From outcomes to actions: Fundamental mechanisms in reward seeking
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Appendix B

Appendix to Chapter 8: Disrupting the Pavlovian-to-instrumental transfer effect

In this document we provide brief details of pilot studies referred to in chapter 8.
1. **Introduction**

Cue-elicited responding for outcomes can be examined with the Pavlovian-to-instrumental-transfer (PIT) task. Using this task, Watson and colleagues (2014) first trained participants to associate two keyboard responses with the delivery of popcorn or chocolate Smarties. After this instrumental training phase, they then underwent a separate Pavlovian training phase, learning the relationships between abstract stimuli and these same two food outcomes. Finally in a transfer test, responding for the two food outcomes was assessed both in the presence and absence of the Pavlovian stimuli. Using this and similar tasks, a number of studies have demonstrated that cues previously associated with rewarding outcomes continue to elicit instrumental responses directed towards those outcomes, even when the outcomes are no longer desired (Hogarth, 2012; Hogarth & Chase, 2011; Watson et al., 2014).

These previous studies used motivational manipulations such as satiation and health warnings to devalue outcomes before the test phase and observed that while these manipulations affect baseline preference in the absence of cues (e.g. participants respond more for the non-sated food outcome than the food outcome on which they have been sated), cue-elicited responding appears to be inflexible and persistent (Hogarth, 2012; Hogarth & Chase, 2011; Watson et al., 2014). In the current experiments we attempted to manipulate the properties of the Pavlovian cues (rather than the outcomes) in an attempt to disrupt this cue-elicited responding priming for outcomes. In two experiments, we used the PIT task, exactly as has been published previously (Watson et al., 2014; see Chapter 5), with the exception that we used drink rewards rather than food rewards. Instead of a satiation manipulation participants either underwent a counterconditioning
Pilot studies: Disrupting PIT

Counterconditioning involves the retraining of a Pavlovian cue to be predictive of a now aversive outcome. In animals, this has been seen to disrupt the PIT effect, provided that the number of counterconditioning trials is similar to the number of initial Pavlovian training trials (Delamater, 2012). While this has not previously been examined in a human PIT experiment, a counterconditioning manipulation was seen to reduce chocolate consumption in the presence of the counter-conditioned cue (Van Gucht et al., 2010) and we may expect that after being paired with an aversive outcome, a counter-conditioned cue is less able to trigger responding for the rewarding outcome with which it was (previously) associated. Inhibition training on the other hand involves repeatedly inhibiting a “go” response directed towards a rewarding picture (e.g. chocolate) and has been seen to reduce food and alcohol intake (Houben & Jansen, 2011; Houben et al., 2011; Lawrence, Verbruggen, et al., 2015; Veling et al., 2014). Repeatedly inhibiting “go” responses directed towards abstract cues predictive of reward has not previously been examined but we expected that the invigorating properties of the cue that has been repeatedly associated with “stopping” will be diminished. It is unclear whether pairing cues with aversive outcomes (i.e. counterconditioning) or repeatedly stopping in the presence of cues (i.e. inhibition training) would affect the explicit desire ratings of the outcomes that they predicted, but in the current set of studies we assessed the desire ratings for the two drink outcomes both before and after the manipulations (Experiments 1a and 2a). We also assessed the pleasantness ratings of the Pavlovian cues (CSs) and
expected that both cue manipulations would decrease the pleasantness of the cues (Kerkhof, Vansteeniswen, Baeyens, & Hermans, 2011; Veling et al., 2013a). Our main measure of interest, however, was the effect of the cue manipulations on the PIT effect. We expected that both counterconditioning and inhibition training of one of the cues would diminish the ability of that cue to trigger responding for the outcome it signaled, whilst not having an effect on the baseline response rates (choice during non-cued trials, in the absence of Pavlovian stimuli).

