

Action Slips: The Effects of Devaluation and Amount of Training

Katie M. J. Wood (k.m.j.wood@exeter.ac.uk)

Department of Psychology, University of Exeter,
Devon, EX4 4QG UK

Chris J. Mitchell (christopher.mitchell@plymouth.ac.uk)

School of Psychology, University of Plymouth,
Devon, PL4 8AA UK

Abstract

Repetitive habitual behaviour can persist even when it conflicts with goals. This is termed an action slip. Wood et al. (2023) demonstrated this effect using a novel procedure, where participants' performance was strong on congruent trials but comparatively poor on incongruent trials. The current study extends their work by exploring a devaluation version of the experiment, followed by a further experiment that manipulates training duration. The devaluation approach eliminated the congruency effect, while reinstating standard testing with varied training led to its reappearance—even after a short amount of training. These findings challenge the Stimulus-Response (S-R) account and dual-process theory. We discuss the question of whether the congruency effect seen in these experiments is evidence to support a dual-process account of habitual behaviour.

Keywords: habits; goal-directed control, action slips; devaluation

Introduction

Performing familiar responses automatically is a crucial cognitive skill, enabling individuals to navigate complex tasks while conserving mental resources for adaptive goal pursuit. However, repetitive habitual behaviour is thought to occur even when it conflicts with intended actions (Wood et al., 2022) – this is termed an action slip (Reason, 1979). While there are varying definitions of habitual behaviour, experts in the field of associative learning differentiate between goal-directed actions influenced by the present motivational value of outcomes and ingrained habitual behaviours triggered directly by the surrounding environment (Watson & de Wit, 2018). An important question to consider is how habitual responses can be distinguished from genuine mistakes. One possible way of defining the difference between a habitual response and a mistake is by simplifying behaviour into responses made to stimuli. An example of a mistake could be failing to process the stimulus, and consequently generating a random response to that stimulus, generating a response to a different stimulus, or making no response at all. Another example of a mistake could be where the stimulus is processed, but the correct response to that stimulus was too weak to be generated. Therefore, the response is either random, or there is no response at all. An example of a habit, on the other hand, is where the stimulus is processed and the correct response is available, but the correct response is not executed because an inappropriate

response is generated instead. That inappropriate response may have been appropriate at a previous point in time or in a different context.

Dual-process theories of instrumental learning propose that instrumental behaviours are controlled by two distinct systems: the goal-directed system and stimulus-triggered habitual system (e.g., Dickinson & Balleine, 1994; Verplanken, 2018). The goal-directed system is suggested to facilitate deliberate, reward-driven actions, while the habitual system is suggested to produce comparatively automatic responses based on S-R associations. When participants stop responding for outcomes that have been devalued in an outcome devaluation procedure, this is seen as evidence for goal-directed behaviour. The outcome is no longer valuable to the participant. Therefore, they no longer make the conscious effort to obtain it. On the other hand, if responding continues for a devalued outcome, this is considered evidence for automatic, habitual behaviour, developed through repeated S-R training. In line with this, extensive training is considered critical for developing habitual responses. Automatic habitual behaviour is formed through repeating the behaviour to the point where conscious effort is no longer needed to make this response. For example, in Tricomi et al.'s (2009) experiment, participants who had received moderate training performed significantly fewer instrumental responses for the devalued outcome than the valued outcome, showing evidence for goal-directed behaviour. Participants who received extensive training, by contrast, showed no significant difference in response rates for the still valued and devalued outcomes, providing evidence of habitual behaviour. Following this, a new, simple instrumental action-slip task was reported by Wood et al. (2023), which sets goal-directed action against putative Stimulus-Response (S-R) associations. The key difference between Wood et al.'s (2023) procedure and devaluation procedures is that Wood et al.'s experiments focus on outcome availability rather than outcome value. In their experimental design, participants first learn two stimulus-response-outcome (S-R-O) relationships, as shown in Table 1. The stimuli are the background colours of the screen (green or blue), the responses are joystick movements (left or right), and the outcomes are pictures of food rewards (Pringles or jellybeans) presented on screen. The participants are instructed to move the cursor as quickly as possible to earn points towards the food rewards. On S1 trials, R1 responses produce O1 points (e.g., if green then left responses produce jellybean points), while R2 responses

