decreasing $P(O|{\sim}A)$, thus increasing ΔP in high OD conditions in particular (Msetfi, Murphy, Simpson, & Kornbrot, 2005; Msetfi, Murphy, & Simpson, 2007). While non-depressed people's judgements were consistent with the ITI integrated contingency, judgements of control made by people with mild depression seemed to be less sensitive to this information.

Msetfi and colleagues (2005) argued that the reason ITIs are relevant to the contingency, in spite of containing no actions or outcomes, is because they occur in the same context as all the other contingency events. As depressed people's judgements seem to be insensitive to ITI duration, possibly due to depression-related cognitive processes such as rumination (Nolen-Hoeksema, 1991; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008), the findings were consistent with the idea that impaired contextual learning might underlie depressive realism effect. This hypothesis would also be compatible with the associative learning model (e.g., Rescorla & Wagner, 1972), if ITIs are considered "context only" trials (e.g., no action-no outcome). This would result in a decrease in associative strength between context and outcome, leading the action to gain associative strength (Msetfi, Murphy, Simpson & Kornbrot, 2005).

While it is possible that contextual learning is related to reduced OD effects in depression, the exact process of how contextual learning occurs (e.g., automatic vs. controlled) remains unknown. Although, it is known that depressed people have a higher tendency to display self-referent and ruminative thinking (Nolen-Hoeksema, 1991; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008), which might be related to performance-related impairments in cognitive tasks (see Whitmer & Gotlib, 2012 for a review). Based on this, we hypothesised that reduced cognitive capacity to integrate contextual information present during idle task periods (i.e, ITIs) will impact perceived control. To test this hypothesis, we manipulated the level of cognitive load during the ITIs of an operant contingency learning task.

1.3. The effects of working memory load on learning

Working memory (WM) is the ability to maintain and manipulate limited information in short periods, and is thought to play an important role in complex cognition (Baddeley, 1992, 1996; DeCaro, Thomas, & Beilock, 2008; Engle, 2002; Engle & Kane, 2004; Veltman, Rombaust, & Dolan, 2003; however also see Tharp & Pickering, 2009). It is believed that WM consists of different functions such as maintenance and manipulation of information.

Previously, studies have tested the effects of WM load on rule-based and associative learning processes (De Houwer & Beckers, 2003; Otto, Gershman, Markman, & Daw, 2013; Waldron & Ashby, 2001; Wills, Barrasin, & McLaren, 2011; Wills, Graham, Koh, McLaren, & Rolland 2011). For example, in two experiments, De Houwer and Beckers (2003) varied the cognitive load imposed by a concurrent task during a forward blocking version of a contingency learning task. In this task, participants must learn that action A predicts outcome O. Following this, participants were exposed to conditions where actions A and B simultaneously predicted O. In such conditions, the strong association between A and O usually blocks the acquisition of the B-O relation (e.g., Kamin, 1969). However, De Houwer and Becker's findings indicated that concurrent WM load led to higher ratings for the extent to which B was considered to be the cause of the outcome, compared to the no load condition. In other words, the blocking effect was disrupted by high cognitive load, depending on secondary task difficulty and whether the load was imposed during both the learning and the test phase of the contingency learning task. Given that the secondary task processing influenced forward blocking, De Houwer and Beckers explained that forward blocking seems to depend on higher-order cognition, rather than associative processes. Others have suggested that, under cognitive load, low-level associative processes such as cue-competition drive causal learning, similar to those in studies of animal conditioning (Le Pelley, Oakeshott, & McLaren, 2005). Consistent with this, recent findings also show that the learning process affects cue-competition in evaluative contingency learning in humans (Kattner & Green, 2015).

Relating these findings back to our central question, we might ask whether it is the use of different learning processes or a more general cognitive phenomenon that underlies the

OD and depressive realism effects in zero contingencies. If learning of action-outcome relations is context-dependent, then reduced OD effects could be explained by limited capacity to process contextual information (limited capacity hypothesis), whereas available capacity would relate to "illusory" relations observed in operant contingency tasks with sufficiently long ITIs. Therefore, we hypothesise that WM load during contextual learning periods of a contingency learning task will influence levels of perceived control and the size of OD effects in zero contingencies. Specifically, we predict that high WM load will reduce the size of OD effects in non-depressed participants, whereas conditions with no WM load will produce sizeable OD effects, as seen in numerous other experiments. We also hypothesised that action and context judgements would interact, as predicted by the associative learning model (e.g., Rescorla & Wagner, 1972).

2. Experiment 1

In order to test our hypotheses, we used a dual task procedure, which incorporated a verbal WM component (Mason et al., 2007) into the ITIs of an operant contingency learning task. The contingency learning task included two rating scales (i.e., one for action and one for context). Participants rated how much control action and context exerted upon outcomes in zero contingency conditions with low and high levels of OD.

2.1. Method

Ethical approval of this research was obtained from the University of Limerick Education and Health Sciences Faculty Research Ethics Committee (Approval code: EHSREC-1091). Before taking part, the participants provided written informed consent using a consent form approved by the research ethics committee. The data have been reposted to Open Science Framework and are publicly available at osf.io/vjwzp.

2.1.1. Participants

University students were invited via e-mail to take part in an experiment about mood changes and judgements. Volunteers were entered into a prize draw with the possibility of winning a €100 voucher. The inclusion criteria were to be over 18 years old and to have a score less than or equal to 8 in the Beck Depression Inventory (Beck et al., 1961) at the time of test. Thirty-eight participants, who volunteered to take part, were randomly assigned to one of two conditions: no load and high load.[1] Three participants failed to follow the contingency task instructions (two in no load and one in high load condition), resulting in a very high response probability (> .80), and one participant in the high load condition pressed the wrong key during the computer task disabling the computer to record the response rate and the experienced contingency. These participants were therefore excluded from the analyses. The final sample consisted of 34 participants (17 in the high load condition). The mean age of the participants was 21.09 (*SE*= .51) and 25 of them were female (13 in the no load and 12 in the high load conditions). The population means of the two load groups did not significantly differ on a range of relevant demographic and cognitive variables, including age, WM span scores (digit span forward), depression, anxiety, and stress levels, *t*s< 1.42 *p*s> .17.

2.1.2. Design

Experiment 1 involved a (2 × 2) × 2 fully factorial mixed design. The two within-subjects variables were OD (low vs. high) and Cue (action vs. context judgements). The between-subjects variable was WM load (no load vs. high load). Dependent variables were

---

[1] This sample size was predetermined based on a power analysis for within-subjects effect in order to attain a power of .80 and medium effect size (*f*= .25). A small margin of error was also included, as rarely participants do not follow the task instructions during discrete-trial operant contingency learning tasks, resulting in a very low or high response probability and deviations from the pre-programmed contingencies. Our sample size was sufficient for the hypothesised within-between interactions, while we did not have power to test between subject effects.

action and context ratings. In each group, participants were exposed to both low and high OD zero contingency conditions in two virtual rooms, respectively. The OD order was counterbalanced with approximately half of the participants completing the task in Low-High order.

2.1.3. Materials

Pre-test measures. WM span was measured using the forward version of the digit span task (Lezak, 1995). We used the Beck Depression Inventory (BDI; Beck, Ward, & Mendelson, 1961) to measure depressed mood. In addition to the BDI, we also used the shorter version of the Depression, Anxiety, and Stress Scales (DASS-21; Lovibond & Lovibond, 1995) to measure depression, anxiety, and stress-related symptoms.