2. Experiment 1a: Counterconditioning

Participants first learned the relationships between two response keys and two drink outcomes – cola and orange juice. In a Pavlovian training phase they then learned the relationship between two CSs (colored patterns) and these same drink outcomes. Before cue-elicited responding was assessed in a transfer test, participants underwent a counterconditioning condition in which they saw repeated presentations of one of the CSs and drank a distasteful liquid. Finally, during the transfer test participants could respond for either drink reward whilst the colored patterns were occasionally presented on screen.

2.1. Methods:

Participants: 24 participants were tested and two participants were excluded for scoring less than 50% chance level on the final instrumental query trials. The final dataset consisted of 22 individuals (14 females) with a mean age of 22.3 years (SD: 3.3 years).
Pilot studies: Disrupting PIT

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<th>1. Instrumental Training</th>
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<tr>
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<td>Right Key →  <em>Soda</em></td>
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<th>2. Pavlovian Training</th>
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<th>3. Counterconditioning OR Go-NoGo task</th>
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<th>4. Transfer Test (intermixed trials):</th>
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| Cued Trials                          |
| ![Diagram](image5)                  |
| Left Key?                            |
| Right Key?                           |

Figure 1: *Procedure of the PIT task*: Outlined for Experiments 1a and 2a. For Experiments 1b and 2b the Pavlovian stimuli were abstract black and white patterns.
Procedure: The procedure can be visualized in Figure 1. The task is as described in Watson et al (2014) but will be briefly outlined below.

Rating Phase T1: Participants were first asked to taste and rate their desire for the two drinks (cola and orange) as well as their thirst. They also rated their hunger before they then ate two plain water crackers and tasted and rated again desire for the two drinks and their thirst.

Instrumental Training: Participants could earn cola and orange juice by pressing on two keyboard keys when a purple box was presented in the center of the screen (the availability window; see Figure 1). One of these two keys was assigned to cola and the other to orange juice (counterbalanced). On each of 24 trials, participants were instructed that only one of the two drink outcomes would be available and that they would have to work out which drink outcome that was by trial and error. They were told to continue trying both keys until they won something – as would be evidenced by the appearance of either a cola or orange juice image on the screen. Participants were told that they should try and learn the relationships between the keys and the drink outcomes and that occasionally they would be tested on what they had learned. A variable ratio schedule of 10, between 5 and 15 key presses, determined the amount of specific key presses needed for the image of the drink outcome available on that trial to appear. Every fourth time that a specific drink image was presented, there was also a ‘ding’ sound signaling that the participant should take one small (5cc) plastic cup of either cola or orange juice, using their non-dominant hand, and consume it immediately. At the end of the second and fourth instrumental blocks, a block of four instrumental query
trials was inserted to test the participants on their knowledge of the relation between the two keys and the two drink outcomes. Feedback (correct/incorrect) was given.

**Rating Phase T2:** Participants rated their thirst both before and after eating two plain water crackers. They also saw the two colored patterns that functioned as Pavlovian stimuli and rated how pleasant they found each one.

**Pavlovian Training:** Participants learned the relationships between two Pavlovian cues (orange and brown patterns; see Figure 1) and the two drink outcomes. Because this study was the first attempt to disrupt PIT via cue-related manipulations, the cues were visually related to the two drink outcomes and as such were not counterbalanced – the orange pattern was always paired with the orange juice and the brown pattern always paired with the cola. During this training phase, participants passively viewed the screen and were not required to make any responses. They were told that they should pay attention because they would be occasionally tested on their knowledge of the relationships between the patterns and the drink outcomes. Every fourth time that a specific drink outcome picture was presented, there was also a ‘ding’ sound signaling that the participant should consume a 5cc plastic cupful of that drink. At the end of the second and fourth block, a block of four Pavlovian query trials was inserted to test the participants on their knowledge of the cue-outcome contingencies. Feedback was provided.