produce no points. Conversely, on S2 trials, R2 responses produce O2 points (e.g., if blue, then right responses produce Pringles points), while R1 responses earn no points. In the test phase of their procedure, each trial begins with the presentation of either outcome O1 or O2. The participants were instructed to perform the response that, during the training phase, produced the presented outcome (i.e., O1 -> R1, O2 -> R2). Hence, the presentation of the outcomes at the start of each test trial communicates to participants which outcome they could earn on that trial. The presented stimulus (which signals to the participant they can now respond) could be either congruent or incongruent with the outcome that had been presented at the start of the trial. Therefore, it is also congruent or incongruent with the correct response on that trial. On a congruent trial, O1 might be followed by S1, both of which are associated with R1 in training. Conversely, on an incongruent trial, O1 might be presented first, indicating that R1 is the correct response but S2, associated with R2, would signal that a response could now be executed. Hence, any S-R link that might form in training would promote the incorrect response on incongruent trials on test. Importantly, participants are informed that they should ignore the colour of the stimulus on test, and only use the presentation of S1 and S2 to signal when to respond, not how to respond.

Table 1. Experiment design: 2-way congruency (congruent, incongruent)

Instrumental Training			Test			
Stimulus	Response	Outcome	Outcome	Stimulus	Correct Response	Test Trial
S1	R1	→ O1	O1	S1	R1	Congruent
	R2	→ ∅		S2	R1	Incongruent
S2	R2	→ O2	O2	S2	R2	Congruent
	R1	→ ∅		S1	R2	Incongruent

According to the dual-process theory, goal-directed control will be disrupted when there is less time to prepare responses in advance, as goal-directed behaviour is time consuming and effortful (Heyes & Dickinson, 1990), in comparison with automatic habitual behaviour, which is fast and effortless. Therefore, in addition to the congruency manipulation, an O-S delay manipulation was applied to Wood et al.'s procedure to see if manipulating the amount of time participants had to prepare their response would influence the number of action slips made. A long delay was added between presentation of the O and the S on half of the trials, and a short O-S delay on the other half of the trials. Wood et al.'s results showed a congruency effect that appears to provide evidence of habitual behaviour. The stimuli presented on incongruent trials appear to disrupt goal-directed behaviour, regardless of the O-S delay condition; participants' responses were influenced by the stimuli presented, even though participants were explicitly instructed to ignore those stimuli. The current

research aims to adapt Wood et al.'s (2023) procedure to follow traditional devaluation procedures more closely, and apply two approaches that are commonly used in existing literature to measure habitual behaviour versus goal-directed action: manipulation of outcome value, and manipulation of amount of training (Adams & Dickinson, 1981; de Wit et al., 2018; Luque et al., 2020; Tricomi et al., 2009). The overall aim of the current research is to explore the extent to which performance in these tasks connects to the existing habit literature.

Experiment 1

Outcome devaluation has become a standard procedure for distinguishing goal-directed behaviour from habitual behaviour by specifically manipulating the value of the outcomes at test and observing the resulting effects on participants' performance (Corbit, 2018). The aim of Experiment 1 was to investigate whether we could find evidence of habitual behaviour by adapting our procedure to more closely reflect the existing devaluation procedures. As in Wood et al.'s (2023) procedure, participants were told that they would win jellybean/Pringles points for making the correct response during the test trials. However, in this experiment we devalued one of the outcomes by presenting both outcomes together at the start of each test trial, with a cross placed over the outcome that produced no points. This followed the same devaluation procedure of de Wit et al.'s (2007) Fabulous Fruit Task, where a cross superimposed on one of the fruits signaled that the instrumental response that produced that fruit previously no longer earned points, and participants were to perform the instrumental response that previously produced the still-valued outcome. We also emphasised the value of the outcome and the importance of the points by adding a Leaderboard.

Method

Participants. Eighty-three undergraduate psychology students (73 females, 10 males) from the University of Plymouth participated in exchange for course credits. The participants were aged between 18 and 44 years ($M = 21.86$ years, $SD = 5.88$ years).

Design, Stimuli and Procedure. The experiment was very similar to Wood et al.'s procedure, with the following exceptions. At the beginning of the experiment, participants were told that the aim of the task was to win as many jellybeans and Pringles points as possible to beat the Leaderboard. During the test trials, instead of displaying one outcome picture before the screen changed colour, both the jellybeans and Pringles pictures were displayed together with a cross through one of them. Participants were instructed at the start of the test that the cross indicated which outcome had no points available on that trial, and therefore, no value. Presentation of the jellybean and Pringles pictures were randomised on each test trial. At the end of the experiment, participants were shown a Leaderboard of the top 5 scorers, based on the points earned in the test trials. If the participant's

score was one of the five highest, their score was shown to them in red in the Leaderboard at the end of the experiment.