The dual contingency and WM load task. The dual task superimposed a verbal WM task (Mason et al., 2007) over the ITIs of the contingency learning task (Msetfi, Wade, & Murphy, 2013). In the contingency learning task, participants were given a cover story in which they were asked to test whether an audio system in a residence was working properly. They could control the music switching on in each of the rooms in the residence (i.e., distinct room representations) using a virtual remote control. However, participants were told that the remote control had been working intermittently, and that sometimes music switches on when no one is touching the remote control. The task was therefore to test the remote control in each of the rooms separately. Participants were asked to press the space bar on approximately half of the opportunities and observe whether an outcome occurred (i.e., 2000ms music clip play) in 80 experimental trials (40 in each OD condition, hence in each virtual room). Action was signalled by a short beep sound and an on-screen prompt (i.e., "You may press the button now!") that appeared on the screen for 3000ms in every trial. These signals indicated the contingency task trials, similar to the yellow light in Alloy and

Abramson's (1979) discrete-trial procedure. During this time, participants could press the space bar. Each experimental trial was separated by a 5000ms ITI. This duration was chosen to accommodate the trials of the WM component. Trials and the ITIs occurred in the same virtual context in each OD condition. Each OD condition occurred in a virtual context represented by two room pictures (each decorated differently) on the computer screen. The contingency task consisted of two conditions (low OD and high OD) with different levels of outcomes (see Table 1, zero contingency for the pre-programmed contingencies). In each OD condition, the outcome schedules were randomised in blocks of every four trials. Participants were asked how much control they or the context had upon the outcome in the middle and at the end of each condition using two scales displayed on the computer screen (one for action and one for context).[2] These scales were constructed with increments of +/ −1 and ranged from −100 (totally prevent) to 100 (totally control). The rating scales were presented on the same window simultaneously, and the exact wording for the action and context rating scales is provided in Appendix A.

The WM component of the dual task was adapted from Mason and colleagues' verbal WM task (Mason et al., 2007), and was only presented during the ITIs of the contingency task in a white box on the top part of the screen. As the introduction of a secondary task materials during the ITI makes the ITI context differ from the trial context which could potentially influence the contextual learning process, we chose to present the WM component in both high and no load groups, without giving the latter the instructions to complete it. Thus the two groups were presented exactly the same visual stimuli during the contingency

[2] Action and context ratings were taken twice: once after the 20th trial (middle judgement window), and the other at the end (final judgement window). We analysed this by entering time of judgements as a within-subjects variable. Because, time of judgements did not significantly interact with OD, cue, and WM load in both experiments (*F*s< 1), we chose to report the analyses conducted with the final judgements.

task trials as well as the ITIs. The WM task involved remembering and manipulating four-letter strings (e.g., “SRJN”). In this modified version, each task trial (the ITI) began with a fixation cross (1000ms), displayed in the white box, and followed by a four-letter string (1000ms). An arrow pointing backward or forward then followed the letter strings (1000ms) indicating the direction of the retrieval. The letter to be retrieved was indicated by a number (e.g., 2) after the arrow and stayed on the screen for 2000ms. For example, when the arrow was backward and the number was 2, the correct answer for the “SRJN” letter string would be “J”. However, when the arrow was forward, the correct answer would be “R” for the same string. In each trial of the WM task, the letter string, the direction of the arrow, and the number were pseudo-randomly determined. In contrast to the original task, participants were instructed to give their responses verbally right after they saw the number rather than pressing a key, since key press could lead to motor interference with the responses given for the contingency task. We also did not provide online feedback to the participants about their performance in the WM component, as this could increase the stress levels experienced in the high load group. Participants were also instructed to give their responses until they heard a short beep sound as this signalled the end of the ITI and the beginning of the contingency trial. These responses were audio recorded and analysed by the experimenter.

Across the two experiments reported here retrieving the correct letter was more difficult for the backward trials than the forward trials, see Table 2. This was confirmed by a 2 × 2 repeated measures analysis, where the within-subjects factor was retrieval direction (backward vs. forward) and the between subjects factor was experiment. The findings indicated a significant main effect of retrieval direction, $F(1, 32)= 20.429$, $p<.001$, $\eta_p^2= .39$, $CI_{.90}$ for η_p^2 [.166, .544]. The interaction between retrieval direction and experiment was not significant, $F(1, 32)= 1.649$, $p= .209$, $\eta_p^2= .05$, $CI_{.90}$ for η_p^2 [0, .202].

PLEASE INSERT TABLE 2 AROUND HERE

Apparatus. Experimental materials were programmed in REALbasic (2009, Release 2.1) software, and presented on Macintosh computers (iMac, 17" screen size). Audacity (2013, Release 2.0.5) software was used to record verbal responses given during the dual task.

2.1.4. Procedure

Participants were recruited via e-mail to volunteer in a study about mood changes and judgements. Upon reading the information sheet and signing the informed consent form, participants completed all the pre-test measures. Then, they were randomly assigned to either one of the experimental conditions (no load or high load) in order to complete the contingency task. First, participants read the instructions for the contingency task (see Appendix B for the task instructions). In order to make sure that they understood the task instructions, participants were verbally reminded to press the space bar on the keyboard on approximately half of trials, and were given more explanation if they had any questions. In the high load condition, participants were instructed to complete the WM component as instructed. In the no load condition, participants were informed that the WM task stimuli were not relevant for the purposes of the experiment, and were not given the instructions to complete it. The experimenter then left the individual experimental cubicle and the participants started the task.

The contingency task took approximately 15 minutes to complete. In the middle and at the end of each game, a judgement window appeared and participants were asked to rate how much control their action or the context exerted upon the music. At the end of the experiment, participants were debriefed and thanked for their participation.

2.2. Results and Discussion

Visual inspection of the results suggested that participants in the no load condition displayed OD effects for the action judgements (i.e., higher judgements in high OD condition), whereas high load participants did not (see Figure 1). These observations were tested using parametric tests with an alpha level maintained at .05 unless stated otherwise.

PLEASE INSERT FIGURE 1 AROUND HERE

Judgement of control data were analysed using (2 × 2) × 2 mixed analysis of variance (ANOVA). The between-subjects variable was group (high load, no load), and the two within-subjects variables were OD (low, high) and cue (action, context). The results showed a significant main effect of OD, $F(1, 32)= 9.70$, $p= .004$, $\eta_p^2= .23$, $CI_{.90}$ for η_p^2 [.049, .409], and a significant three-way interaction between OD, cue, and WM load, $F(1, 32)= 4.39$, $p= .044$, $\eta_p^2= .12$, $CI_{.90}$ for η_p^2 [.002, .296]. None of the other effects were significant (Table 3).

PLEASE INSERT TABLE 3 AROUND HERE

In order to understand the three-way interaction, we analysed the action and context judgements separately. There was a reliable OD and WM load interaction for the action judgements, $F(1, 32)= 10.01$, $p= .003$, $\eta_p^2= .24$, $CI_{.90}$ for η_p^2 [.052, .415]. The main effect of OD was marginally significant for context judgements, $F(1, 32)= 3.41$, $p= .074$, $\eta_p^2= .10$, $CI_{.90}$ for η_p^2 [0, .267], and the OD and WM load interaction was not significant for the context judgements, $F<1$. We then conducted pairwise comparison analyses for action and context ratings of each load group in two different OD conditions. The results showed that ratings of control in Low versus High OD conditions differed significantly for action judgements in the no load group, $p< .001$ whereas this effect was not reliable in the high load group, $p=.719$.. As expected, the ratings of control in Low versus High OD conditions did not significantly differ for context ratings in both load groups, $p>.07$. Thus, WM load reduced the OD effect for action ratings in the high load group.