**Rating Phase T3:** Participants saw the two colored patterns that functioned as Pavlovian stimuli and rated how pleasant they found each one.
Counterconditioning: A tray with 12 5cc plastic cups of liquid was placed before each participant. This liquid was a mixture of water and tween 20—a bitter tasting liquid. Participants were instructed to watch the screen and follow the instructions. One of the CS colored patterns was presented 12 times (which CS was seen was counterbalanced across participants). Each CS presentation lasted for 2 seconds and the pattern was then overlaid with the text “Take a sip” for 1 second. The ITI was then 12 seconds long before the same CS was presented again. Each participant saw one of the CS pictures 12 times and never saw the other one. This counterconditioning phase lasted approximately 3 minutes.

Rating Phase T4: Participants were asked to rate how tasty they had found the “new” drink, rated their thirst and rated the pleasantness of each of the two Pavlovian stimuli. Finally they tasted and rated their desire for cola and orange juice.

Transfer Test: Participants then performed the test phase of the PIT task during which they were free to respond on the cola and orange juice keys as often as they liked in order to win these drink outcomes. No drinks were in sight during this phase of the task. At the beginning of the test phase participants received the instruction that while the purple box was on screen (the availability window) they could push on either key as often as they liked in order to win cola or orange juice. They were told that, as before, only one of the two drink outcomes would be available on each trial but that this time they would not be told after each trial what they had won. Instead they would find out at the end of the phase how many cups of orange juice or cola they had earned and they would then drink these,
whilst they filled in questionnaires (nominal extinction). The transfer test consisted of 30 intermixed cued and non-cued trials. During the 10 non-cued trials the purple box was presented. During the 20 cued test trials, one of the Pavlovian cues was presented, overlaid with the purple ‘availability window’ box (see Figure 1). The number of presses on each key was recorded, as was the RT of the first key press. Finally, a block of four instrumental query trials tested whether the participants had remembered the instrumental R-O relationships from the instrumental training session (no feedback was given).

Statistics: Repeated Measures ANOVA was used in all experiments to check whether the manipulations affected pleasantness ratings of the two CS’s with time (before/after manipulation) and CS (nonpaired/paired) as within-subject factors. A similar analysis was conducted on the drink desire ratings for Experiments 1a and 2a with time (beginning of experiment/before transfer test) and CS (nonpaired/paired) as within-subject factors. During the transfer test, mean percentage of responses directed towards each drink was calculated, per trial type (cued/non cued). Baseline preference for the two drinks in the absence of Pavlovian cues (baseline condition) was assessed with one-sample t-test to see whether responding for the drink that was paired with the counterconditioned/stopping CS was significantly different to 50% during no-stimulus trials (where 50% indicates that both keys were sampled equally often). To examine the effect of the CS manipulation on the outcome-specific transfer effect we examined the rate at which the two CSs augmented responding above baseline response rates for the drinks that they signaled. To do this we subtracted the baseline response rates (during the no-stimulus condition) from the percentage of
presses for each drink during trials in which the CS for those outcomes was presented. These values were then compared with a paired-sample t-test.

### 2.2. Results: Experiment 1a (Counterconditioning)

**Preference for drinks:** There was no difference in the desire ratings of the cola (68%, SD: 24%) versus the orange juice (mean: 59%, SD: 28%) at the beginning of the experiment, \( t(21) = 1.4, p = 0.19 \).

**Manipulation Checks:** As expected, participants found the Tween mixture distasteful and rated its tastiness as 4.8% (SD: 7.1%).

For the pleasantness ratings of the two CS’s the analysis revealed the expected interaction between time and counterconditioning, \( F(1,21) = 10.9, p = 0.003 \). Before the manipulation there was no difference in ratings for the two CSs (\( t(21) = 1, p = 0.77 \)), but after the manipulation the counterconditioned CS (CC-CS) was rated as less pleasant than the non-counterconditioned CS (non-CC-CS) \( t(21) = 3.6, p = 0.002 \).

The analysis of the drink desire ratings showed a marginally significant effect of time \( F(1,21) = 3.7, p = 0.068 \), such that after counterconditioning the desire ratings for both drinks had slightly increased, but no other significant results (\( ps>0.39 \)).