Results

Exclusions. We chose to follow Wood et al.'s exclusion criteria, excluding participants who achieved less than 80% accuracy on the final test. Participants who performed poorly may have simply misunderstood the instructions and responded to the stimulus (screen colour) that was presented on each test trial, rather than the outcome. This would produce a large congruency effect (good performance on congruent trials but comparatively poor performance on incongruent trials), but it would not be a true demonstration of habitual responding. In order to be cautious, we therefore took 80% accuracy during the test as a conservative cut-off for differentiating participants who showed a lack of understanding or effort from those showing habitual behaviour. Any demonstration of a congruency effect under these circumstances would be against the backdrop of good overall performance, which would suggest that the participant had understood the test instructions. Twenty-one participants were removed for achieving less than 80% accuracy in test trials, leaving 62 participants (54 females, 8 males).

Training. Figure 1 shows, as in previous experiments, the participants learnt the contingencies quickly, staying above 90% accuracy after 40 training trials.

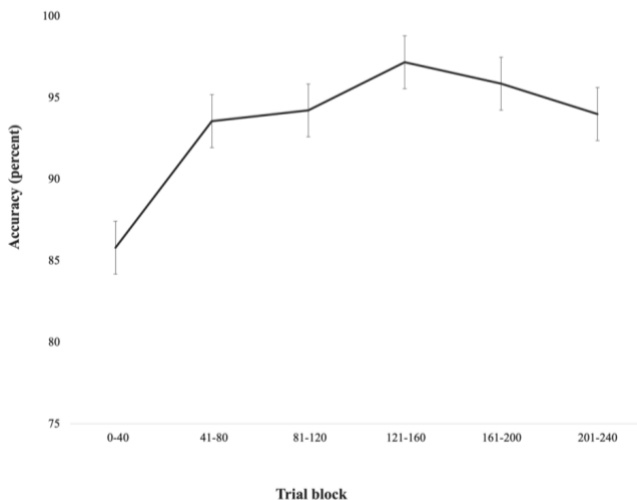


Figure 1: Line graph of mean accuracy (%) of training trials for S1 and S2 in Experiment 1.

Test response accuracy. Figure 2 shows the mean percentage of responses that earned points during the test, separated by congruency and delay conditions. The graph suggests that the participants were more accurate on congruent trials than incongruent trials, and that this pattern was not affected by the delay manipulation. A 2 (congruency condition: congruent vs. incongruent) by 2 (delay condition: short delay vs. long delay) repeated-measures ANOVA, however, revealed that the difference between response

accuracy on congruent and incongruent trials was not significant, $F(1, 61) = 3.21, p = .078, dz = 0.23, BF_{10} = 0.47$. There was no main effect of the delay condition, $F(1, 61) = 0.14, p = .709, BF_{10} = 0.15$, nor a congruency \times delay interaction, $F(1, 61) = 0.02, p = .885, BF_{10} = 0.21$.

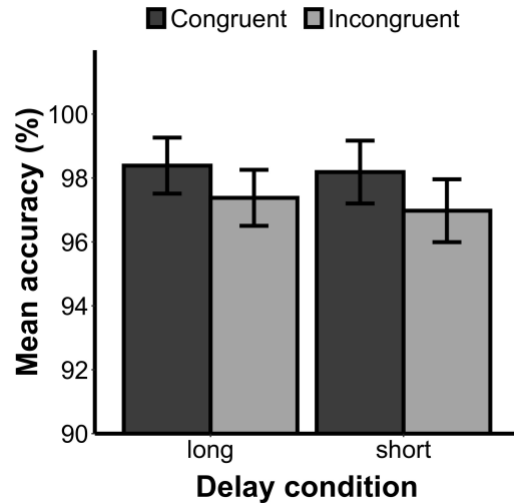


Figure 2: Bar graph of mean accuracy (%) for congruency and delay conditions in Experiment 1 (n=62).