We looked at whether the two load groups had experienced different levels of experienced contingency (ΔP_{EXP}), response probabilities, and reaction times due to WM load. In both groups, mean ΔP_{EXP} approximated zero (see Table 4), $F<1$, and the overall response probabilities were similar, (*M* = .61, *SE*= .04, in the no load group, and *M* = .61, *SE*= .03, in the high load group), $F < 1$.

PLEASE INSERT TABLE 4 AROUND HERE

We also analysed whether there were differences in RTs to the key press trials of the contingency learning task due to load. Participants in the high load condition made slower responses (*M*= 1144ms, *SE*= 48ms) on the contingency task trials compared to the participants in the no load condition (*M*= 1011ms, *SE*= 51ms). However, this difference was marginally significant, $F(1, 30) = 3.66$,, $p = .065$, $\eta_p^2 = .11$, $CI_{.90}$ for η_p^2 [0, .275].

In Experiment 1, we tested whether WM load during ITIs influenced judgements of control in an operant contingency learning task with zero contingencies. The findings showed that under high WM load, the OD effect for action judgements was eliminated. There were no significant load effects on context ratings. While these findings are consistent with the limited capacity hypothesis that WM load during the ITIs impacts contextual learning during contingency learning and eliminates OD effects, there is another possible and simple explanation. These findings might be related to increased task difficulty due to the dual task procedure and lack of OD effects in the high load group simply represents an inability to do contingency learning under these conditions. Namely, participants in the high load condition might simply rated no control due to completing a difficult task that prevented them learning contingencies.

3. Experiment 2

In Experiment 2, we tested the possibility that WM load might interfere with contingency learning in general as opposed to OD effects specifically. One way of testing this is to compare the effects of WM load under different contingency conditions (i.e., zero vs. positive) as well as levels of OD. Thus if participants' judgements under high WM load reflect discrimination between different levels of contingency in a within-subjects design with reduced or eliminated OD effects, this indicates that they can learn the difference between those statistical relations and that the WM effect is specific to the OD effect. If on the other hand, high WM participants neither discriminate between zero and positive contingencies nor show OD effects, this would suggest that WM load affects the ability to learn contingencies in general, other than contextual information as we hypothesised.

Therefore, in Experiment 2, we used both zero and positive contingencies to investigate whether WM load during the ITIs influence contingency learning proper. It was hypothesised that contingency will influence perceived control levels in both no load and high load groups, whereas high WM load will reduce OD effects for action judgements. Similar to Experiment 1, we hypothesised an interaction between action and context ratings, particularly in zero contingency condition.

3.1. Method

Details of Experiment 2 are identical to Experiment 1, and only pertinent details will be included here.

3.1.1. Participants

Volunteers were given €5 or course credits for participation. Thirty-six participants were assigned to the no load and high load groups. Two participants (one in high load group) failed to follow the contingency task instructions, resulting in high response probability ($> .80$) and were therefore excluded from the analyses. The final sample consisted of 34 participants (17 in the high load condition). The mean age of the participants was 24.23 (*SE*=1.17). Twenty of the participants were female (9 in the no load and 11 in the high load condition). The population means of the two load groups did not significantly differ on a range of relevant demographic and cognitive variables, including as age, WM span (digit span forward), depression, anxiety, and stress levels, ts< 1.06, ps$> .29$.

3.1.2. Design

Experiment 2 involved a (2 × 2 × 2) × 2 fully factorial mixed design. The three within-subjects factors were OD (Low vs. High), cue (Action vs. Context), and contingency (zero vs. positive) and the between-subjects factor was WM load (no load vs. high load). We also controlled for the contingency order (zero first vs. positive first) in the analyses (Marsh & Ahn, 2006). The same task instructions were used as of Experiment 1. In each group, participants were exposed to zero and positive contingencies with low and high OD levels resulting in four conditions (i.e., Zero contingency-Low OD and High OD, Positive contingency-Low OD and High OD). Each condition took place in a unique virtual room. The task order was counterbalanced using combinations of the four conditions.

3.1.3. Materials and Procedure

Details are the same as Experiment 1, except that in the positive contingency conditions participants were exposed to $\Delta P = .50$, low and high OD schedules [P(O)= .25 and .75, see Msetfi, Murphy, & Simpson, 2007 for the pre-programmed contingencies, assuming a response probability of .5).

3.2. Results and Discussion

Participants judged zero and positive contingencies with low and high levels of OD. Visual inspection of the results revealed that two groups were able to discriminate zero and positive contingencies but that WM load appeared to have reduced the size OD effect on action judgements (Figure 2).

PLEASE INSERT FIGURE 2 AROUND HERE

The results showed a significant main effects of OD, $F(1, 30) = 30.96$, $p < .001$, $\eta_p^2 = .51$, $CI_{.90}$ for η_p^2 [.265, .626], contingency, $F(1, 30) = 12.79$, $p = .001$, $\eta_p^2 = .30$, $CI_{.90}$ for η_p^2

[.082, .458], and cue, $F(1, 30)= 5.27$, $p= .029$, $\eta_p^2= .15$, $CI_{.90}$ for η_p^2 [.008, .319]. There was a significant two-way interaction between cue and contingency, $F(1, 30)= 13.89$, $p< .001$, $\eta_p^2= .32$, $CI_{.90}$ for η_p^2 [.094, .473], and a significant three-way interaction between OD, cue, and WM load, $F(1, 30)= 4.44$, $p= .044$, $\eta_p^2= .13$, $CI_{.90}$ for η_p^2 [.002, .297]. None of the other effects were significant (Table 4).

PLEASE INSERT TABLE 4 AROUND HERE

We then carried out simple effects analyses in order to understand the interaction terms. The findings showed a significant effect of contingency for action judgements, $F(1, 30)= 30.51$, $p< .001$, $\eta_p^2= .50$, $CI_{.90}$ for η_p^2 [.261, .623], but not for context judgements, $F<1$. This means that as we expected the participants' action judgements reflected different levels of contingencies tested. In terms of the three-way interaction between OD, cue, and WM load, the findings showed significant OD effects for action and context judgements in the no load group, $F(1, 30)= 16.92$, $p<.001$, $\eta_p^2= .36$, $CI_{.90}$ for η_p^2[.127, .510], and $F(1, 30)= 7.28$, $p= .011$, $\eta_p^2= .20$, $CI_{.90}$ for η_p^2 [.205, .365], respectively. There was a significant OD effect on context judgements in the high load group, $F(1, 30)= 15.80$, $p= .001$, $\eta_p^2= .35$, $CI_{.90}$ for η_p^2 [.115, .497] but not on action judgements, $F(1, 30)= 2.25$, $p= .146$, $\eta_p^2= .07$, $CI_{.90}$ for η_p^2 [0, .227]. In sum, OD effects were significantly reduced for action ratings in the high load condition as compared to the no load condition.