**Transfer Test Phase:** The counterconditioning manipulation did not affect baseline response rates and during non-cued trials participants responded on the two keys about equally often (see Figure 2, baseline responding depicted in black). The mean response rate for the drink that had been
paired with the CC-CS was 44% (SD: 21%), which was not significantly less than 50% (1 sample t-test, \( t(21) = 1.3, p = 0.20 \)).

As can be seen in Figure 2, responding for the drink that had been paired with the CC-CS increased 26 percentage points (pp.; SD = 22 pp.) above the baseline rate, when the CC-CS was on screen. This was not significantly different to the augmentation rate of the non-CC-CS (mean = 25 pp.; SD = 30 pp.), \( p = 0.90 \). This suggests that the counterconditioning manipulation, whilst affecting pleasantness of the counterconditioned CS, did not diminish the degree to which that CS triggered responding for the drink outcome it predicts.
Figure 2: **Experiment 1a.** On non-cued (baseline) trials (depicted in black), participants responded about equally often for the drinks that had been paired with the CC and non-CC CS. Each CS increased responding for the drink it signaled (depicted in gray), regardless of whether it had undergone counterconditioning or not. Dotted line at 50% represents responding equally often for the two drink outcomes. Error bars represent standard error of the mean.

3. **Experiment 1b: Counterconditioning**

While the counterconditioning manipulation in Experiment 1a was successful in that people found the Tween mixture distasteful and rated the Tween-paired CS as less pleasant, the counterconditioned CS still augmented responding for the outcome it signaled to the same degree as the non-counterconditioned CS did. It is possible, however, that as participants had the chance to taste and rate the drinks after the counterconditioning phase, motivation for the tasty drinks may have been
high (in contrast to the aversive Tween taste) and this might have overridden any effects of the counterconditioning manipulation. We therefore replicated the study with some important procedural changes.

3.1. Methods

Procedure: In Experiment 1a the Pavlovian CSs were perceptually very similar to the drink outcomes (and not counterbalanced), so in Experiment 1b we used abstract black and white stimuli as the CSs (the CS-outcome relationship was counterbalanced across participants). In addition, we did not give participants a chance to sample the drinks again before the transfer test (T4). All other parts of the procedure were identical.

Participants: 28 participants were tested although one participant experienced technical difficulties and the task had to be stopped. Another was excluded for scoring less than 50% chance level on the final instrumental query trials. The final dataset consisted of 26 individuals (18 females) with a mean age of 22.6 years (SD: 3.4 years).

3.2. Results: Experiment 1b (Counterconditioning)

Preference for drinks: There was no difference in the desire ratings of the cola (65%, SD: 18%) versus the orange juice (mean: 57%, SD: 23%) at the beginning of the experiment, $t(25) = 1.4, p = 0.17$.

Manipulation Checks: Participants found the Tween mixture distasteful, rating the tastiness as 7% (SD: 9%). For the pleasantness ratings for the two CSs the analysis revealed the expected interaction between time and counterconditioning, $F(1,25) = 18.5, p <0.0001$. Before the manipulation there was no difference in ratings for the two CSs ($t(25) = 1.4, p = 0.19$),
after the manipulation the counterconditioned CS was rated as less pleasant
\[ t(25) = 4.0, p = 0.001. \]

**Transfer Test Phase:** Replicating the results of Experiment 1a, participants responded equally often for the two drinks during the baseline (non-cued) trials. The mean response rate for the drink that had been paired with the CC-CS was 50% (SD: 27%).

Responding for the drink that had been paired with the CC-CS increased 23pp. (SD: 28 pp.) above the baseline rate when the CC-CS was on screen. Replicating the results of Experiment 1a, this was not significantly different to the augmentation rate of the non-CC-CS (mean: 18 pp., SD = 28 pp.), \[ t(25) = .68, p = 0.50. \]

4. **Experiment 2a: Inhibition training**

As an alternative approach to counterconditioning we used inhibition training in Experiment 2 in an attempt to reduce the invigorating properties of the Pavlovian cues on responding for the outcome that they signaled. Participants performed a Go-NoGo task (Houben & Jansen, 2011) in which one of the Pavlovian cues was consistently paired with the stopping signal, before they began the transfer test.