Test reaction times. A comparable analysis was conducted on the reaction times (RT) for correct trials only at test. Figure 3 shows there was a main effect of delay condition on RT, $F(1, 61) = 11.68, p = .001, dz = 0.37$, with participants responding more quickly on long delay trials than short delay trials. The Bayes Factor analysis provided extreme evidence for this delay effect, $BF_{10} > 100$. No significant effect of congruency condition, $F(1, 61) = 0.74, p = .394, dz = 0.11, BF_{10} = 0.19$, nor congruency \times delay interaction, $F(1, 61) = 0.33, p = .566, BF_{10} = 0.19$, was observed.

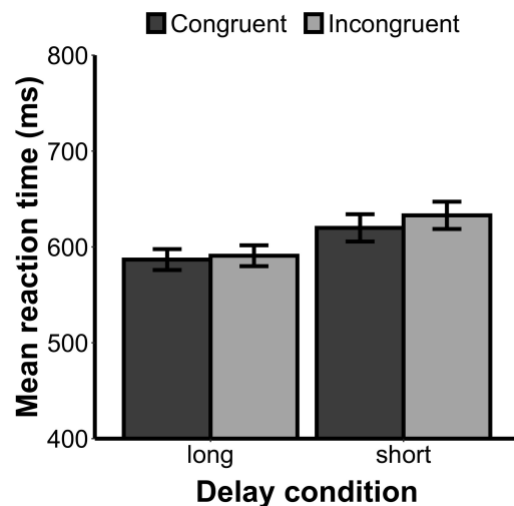


Figure 3: Bar graph of mean reaction times (ms) for congruency and delay conditions in Experiment 1 (n=62).

Discussion

Experiment 1 applied a very similar procedure to Wood et al. (2023), with a few changes in design to be more in line with existing devaluation procedures. A cross was shown over the outcome with no value to highlight that one of the outcomes had been devalued on the trial. A Leaderboard was also added to highlight the aim of winning points. In previous experiments, Wood et al. (2023) found a significant congruency effect, indicating that participants were making action slips on incongruent trials. However, in this experiment, there was no significant congruency effect. This suggests that participants were able to keep the goal in mind, even for incongruent trials, and respond to the valued outcome. If participants were making automatic S-R responses, we would have expected to see more errors on incongruent trials, regardless of outcome value (Adams & Dickinson, 1981; de Wit et al., 2018; Luque et al., 2020; Tricomi et al., 2009). One possible explanation for this is that emphasising the value of the outcome strengthened goal-directed behaviour across all trials. Participants may have found it easier to keep the goal in mind and ignore the stimulus when the devalued outcome was also presented at the start of the trial. It is also possible that adding a Leaderboard for participants to beat other participants' scores added an element of competition and therefore increased their motivation to earn points across all trials (Landers et al., 2015). It is important to note that this null result is not because the devaluation did not 'work' - participants were extremely accurate in this experiment. Therefore, the devaluation, if anything, worked too well. Participants responded for the outcome that would earn points and ignored the screen colour. Few, if any, action slips were made. The results in Experiment 1 are in line with previous findings, that devaluation procedures with human participants result in evidence for goal-directed behaviour, rather than habitual behaviour. These results raise the question of whether the congruency effect seen in Wood et al.'s (2023) experiments is evidence to support a dual-process account of habitual behaviour. In order to investigate this further, Experiment 2 focuses on manipulating the amount of training presented to participants, as this is a procedure commonly used in the existing literature to measure habitual behaviour versus goal-directed action.

Experiment 2

As existing research emphasises the importance of training duration for increased habitual behaviour, Experiment 2 applied a between-subject manipulation of training. We ran a very similar procedure to Wood et al.'s (2023) congruency x delay procedure. However, whilst one group of participants were given a long amount training (240 training trials), a second group of participants were given a shorter version of the training (24 training trials). As Wood et al.'s (2023) findings showed a congruency effect, we expected to see a congruency effect for participants conducting the same experiment (those in the 'long training' condition). However, in line with existing research on habitual behaviour (Adams

& Dickinson, 1981; de Wit et al., 2018; Luque et al., 2020; Tricomi et al., 2009), we expected the congruency effect to significantly reduce for the participants in the 'short training' condition.

Method

Participants. 171 undergraduate psychology students (144 females, 27 males) from the University of Plymouth participated in exchange for course credit (90 participants in the short training condition, 81 participants in the long training condition). The participants were aged between 18 and 57 years ($M = 19.68$ years, $SD = 3.79$ years).