As in Experiment 1, we analysed whether two groups experienced different levels of ΔP_{EXP}, response probabilities, and RTs to the contingency task due to WM load. In both groups, the mean ΔP_{EXP} approximated the pre-programmed contingencies in zero and positive contingency conditions (see Table 4). We carried out a repeated measures analysis to control whether there was a difference in experienced contingencies. The within-groups factor was contingency (zero vs. positive), and the between groups factor was condition (no load vs. high load). There was a significant main effect of contingency manipulation on experienced contingencies, $F(1, 32)$= 196.464, p= <.001, η_p^2= .95, $CI_{.90}$ for η_p^2 [.759, .897], but not a significant interaction between contingency and condition, F< 1. Overall response probabilities were similar between the load groups, (Ms = .54, SEs= .02), F< 1. We also analysed whether there were differences in RTs to the key press trials of the contingency learning task. Average RTs of both groups were within the allowed interval (i.e., <3000ms). Participants in the high load condition had slower RTs (M= 1188ms, SE= 55ms) to the task trials compared to the participants in the no load condition (M= 925ms, SE= 61ms), $F(1, 29)$= 10.22, p= .003, η_p^2= .26, $CI_{.90}$ for η_p^2 [.055, .418].

In Experiment 2, we tested whether WM load during the ITIs influenced OD effects and contingency sensitivity. The findings showed that WM load did not influence contingency sensitivity, such that participants under high WM load could still discriminate between zero and positive contingency conditions. This confirms that the WM load effect is not simply due to task difficulty. Similar to the findings of Experiment 1, the OD effect was reduced in zero and positive contingency conditions.

4. General discussion

In two experiments, we tested whether available WM capacity during the ITIs of an operant contingency learning task plays an important role in OD effects and perception of control. Our findings have shown that OD effects were reduced under cognitive load during the ITIs (Experiment 1 and 2), and yet the participants' ratings of control were still sensitive to different levels of contingencies (Experiment 2). Thus, the findings reported here support the hypothesis that increasing WM load during contingency learning results in reduced OD effects. We had also hypothesised that high WM load during ITIs would use up limited cognitive capacity and impact contextual learning. It was this mechanism, we reasoned, that would cause the reduction in the size of OD effects. The participants' action ratings were consistent with these predictions. For example, WM load effects on action ratings were expected to be the most prominent in the high OD conditions. The results from Experiment 1 and 2 were consistent with this prediction such that action ratings mostly differed in high OD conditions. Generally, these findings are consistent with previous work suggesting that OD effects on contingency learning is influenced by learning of contextual information present during ITIs (e.g., Msetfi, Murphy, Simpson & Kornbrot, 2005), and provide important insights into puzzling phenomena, such as illusory control and depressive realism effects (e.g., Alloy & Abramson, 1979; Msetfi, Murphy, Simpson & Kornbrot, 2005), which might be influenced by available cognitive resources to process contextual information. In the remainder of our discussion, we will first focus on the OD effects on action and context ratings and associative learning theory explanations for these effects, and then the limitations of our study as well as future directions.

Human judgements of control systematically deviate from ΔP when OD is manipulated (Allan & Jenkins, 1983). These deviations observed in human contingency learning can be simulated by a non-normative account, in which one treats the contingency events unequally salient and associable (e.g., Dickinson, Shanks, & Evenden, 1984; Shanks, 1985; Shanks, Lopez, Darby, & Dickinson, 1996; Wasserman et al., 1993). For example, when absence of the outcome is considered to be more salient than its presence, the associative learning model (e.g., Rescorla & Wagner, 1972) can predict OD effects (Shanks, Lopez, Darby, & Dickinson, 1996). However, one could also explain deviations on the grounds of cue-competition while maintaining normative assumptions. For example, Msetfi et al.'s (2005) simulations show that when ITIs are considered no action-no outcome trials, the Rescorla-Wagner model can account for OD effects without any parameter manipulation.

Associative learning theory assumes that associations develop between cues (action and context) and outcomes after repeated pairings. The Rescorla-Wagner model (Rescorla &

Wagner, 1972) is an exemplar model of associative learning that has frequently been applied to human operant contingency learning (Blanco & Matute, 2014; Dickinson, Shanks, & Evenden, 1984; Msetfi, Murphy, Simpson & Kornbrot, 2005). In this model, an error correction algorithm governs the change in associative strength on any given trial

$$\Delta V = \alpha\beta(\lambda - \sum V) \qquad [1]$$

In Equation 1, ΔV represents the trial-by-trial change in predictive strength, α represents salience of cue, β represents outcome associability, and λ represents the maximum associative strength that can be carried by the model, with a value of 1 for outcome occurrence and 0 for outcome non-occurrence. The Rescorla-Wagner model can treat context as a discrete cue that can enter into associative relations with the outcome, and, due to summation of the associative strength of all cues present during a trial (e.g., $\sum V = V_{Action} + V_{Context}$), the model predicts competition between action and context in the acquisition and extinction of associations with the outcome (i.e., cue-competition). This leads the associative strength for action to converge with ΔP at the end of learning (Chapman & Robbins, 1990). Hence, the Rescorla-Wagner model does not predict OD effects for action asymptotically (however, see Allan, 1993 for pre-asymptotic OD effects the model predicts).

On the other hand, the Rescorla-Wagner model always predicts OD effects for context-outcome associations at the end of learning (see Allan, 1993 and Msetfi, Murphy, Simpson & Kornbrot, 2005 for simulations). Consistent with these prediction and previous findings (e.g., Byrom, Msetfi, & Murphy, 2015; Chase et al., 2011; Reed, 2015; Msetfi, Brosnan, & Cavus, 2016), here we found a significant OD effect on context ratings in Experiment 2, as well as in the combined data set (Experiment 1 and 2), F (1, 64)= 16.337, p<.001 , η_p^2= .20 ,$CI_{.90}$ for η_p^2 [.071, .329], although this effect was not significant in Experiment 1, possibly due to low statistical power. However, if context-outcome associations are somewhat decreased due to additional context-no outcome information (i.e., cell ‘d’) occurring during the ITIs, the action can gain additional associative strength particularly when OD is high (Msetfi, Murphy, Simpson & Kornbrot, 2005). We could hence speculate that high WM load during the ITIs might have interfered with the ability of the action-outcome association to gain additional associative strength. While it might not be straightforward to map judgements of control onto associative strength, the Pearson’s correlations between action and context ratings in our data set resembled asymptotic predictions of the Rescorla-Wagner model in terms of the relation between action and context ratings (Table 6). That is, in the no load condition action and context ratings were positively and significantly correlated in zero contingency high OD condition, suggesting that cue-competition was either absent or incomplete (see Byrom, Msetfi, & Murphy, 2015 and Reid, 2015 for similar findings). On the other hand, in the high load condition action and context ratings were negatively correlated, albeit non-significantly. It should be noted that findings from previous animal learning research have also suggested that cue-competition might not always occur to the same degree that the Rescorla-Wagner model predicts (e.g., Rescorla, 2000), and whether available cognitive resources impact cue-competition and human contingency learning remains to be investigated in future research more comprehensively.