4.1. **Methods**

**Procedure:** Experiment 2a was identical to that of Experiment 1a outlined above, but the counterconditioning manipulation was replaced by inhibition training (a Go-NoGo task).
**Go-NoGo Task:** Participants were instructed to push the spacebar every time that they saw an “F” appear in the middle of the screen and to not respond every time that a “P” was shown (half the participants were given the opposite instructions for F and P). They were told to be as fast as possible and that they would receive feedback - a green square for correctly responding/not responding and a red square if an error was made. The F and P were colored white and presented in the middle of the screen in font size 36. The F was always presented against the brown pattern (cola CS). The P was always presented against the orange pattern (orange juice CS). In this way half of the participants repeatedly inhibited responding during the cola CS and the other half inhibited responding during the orange CS. The two CSs were presented twice randomly, a total of 80 times resulting in 320 trials in total. After 160 trials, participants were instructed to take a break. The Go-NoGo task took approximately 7 minutes to complete. All other parts of the procedure were identical.

**Participants:** 20 participants (13 females) with a mean age of 21.3 years (SD: 2.4 years) took part.

**4.2. Results: Experiment 2a (Inhibition training)**

*Preference for drinks:* There was no difference in the desire ratings of the cola (69%, SD: 17%) versus the orange juice (mean: 58%, SD: 20%) at the beginning of the experiment, \( t(19) = 1.7, p = 0.10 \).

*Manipulation Checks: CS pleasantness ratings:* When analyzing pleasantness ratings of the two CSs a marginal interaction between time and counterconditioning, \( F(1,19) = 3.8, p = 0.064 \), was observed, but post hoc comparisons showed no differences in pleasantness ratings between
the two CSs either before or after Go/NoGo ($ps > 0.31$). There were no other significant effects ($ps > 0.26$).

**Accuracy during Go-NoGo Task:** Participants made a correct Go response on 100% (SD: 5%) of the Go trials and correctly stopped on 99% of the No-Go trials (SD: 11%).

**Desire for Drinks:** After the Go-NoGo task, the desire for both drinks had reduced as indicated by a main effect of time, $F(1,19) = 7.6, p = 0.013$, in the analysis.

**Test Phase:** Surprisingly, the manipulation did affect baseline response rates during the non-cued trials. As can be seen in Figure 3 (depicted in black), baseline responding for the drink that was paired with the stopping CS was 40% (SD: 18%), which was significantly less than 50% (1 sample $t$-test, $t (19) = 2.4, p = 0.025$).

As can be seen in Figure 3 (depicted in gray), responding for the drink paired with the stopping-CS increased by 29 pp. (SD = 30 pp.) above the baseline rate when the stopping-CS was on screen. This was not significantly different to the augmentation rate of the go-CS (mean: 18 pp.; SD = 18 pp.; $t (19) = 1.6, p = 0.12$).
5. **Experiment 2b: Inhibition training**

In line with previous studies using inhibition training, we observed a reduction in baseline instrumental responding for the drink that was paired with the stopping CS (Houben & Jansen, 2011; Houben et al., 2011;
Lawrence, Verbruggen, et al., 2015; Veling et al., 2014). However, as the Pavlovian stimuli were perceptually very similar to the drink outcomes they predicted, it is not clear whether this effect is mediated by stopping to the CS or whether it is akin to stopping to the drink outcome. Therefore, in the next experiment, we used abstract stimuli as the Pavlovian CSs that were perceptually different to the drink outcomes.

5.1. Methods

Procedure: We repeated Experiment 2a using abstract black and white stimuli as the CSs (the CS-outcome relationship was counterbalanced across participants). In addition, we did not give participants a chance to sample the drinks again before the transfer test (T4). All other parts of the procedure were identical to Experiment 2a.