Design, Stimuli and Procedure. The experiment used a mixed design, where the congruency and delay conditions were manipulated within-subjects, and amount of training was manipulated between-subjects. Participants in the 'long training' condition were given 240 training trials. The procedure was the same for participants in the 'short training' condition, but they only received 24 training trials.

Results

Exclusions. The same exclusion criteria as Experiment 1 was applied, leaving 66 participants in each training condition (long training: 57 females, 9 males; short training: 56 females, 10 males).

Training. As in Experiment 1, the participants in the long training condition learnt the contingencies quickly, with accuracy remaining above 90% after 42 training trials, as shown in Figure 4. The mean accuracy across the 24 training trials in the short training condition was 83.52% (this corresponds to halfway through the first bin in Figure 4).

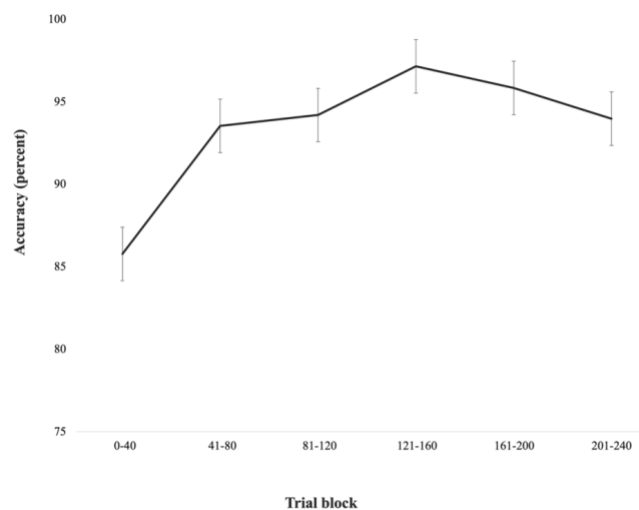


Figure 4: Line graph of mean accuracy (%) of training trials for S1 and S2 in Experiment 2.

Test response accuracy. Figures 5 and 6 show the mean percentage of correct responses during the test, separated by congruency, delay and training conditions. These graphs suggest that the participants were more accurate on congruent trials than incongruent trials in both training conditions. However, for participants who received short training (Figure 6), this difference was only apparent in the short delay condition. These graphs also show that participants made more errors in the short delay trials than the long delay trials in both training groups, but this was particularly prominent in the incongruent trials.

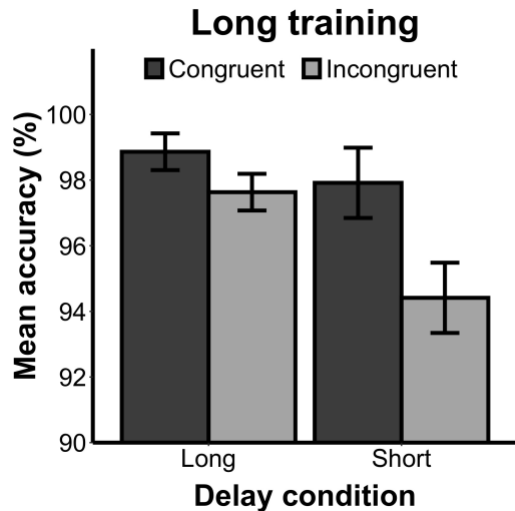


Figure 5: Bar graph of mean accuracy (%) for congruency and delay conditions for the long training condition (n=66).

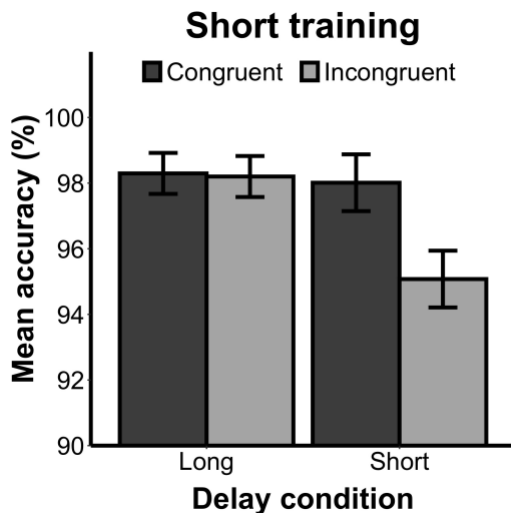


Figure 6: Bar graph of mean accuracy (%) for congruency and delay conditions for the short training condition (n=66).