PLEASE INSERT TABLE 6 AROUND HERE

4.1. Limitations and future directions

A possibility we also addressed was that WM load might have influenced OD effects by eliminating people's ability to learn about contingencies in general, due to increased task difficulty. However, we excluded this possibility as Experiment 2 clearly showed that participants were sensitive to different levels of contingency under WM load. This suggests that reduced OD effects in the high load condition were not due to impaired learning of contingencies in general. Another possibility we should acknowledge is that due to increased cognitive load specific to the ITIs, these periods may actually constitute a unique context in the high WM load condition and this does not necessarily affect the action-outcome contingency, which occurs in a different context (e.g., without increased cognitive load). Similarly, one could argue that increased WM load during the idle task periods represent unique internal 'coding responses' (Estes, 1976). However, any additional cues (context with load or internal coding) would be predicted to dilute the associative strength available to the original context, thus increasing the strength of the action (see arguments presented by Shanks, 1989 and Hammond & Weinberg, 1984), which is not the case in the present study. On the other hand, increased WM load might impact selective attention to contextual information present during the ITIs (Msetfi, Brosnan, & Cavus, 2016), which seems to be a more likely explanation for the current findings. One further limitation of our study is that we did not manipulate the temporal location of WM load. Thus, we cannot fully rule out whether the effects were specific to increased cognitive load during the ITIs or in general.

Whilst acknowledging these limitations, we note that our WM manipulation did not interfere with the overall response probability or experienced contingency, thus ruling out these factors as potential explanations to the current findings. However, the findings from both experiments did indicate that the WM load resulted in slowed down responses within the allowed interval. Slowed down responses in a discrete trial procedure actually produce greater contiguity between action and outcome and might be predicted to produce increased judgements of control in a free-operant task (e.g., Shanks, Pearson, & Dickinson, 1989). On the contrary, participants in the high load group perceived less control in our study. It should be noted that in our study the average RT difference between the no load and high load groups was small (< 200ms). Moreover, evidence elsewhere also suggests that ITI effects are not induced by changes in the temporal contiguity between action and outcome in discrete-trial operant contingency learning tasks (Msetfi, Murphy, Simpson, & Kornbrot, 2005). Thus, taken together, the current findings support the hypothesis that high load compromised the cognitive resources allocated to learning of contextual relations during the idle task periods (i.e., ITIs).

5. Conclusions

It has been suggested that low expectations of control might be related to accurate judgements of control, while apparent illusions of control due to OD bias in zero contingency situations have been related to optimism and inaccuracy in people who are non-depressed (Alloy & Abramson, 1988). Similar to previous work (e.g., Msetfi, Murphy, Simpson & Kornbrot, 2005; Msetfi, Wade, & Murphy, 2013), the evidence from this work suggests that available cognitive resources to process contextual information within idle task periods between the trials might result in overestimated levels of perceived control in high OD conditions. On the other hand, limited cognitive capacity to incorporate additional contextual information during these periods might relate to decreased levels of perceived control. These findings might have implications for the contextual learning process in healthy as well as depressed individuals. For example, there may be consequences to information overload, say from social media and frequent electronic alerts and communications (e.g., Himma, 2007), as well as cognitive ergonomics that are so far unanticipated in terms of consequences to cognitive capacity. Our findings also have implications for understanding the psychological consequences of therapeutic approaches to depression, which involve cognitive training, such as cognitive remediation therapy (e.g., Bowie, Gupta, & Holshausen, 2013).

References

Ackermann, R., & DeRubeis, R. J. (1991). Is depressive realism real?. *Clinical Psychology Review*, *11*(5), 565–584.

Allan , L. G. (1980). A note on measurement of contingency between two binary variables in judgement tasks. *Bulletin of Psychonomic Society, 15*, 147–149.

Allan, L. G. (1993). Human contingency judgments: Rule based or associative?. *Psychological Bulletin*, *114*(3), 435.

Allan, L. G., & Jenkins, H. M. (1983). The effects of representations of binary variables on judgment of influence. *Learning and Motivation, 14*, 381–405.

Allan, L. G., Hannah, S. D., Crump, M. J., & Siegel, S. (2008). The psychophysics of contingency assessment. *Journal of Experimental Psychology: General*, *137*(2), 226.

Allan, L.G., Siegel, S. & Hannah, S. (2007). The sad truth about depressive realism. *The Quarterly Journal of Experimental Psychology, 60*, 482–495.

Alloy, L. B., & Abramson, L. Y. (1979). Judgment of contingency in depressed and non-depressed students: Sadder but wiser? *Journal of Experimental Psychology: General, 108*, 41–485.

Alloy, L. B., & Abramson, L. Y. (1988). Depressive realism: Four theoretical perspectives. In L. B. Alloy (Ed.), *Cognitive processes in depression* (pp. 223–265). New York: Guilford Press.

Baddeley, A. (1992). Working memory. *Science*, *255*(5044), 556-559.

Baddeley, A. (1996). The fractionation of working memory. *Proceedings of the National Academy of Sciences*, *93*(24), 13468-13472.

Baguley, T. (2012). Calculating and graphing within-subject confidence intervals for ANOVA. *Behavior research methods*, *44*(1), 158-175.

Balsam, P., & Tomie, A. (2014). *Context and learning*. Psychology Press.

Beck, A. T., Ward, C. H., Mendelson, M., Mock, J., & Erbaugh, J. K. (1961). An inventory for measuring depression. *Archives of general psychiatry*, *4*, 561–571.

Benassi, V. A., & Mahler, H. I. (1985). Contingency judgments by depressed college students: Sadder but not always wiser. *Journal of Personality and Social Psychology,* 49, 1323–1329.

Blanco, F., & Matute, H. (2014). Exploring the Factors That Encourage the Illusions of Control: The Case of Preventive Illusions. *Experimental Psychology*, *62*(2), 131-42.

Blanco, F., Matute, H., & Vadillo, M. A. (2012). Mediating role of activity level in the depressive realism effect. *PloS One, 7* (9): e46203.

Bouton, M. E., & King, D. A. (1983). Contextual control of the extinction of conditioned fear: tests for the associative value of the context. *Journal of Experimental Psychology: Animal Behavior Processes*, *9*(3), 248.

Bowie, C. R., Gupta, M., & Holshausen, K. (2013). Cognitive remediation therapy for mood disorders: rationale, early evidence, and future directions. *Canadian journal of psychiatry*. *Revue canadienne de psychiatrie*, *58*(6), 319-325.

Byrom, N. C., Msetfi, R. M., & Murphy, R. A. (2015). Two pathways to causal control: use and availability of information in the environment in people with and without signs of depression. *Acta psychologica*, *157*, 1-12.

Chapman, G. B., & Robbins, S. J. (1990). Cue interaction in human contingency judgment. *Memory & Cognition*, *18*(5), 537-545.

Chase, H. W., Crockett, M. J., Msetfi, R. M., Murphy, R. A., Clark, L., Sahakian, B. J., & Robbins, T. W. (2011). 5-HT modulation by acute tryptophan depletion of human instrumental contingency judgements. *Psychopharmacology*, *213*(2-3), 615-623.

Clark, D. A., Beck, A. T., & Alford, B. A. (1999). *Scientific foundations of cognitive theory and therapy of depression*. New York: John Wiley and Sons.

De Houwer, J., & Beckers, T. (2003). Secondary task difficulty modulates forward blocking in human contingency learning. *Quarterly Journal of Experimental Psychology Section B*, *56*, 345–357.

DeCaro, M. S., Thomas, R. D., & Beilock, S. L. (2008). Individual differences in category learning: Sometimes less working memory capacity is better than more. *Cognition*, *107*(1), 284-294.

Dickinson, A., Shanks, D., & Evenden, J. (1984). Judgement of act-outcome contingency: The role of selective attribution. *The Quarterly Journal of Experimental Psychology*, *36*(1), 29-50.