Participants: 28 participants took part although one participant was excluded as desire for both drinks was rated at less than 1% at T1 (also reported to the experimenter that she did not like cola at all). Another was excluded for scoring less than 50% chance level on the final instrumental query trials. The final dataset consisted of 26 individuals (21 females) with a mean age of 23.9 years (SD: 3.1 years).

5.2. Results: Experiment 2b (Inhibition Training)

Preference for drinks: There was no difference in the desire ratings of the cola (64%, SD:27%) versus the orange juice (mean: 63%, SD: 24%) at the beginning of the experiment, $t(25) = 0.14, p = 0.89$.

Manipulation Checks: CS pleasantness Ratings: As was observed in Experiment 2a, inhibition training had no effect on the pleasantness ratings
for the two CSs – there was no significant interaction between time and cue type (Go/No-Go), $F(1,25) = 1.8, p = 0.19$, and no other significant effects, $ps>0.60$.

**Accuracy during Go-NoGo Task:** Participants made a correct Go response on 99% (SD: 1%) of the Go trials and correctly stopped on 99% of the No-Go trials (SD: 2%).

**Transfer Test Phase:** In contrast to Experiment 2a, we did not replicate the effect of inhibition training on baseline response rates. The analysis revealed instead that the mean baseline response rate for the drink that had been paired with the stopping CS was 58% (SD: 23%), which was not significantly less than 50% (1 sample t-test, $t(25) = 1.6, p = 0.092$).

The stopping-CS increased responding for the drink it signaled by 22 percentage points (SD = 27pp.), which was not significantly different to the augmentation rate of the Go-CS (25 pp. (SD =28 pp., $t(25) = 0.5, p = 0.60$). This pattern of results thus replicates that found in Experiment 2a, namely that inhibition training did not diminish the degree to which a cue triggered responding for the outcome that it signaled.

6. **General Conclusions**

Counterconditioning of one CS with tween had no effect on either explicit drink desirability ratings (Experiment 1a) or on baseline responding for either drink (Experiments 1a and 1b). Most importantly, and in contrast to expectations, counterconditioning failed to reduce the degree to which the CS augmented responding above baseline levels (Experiments 1a and 1b). The PIT effect was reliably elicited in each experiment and the manipulation
had no discernable effect on the ability of a counterconditioned CS to trigger responding for the drink it signaled. The counterconditioning manipulation appeared to work as intended, as participants rated the tween mixture as being “completely distasteful” (this was borne out by participant reactions during the experiment). Participants also rated the CS that had been paired with the tween as significantly less pleasant than the non-paired CS, but this effect did not transfer in any way to responding for the associated drinks.

In experiment 2a, the Go/No-Go task did appear to affect baseline responding for drinks in the absence of the cues. While the CS that was paired with the stopping signal was not rated as any less pleasant than go CS, participants nonetheless (during the non-cued trials of the transfer test) responded more often for the go-CS paired drink relative to the stopping-CS paired drink. In Experiment 2b, however, this effect was not replicated using black and white abstract patterns as the CSs. The most likely explanation is that the baseline effect observed in Experiment 2a (preferential responding for the go-CS paired drink in the non-cued trials) was due to the perceptual similarity between the CSs and the drinks that they were associated with and that stopping to one of the CSs was akin to stopping to one of the outcome pictures. The data of Experiment 2a, therefore, can be considered a replication of previous work in this area (Houben & Jansen, 2011; Lawrence, Verbruggen, et al., 2015; Veling et al., 2013b), although our results suggest that inhibition training can also reduce instrumental responding directed towards outcomes (in addition to Pavlovian approach responses which have been utilized in previous studies). However the focus of these studies was the PIT effect and contrary to expectations, augmentation of responding above baseline was equivalent for both CS’s in
both Experiments 2a and 2b. It seems fair to conclude, therefore, that inhibiting responses to abstract Pavlovian cues does not lead to reduced responding for the drinks that they predict, in the presence of those cues. The inhibition training effect may be highly specific to the inhibition of instrumental and/or Pavlovian approach responses directed towards outcomes.