A 2 (congruency condition: congruent vs. incongruent) by 2 (delay condition: short delay vs. long delay) by 2 (training condition: short training vs. long training) mixed ANOVA confirmed that there was a significant main effect of congruency on response accuracy and extreme support from the Bayes Factor analysis, $F(1, 130) = 20.40, p < .001, dz =$

$0.39, BF_{10} > 100$, with higher accuracy during congruent trials than during incongruent trials. There was also a significant main effect of delay with extreme evidence from the Bayes Factor analysis, $F(1, 130) = 16.90, p < .001, dz = 0.36, BF_{10} > 100$, with higher accuracy in long delay trials than in short delay trials, and a significant congruency \times delay interaction, $F(1, 130) = 11.60, p < .001, BF_{10} = 10.58$, where the congruency effect was more prominent in short delay trials than long delay trials. There was no main effect of training condition on response accuracy, $F(1, 130) = 0.08, p = .784, BF_{10} = 0.15$, congruency \times training interaction, $F(1, 130) = 0.98, p = .323, BF_{10} = 0.21$, delay \times training interaction, $F(1, 130) = 0.17, p = .682, BF_{10} = 0.14$, nor congruency \times delay \times training interaction, $F(1, 130) = 0.14, p = .706, BF_{10} = 0.06$.

Breaking our results down further, we ran repeated-measures ANOVAs on each training group individually. In the 'long training' condition, there was a significant main effect of congruency on response accuracy, $F(1, 65) = 14.82, p < .001, dz = 0.47, BF_{10} = 59.92$, with higher accuracy during congruent trials than during incongruent trials. There was also a significant main effect of delay, $F(1, 65) = 8.88, p = .004, dz = 0.37, BF_{10} = 14.36$, with higher accuracy in long delay trials than in short delay trials. The congruency \times delay interaction was not significant, $F(1, 65) = 3.65, p = .060$. In the 'short training' condition, there was a significant main effect of congruency, on response accuracy, $F(1, 65) = 6.36, p = .014, dz = 0.31, BF_{10} = 3.45$, with higher accuracy during congruent trials than during incongruent trials. There was also a significant main effect of delay, $F(1, 65) = 8.06, p = .006, dz = 0.40, BF_{10} = 10.44$, with higher accuracy in long delay trials than in short delay trials, and a significant congruency \times delay interaction, $F(1, 65) = 9.60, p = .003, BF_{10} = 3.38$, where the congruency effect only occurred in the short delay trials, $t(65) = 3.38, p = .001, dz = 0.42$. There was no significant congruency effect in the long delay trials, $t(65) = 0.15, p = .880$.

Test reaction times. As in previous experiments, a comparable analysis was conducted on the RTs for correct trials only at test. Figures 7 and 8 show there was a main effect of congruency condition, $F(1, 130) = 13.48, p < .001, dz = 0.32, BF_{10} = 15.15$, with participants responding more quickly on congruent trials than incongruent trials. There was also a main effect of delay on RT and extreme evidence for this effect, $F(1, 130) = 31.52, p < .001, dz = 0.47, BF_{10} > 100$, with participants responding more quickly on long delay trials than short delay trials, and a significant delay \times training interaction, $F(1, 130) = 9.03, p = .003, BF_{10} = 36.82$, where a short delay resulted in a slower reaction time, but only for participants in the long training condition. No significant effect of training condition, $F(1, 130) = 0.81, p = .371, BF_{10} = 0.45$, congruency \times delay interaction, $F(1, 130) = 0.42, p = .520, BF_{10} = 0.15$, congruency \times delay \times training interaction, $F(1, 130) = 0.16, p = .687, BF_{10} = 0.34$, or congruency \times training interaction, $F(1, 130) = 3.33, p = .070, BF_{10} = 0.44$, were observed.

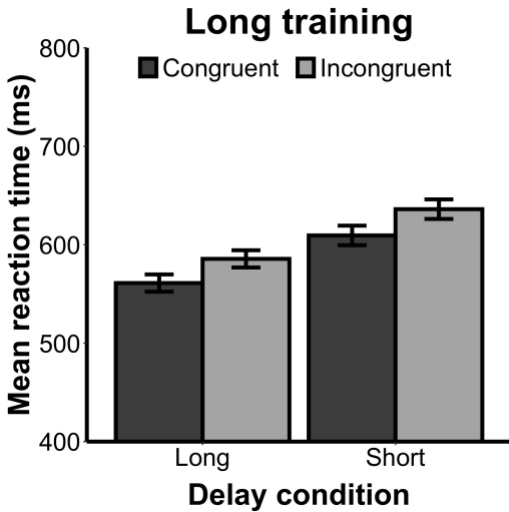


Figure 7: Bar graph of mean reaction times (ms) for congruency and delay conditions for the long training group in Experiment 2 (n=66).