Dobson, K., & Franche, R. L. (1989). A conceptual and empirical review of the depressive realism hypothesis. *Canadian Journal of Behavioural Science/Revue canadienne des sciences du comportement*, *21*(4), 419.

Engle, R. W. (2002). Working memory capacity as executive attention. *Current directions in psychological science*, *11*(1), 19-23.

Engle, R. W., & Kane, M. J. (2004). Executive attention, working memory capacity, and a two-factor theory of cognitive control. *Psychology of learning and motivation*, *44*, 145-200.

Estes, W. K. (1976). The cognitive side of probability learning. *Psychological Review*, *83*(1), 37.

Hammond, L. J., & Weinberg, M. (1984). Signaling unearned reinforcers removes the suppression produced by a zero correlation in an operant paradigm. *Animal Learning & Behavior*, *12*(4), 371-377.

Harvey, A., Watkins, E., Mansell, W., & Shafran, R. (2004). *Cognitive behavioural processes across psychological disorders: A transdiagnostic approach to research and treatment*. New York: Oxford University Press.

Himma, K. E. (2007). The concept of information overload: A preliminary step in understanding the nature of a harmful information-related condition. *Ethics and Information Technology, 9*(4), 259-272.

Jenkins, H. M., & Ward, W. C. (1965). Judgment of contingency between responses and outcomes. *Psychological Monographs: General and Applied*, *79*(1), 1.

Kamin, L. J. (1969). Predictability, surprise, attention, and conditioning. *Punishment and aversive behavior*, 279-296.

Kattner, F., & Green, C. S. (2015). Cue competition in evaluative conditioning as a function of the learning process. *Acta Psychologica*, *162*, 40-50.

Langer, E. J. (1975). The illusion of control. *Journal of personality and social psychology*, *32*(2), 311.

Le Pelley, M. E., Oakeshott, S. M., & McLaren, I. P. (2005). Blocking and unblocking in human causal learning. *Journal of Experimental Psychology: Animal Behavior Processes*, *31*(1), 56-70.

Lezak, M. D. (1995). Neuropsychological assessment (3rd ed.). New York: Oxford University Press.

Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. *Behaviour research and therapy*, *33*, 335–343.

Maren, S., Phan, K. L., & Liberzon, I. (2013). The contextual brain: implications for fear conditioning, extinction and psychopathology. *Nature Reviews Neuroscience*, *14*(6), 417-428.

Marsh, J. K., & Ahn, W. K. (2006). Order effects in contingency learning: The role of task complexity. *Memory & cognition*, *34*(3), 568-576.

Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T., & Macrae, C.N. (2007).Wandering minds: the default network and stimulus-independent thought. *Science, 315*, 393–5.

Matute, H. (1996). Illusion of control: Detecting response-outcome independence in analytic but not in naturalistic conditions. *Psychological Science, 7*, 289–293.

Metcalfe, J., Van Snellenberg, J. X., DeRosse, P., Balsam, P., & Malhotra, A. K. (2014). Judgments of agency in schizophrenia: an impairment in autonoetic metacognition. In *The Cognitive Neuroscience of Metacognition* (pp. 367-387). Springer Berlin Heidelberg.

Moore, M. T., & Fresco, D. M. (2012). Depressive realism: a meta-analytic review. *Clinical psychology review*, *32*(6), 496-509.

Msetfi, R. M., Brosnan, L., & Cavus, H. A. (2016). Enhanced Attention to Context: An Intervention which Increases Perceived Control in Mild Depression. *The Quarterly Journal of Experimental Psychology*, (just-accepted), 1-42.

Msetfi, R. M., Murphy, R. A., & Simpson, J. (2007). Depressive realism and the effect of intertrial interval on judgments of zero, positive, and negative contingencies. *The Quarterly Journal of Experimental Psychology, 60*, 461–481.

Msetfi, R. M., Murphy, R. A., Simpson, J., & Kornbrot, D. E. (2005). Depressive realism and outcome density bias in contingency judgments: the effect of the context and intertrial interval. *Journal of Experimental Psychology: General*, *134*(1), 10.

Msetfi, R.M., Wade, C. & Murphy (2013). Context and time in causal learning: Contingency and mood dependent effects. *PloS One, 8* (5): e64063.

Nolen-Hoeksema, S. (1991). Responses to depression and their effects on the duration of depressive episodes. *Journal of abnormal psychology*, *100*(4), 569.

Nolen-Hoeksema, S., Wisco, B. E., & Lyubomirsky, S. (2008). Rethinking rumination. *Perspectives on psychological science*, *3*(5), 400-424.

Otto, A. R., Gershman, S. J., Markman, A. B., & Daw, N. D. (2013). The curse of planning dissecting multiple reinforcement-learning systems by taxing the central executive. *Psychological science*, 0956797612463080.

Pearce, J. M., & Hall, G. (1980). A model for Pavlovian learning: variations in the effectiveness of conditioned but not of unconditioned stimuli. *Psychological review*, *87*(6), 532.

Reed, P. (2015). Response-independent outcomes impact response rates and judgments of control differentially depending on rate of response-dependent outcomes. *Learning & Behavior* 43(3), 301-311.

Rescorla, R. A. (2000). Associative changes in excitors and inhibitors differ when they are conditioned in compound. *Journal of Experimental Psychology: Animal Behavior Processes*, *26*(4), 428.

Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. *Classical conditioning II: Current research and theory*, *2*, 64-99.

Reuven-Magril, O., Dar, R., & Liberman, N. (2008). Illusion of control and behavioral control attempts in obsessive-compulsive disorder. *Journal of Abnormal Psychology*, *117*(2), 334.

Shanks, D. R. (1989). Selectional processes in causality judgment. *Memory & Cognition*, *17*(1), 27-34.

Shanks, D. R., Lopez, F. J., Darby, R. J., & Dickinson, A. (1996). Distinguishing associative and probabilistic contrast theories of human contingency judgment. *Psychology of learning and motivation*, *34*, 265-311.

Shanks, D. R., Pearson, S. M., & Dickinson, A. (1989). Temporal contiguity and the judgement of causality by human subjects. *The Quarterly Journal of Experimental Psychology*, *41*(2), 139-159.

Skinner, E. A. (1996). A guide to constructs of control. *Journal of personality and social psychology*, *71*(3), 549.

Taylor, S. E., & Brown, J. D. (1988). Illusion and Well-Being–a Social Psychological Perspective On Mental-Health. *Psychological Bulletin, 103*, 193–210.

Tharp, I. J., & Pickering, A. D. (2009). A note on DeCaro, Thomas, and Beilock (2008): Further data demonstrate complexities in the assessment of information–integration category learning. *Cognition*, *111*(3), 410-414.

Vázquez, C. (1987). Judgment of contingency: Cognitive biases in depressed and non-depressed subjects. *Journal of Personality and Social Psychology, 52*, 419–431.

Veltman, D. J., Rombouts, S. A., & Dolan, R. J. (2003). Maintenance versus manipulation in verbal working memory revisited: an fMRI study. *Neuroimage*, *18*(2), 247-256.

Wagner, A. R. (1978). Expectancies and the priming of STM. *Cognitive processes in animal behavior*, 177-209.

Wagner, A. R. (1981). SOP: A model of automatic memory processing in animal behavior. *Information processing in animals: Memory mechanisms*, *85*, 5-44.

Wasserman, E. A., Elek, S. M., Chatlosh, D. L., & Baker, A. G. (1993). Rating causal relations: Role of probability in judgments of response-outcome contingency. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*(1), 174.

Wills, A. J., Graham, S., Koh, Z., McLaren, I. P., & Rolland, M. D. (2011). Effects of concurrent load on feature-and rule-based generalization in human contingency learning. *Journal of Experimental Psychology: Animal Behavior Processes*, *37*(3), 308.

Wills, A.J., Barrasin, T. J., & McLaren, I. P. L. (2011). WM Capacity and Generalization in Predictive Learning. In L. Carlson, C. Hölscher, & T. Shipley (Eds.), *Proceedings of the 33rd Annual Conference of the Cognitive Science Society* (pp. 3205-3210). Austin, TX: Cognitive Science Society.

Acknowledgements

The authors declare no competing financial interests or benefit arising from the direct applications of this research.

Table 1

The standard 2 × 2 operant contingency table and zero contingency high and low outcome density conditions, assuming a response rate of .5.

	Outcome		P(O|A)	P(O|~A)	P(O)	ΔP
Action	Present (O)	Absent (~O)				
	Generic information					
Present (A)	a	b	a / (a + b)	c / (c + d)	(a + c) / N	a / (a + b) − c / (c + d)
Absent (~A)	c	d				
	High OD zero contingency					
Present (A)	15	5	.75	.75	.75	0
Absent (~A)	15	5				
	Low OD zero contingency					
Present (A)	5	15	.25	.25	.25	0
Absent (~A)	5	15				

Notes. The letters in the cells (a, b, c, and d) represent the frequency of co-occurrences and non-co-occurrences of an Action (A) and an Outcome (O). Contingency= ΔP= P(O|A) − P(O|~A). Outcome density (OD) is the probability of outcome to occur and is calculated as P(O)= (a + c) / N, where N is the total number of the events.

Table 2

Mean percentage of incorrect responses to the Working Memory component

	Experiment 1	Experiment 2
Forward	10.26 (3.50)	11.70 (1.58)
Backward	29.57 (5.75)	22.46 (4.67)

Note. Standard errors of the mean are given in parentheses.

Table 3

Analysis of Variance for the Judgements of Control Data in Experiment 1

Source	*F*	*p*	η_p^2	*CI*s around η_p^2 [Lower bound, Upper bound]
OD	9.696	.004	.233	[.049, .409]
OD × WM load	.853	.363	.026	[0, .162]
Cue	.075	.786	.002	[0, .08]
Cue × WM load	.243	.626	.008	[0, .113]
OD × Cue	.089	.767	.003	[0, .085]
OD × Cue × WM load	4.390	.044	.121	[.002, .295]

Notes. *df*s= 1, OD= Outcome density, WM= Working memory

Table 4

Mean experienced contingencies and response rates in Experiment 1 and 2

	Experienced contingency (ΔP_{EXP})				Response rates			
	No WM load		High WM load		No WM load		High WM load	
	Range	Mean (*SE*)	Range	Mean (*SE*)	Range	Mean (*SE*)	Range	Mean (*SE*)
Experiment 1								
Low OD (zero contingency)	−.32-.22	.02 (.04)	−.28-.38	.05 (.04)	.45-.80	.60 (.03)	.48-.75	.62 (.02)
High OD (zero contingency)	−.27-.29	.02 (.04)	−.25-.29	−.01 (.04)	.48-.68	.55 (.02)	.35-.68	.53 (.02)
Experiment 2								
Low OD (zero contingency)	−.30-.33	.02 (.05)	−.18-.48	.03 (.04)	.40-.78	.56 (.02)	.38-.78	.58 (.03)
High OD (zero contingency)	−.25-.17	.02 (.03)	−.23-.29	.03 (.03)	.35-.70	.52 (.02)	.20-.70	.51 (.03)
Low OD (positive contingency)	.38-.80	.56 (.02)	.35-.81	.56 (.03)	.35-.78	.59 (.03)	.38-.75	.59 (.03)
High OD (positive contingency)	.35-.86	.52 (.04)	.29-.68	.49 (.03)	.43-.60	.51 (.01)	.33-.63	.49 (.02)

Note. OD= Outcome density, *SE*= Standard error of the mean

Table 5

Analysis of Variance for the Judgements of Control Data in Experiment 2

Source	*F*	*p*	η_p^2	*CI*s around η_p^2 [Lower bound, Upper bound]
OD	30.962	< .001	.508	[.268, .625]
OD × WM load	.080	.779	.003	[0, .082]
Cue	5.266	.029	.149	[.008, .318]
Cue × WM load	2.237	.145	.069	[0, .227]
Contingency	12.788	.001	.299	[.082, .457]
Contingency × WM load	.048	.828	.002	[0, .068]
Cue × Contingency	13.887	.001	.316	[.094, .472]
Cue × Contingency × WM load	.036	.852	.001	[0, .061]
Cue × OD	2.463	.127	.076	[0, .235]
Cue × OD × WM load	4.440	.044	.129	[.002, .297]
Contingency × OD	.246	.623	.008	[0, .114]
Contingency × OD × WM load	.098	.756	.003	[0, .087]
Cue × Contingency × OD	.821	.372	.027	[0, .161]
Cue × Contingency × OD × WM load	.847	.365	.027	[0, .162]

Notes. *df*s= 1, OD= Outcome density, WM= Working memory

Table 6

Pearson's correlations between action and context ratings in zero and positive contingency high and no Working Memory load conditions, with low and high outcome density

	No WM load		High WM load	
	Low OD	High OD	Low OD	High OD
Zero contingency (*N*=68)	**−.34***	**.43***	−.29	−.23
Positive contingency (*N*=34)	.20	.31	−.15	.42

Notes. *p< .05, OD= Outcome density, WM= Working memory

Figure captions

Figure 1. Mean judgements of action (Act) and context (Cxt) control in low and high OD conditions for the no load (on the left side) and the high load (on the right side) groups in zero contingency. Outcome density is the probability of music playing in each room. The outer tier of the error bars depicts a 95% CI for individual mean, while the inner tier is a difference-adjusted Cousineau–Morey interval (Baguley, 2012).

Figure 2. Mean judgements of action (Act) and context (Cxt) control in low and high outcome density conditions for the no load (on the left side) and the high load (on the right side) groups in zero (Zero) and positive (Pos) contingencies. For the error bars, see the previous figure.

Appendix A

Wording for the judgements of control scales

We would now like you to make some judgements about how much control there was over the music switching on in this particular room. You can make these judgements by using the slider below.

If you think that, when you press the button, you have total control over the music coming on, move the slider to the totally control end. If you think that by pressing the button you totally prevent or interfere with the music switching on, move the slider to the totally prevent end. Or you might think that your button pressing has no influence over the music coming on, then put the slider in the middle. Putting the slider nearer to the totally control end means MORE control, while putting it nearer to the totally prevent end means that your pressing the button interferes or prevents the music from switching on to some degree.