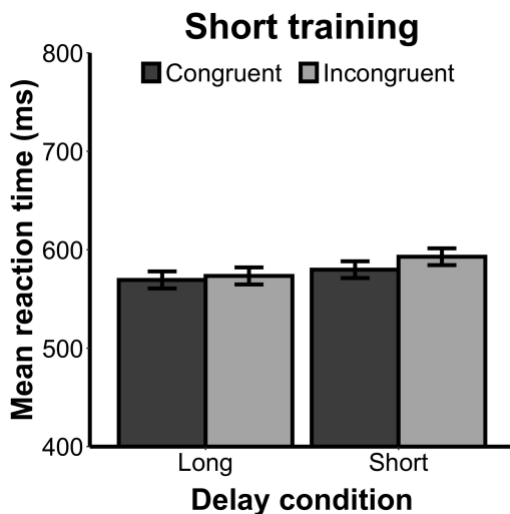


Figure 8: Bar graph of mean reaction times (ms) for congruency and delay conditions for the short training group in Experiment 2 (n=66).

Discussion

We expected to find a significant congruency effect on accuracy in the ‘long training’ condition. The ‘long training’ results were in line with our prediction, showing evidence for habitual behaviour with extensive training. In relation to the ‘short training’ condition, we expected the congruency effect on accuracy to disappear, as existing research specifies that extensive training is required to develop habitual behaviour (Adams & Dickinson, 1981; de Wit et al., 2018; Luque et al., 2020; Tricomi et al., 2009). However, we found a congruency effect in the ‘short training’ condition, and there was no difference in congruency effect between the ‘short training’ condition and the ‘long training’ condition.

We found a main congruency effect, providing evidence of action slips, which is in line with the dual-process theory.

However, there is evidence of action slips in the short training group as well as the long training group, which suggests our congruency effect may not be showing habits after all. Although, of course, it is possible that the task is so simple that even as few as 24 training trials in this experiment were enough to train a habit.

General Discussion

Despite existing evidence for a congruency effect in Wood et al.’s (2023) procedure, when we tried to manipulate devaluation in Experiment 1, we did not observe a congruency effect. Existing literature uses the outcome devaluation procedure to test for evidence of habitual behaviour (de Wit et al., 2018; Luque et al., 2020; Tricomi et al., 2009). According to dual-process theory, continued responding for a devalued outcome can be considered evidence for habitual behaviour (Adams & Dickinson, 1981). On the contrary, high accuracy on incongruent trials suggests a strong effect of devaluation. Accuracy was very high across all conditions in Experiment 1. Therefore, it may be beneficial to use a more subtle devaluation procedure in future experiments to allow an effect of the stimulus. We also found no effect of duration of training on congruency. According to dual-process theories, we would expect to see goal-directed control after moderate instrumental training, but habitual control after extensive instrumental training. However, we found no significant difference between the two groups. The congruency effect was still there when we shortened training. It is possible that our congruency effect is measuring something other than habitual behaviour (or automatic habitual behaviour), or that our task is so simple that we would need to reduce the training even further to see an effect of training condition on congruency. Future research could explore this further by running a ‘no training’ condition, where the pre-test instructions simply state the S-R relationship rather than running training trials. The ‘long training’ condition could also be increased to three days of training (e.g., Tricomi et al.).

An additional point to consider relates to the importance of the long-delay test trials for measuring habitual behaviour. There is a short-delay effect regardless of the level of training, which appears to be related to preparation of the response on test. However, if there is a long delay between Outcome and Stimulus on test, participants have plenty of time to prepare their response. If a long-delay congruency effect is observed in the long training group, this could be considered evidence of habitual behaviour. In line with this, Experiment 2 found a long-delay congruency effect in the long training group, but no significant congruency effect in long delay trials after a short amount of training, which could be evidence of habitual behaviour. Therefore, this may be a key area to investigate in future research when looking for evidence of habitual behaviour.

To conclude, this research may serve as a valuable foundation for future investigations into habitual behaviour, particularly in evaluating the default S-R interpretation against alternative approaches.

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