SLIDER APPEARS HERE (−100 totally prevent to 100 totally control)

To what extent do you think that the music switched on in THIS PARTICULAR room, irrespective of whether you pressed the remote control button or not? If something about this particular room seemed to control the music switching on, move the slider nearer to the totally control end. If something about this particular room seemed to prevent the music from switching on, move the slider nearer to the totally prevent end. Put the slider in the middle if whether you were in this particular room or not made no difference to the music switching on. Make your judgements on the slider shown below:

SLIDER APPEARS HERE (−100 totally prevent to 100 totally control)

Appendix B

Dual task instructions

In this task, you will be taken into several different rooms in a house. The rooms will look similar to the one shown below:

ROOM PICTURE APPEARS HERE

All of the rooms contain hidden speakers, which are connected to the house stereo system. A small remote control is available, in order to allow the residents of the house to listen to music in whichever room they are in. The remote control has a button, which can be used to switch the music on. You will see the remote control on the screen when you are taken into the rooms. You should be able to control the music switching on in the rooms by pressing the music button using the space-bar key on the keyboard. However, the residents of the house think that there may be a problem with the wiring of the stereo system in the rooms and your task here is to test whether you can control the music switching on in each of the rooms in the house. In order to do this, you will have to test the remote control in each of the rooms. We have put a short music clip on the CD in the stereo, which you can try to play using the remote control. When the test starts, you will be taken to the first room and you should wait until you hear a beep sound and an on-screen message tells you that you are allowed to press the music button. You will be allowed to press and test the button in that room on numerous occasions before deciding whether you can control the music switching on. However, you are only allowed to press the button after you hear the beep sound and when you see the onscreen message. When you have finished testing the remote control in one room, you will be taken to the next room to start the next test. When you are allowed to press the button in one of the rooms, the remote control will look like the one shown below, and you will be able to press it using the SPACEBAR key on the computer keyboard.

REMOTE CONTROL PICTURE APPEARS HERE

When you have pressed the button, the music will either switch on for a short period of time or it will remain off. You must then wait for your next opportunity to press one of the buttons. Some of the residents of the house have reported that the music sometimes switches on when no one is using the remote control. So in order to conduct the test properly, on approximately half of the occasions when you are told that you can press the button, you should NOT PRESS it and see what happens. While you are doing this task a cross (+), random letters, arrows and numbers will appear in the white box on top of the screen. These items are not relevant for the purposes of this experiment. You can simply ignore them and concentrate on the music task. About half way through your test in each room, the test will stop and you will be asked to make a judgement about how much control you had over the music switching on in that room. Once you have made that judgement, you will return to the same room and continue the test. Once all of your opportunities to test the button in that room have been used, you will be asked to make your final judgement about how much control you had over the music switching on in that room. When you have done that, you will see a message prompting to start your test in the next room when you are ready. If you have any questions, please ask the experimenter now.

Additional instructions in the high load condition: While you are doing this task, an extra task will appear in the white box on top of the screen. In this box, you will see a little cross (+) appear followed by a 4-letter string (e.g., XHKY). You are required to keep that string in mind, as you will be asked to remember one of the letters in that string shortly. You will then see an arrow (either forward or backwards), and a number will follow indicating which letter in that particular string is asked for you to remember. On the next screen, you will see some examples. Here are some examples:

XHKY

When the arrow is forward (--->) and the following number is 3, you are required to remember the third letter in a forward direction. For the above example, the correct answer would be the letter K. When the arrow is backwards (<---), and the following number is 3, you are required to remember the third letter in a backward direction. For the above example, the correct answer would be the letter H. You need to say your answer out loud as soon as you see the number on the screen. Please try to remember the letter correctly as possible. However, if you cannot remember it, don't worry, you may choose not to give an answer for that particular trial. After that you will hear the beep sound. After that point DO NOT try to remember the letter or give an answer. This is an opportunity to concentrate on the music task until the fixation cross reappears in the white box.

Figure 1

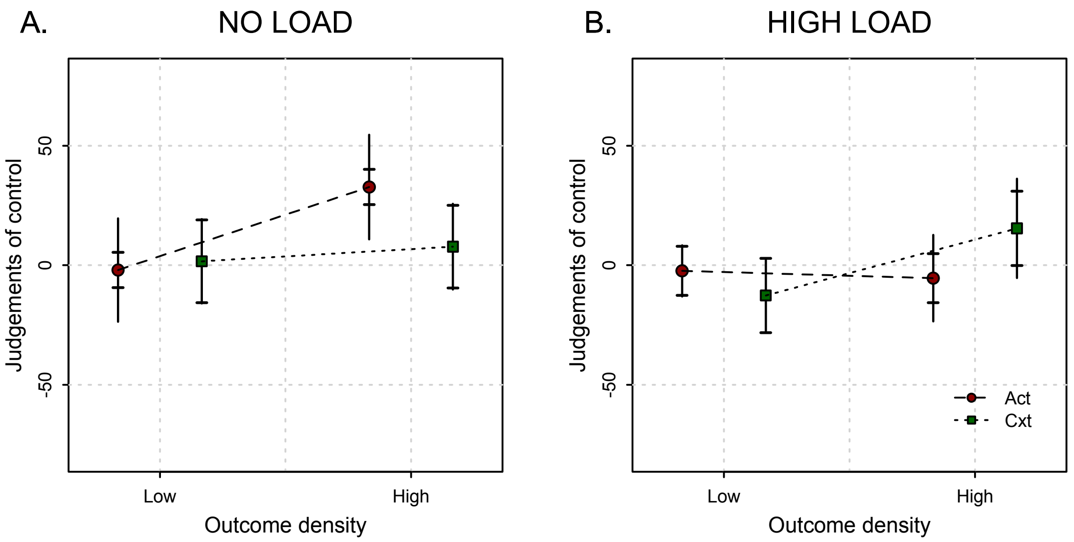
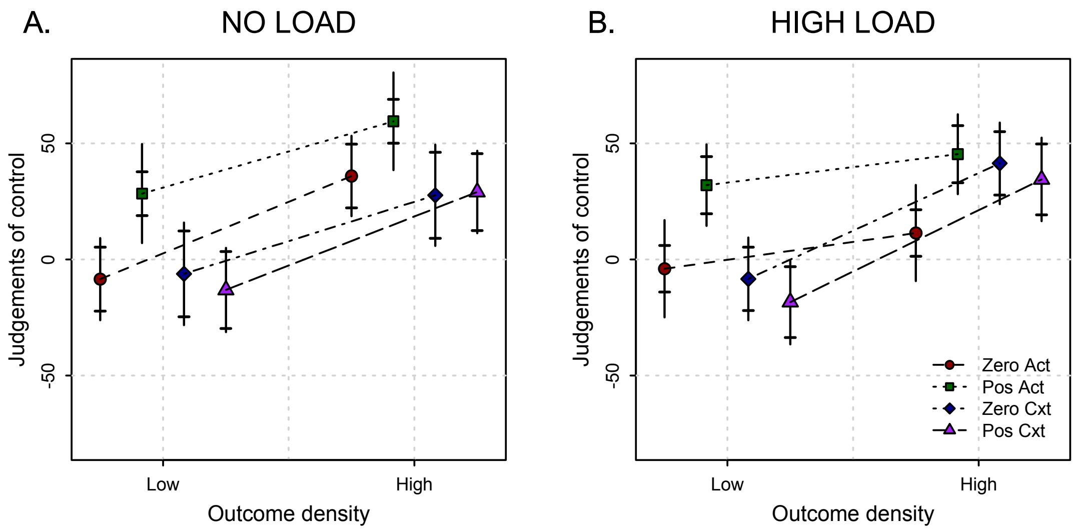

A.
NO LOAD
B.
HIGH LOAD
Judgements of control
50
0
-50
Low
High
Outcome density
Act
Cxt

Figure 2


A.
NO LOAD
B.
HIGH LOAD
Judgements of control
50
0
-50
Low
High
Outcome density
Zero Act
Pos Act
Zero Cxt
Pos Cxt