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Exploring the Role of Goal-Dependent Processes in Action Slips Under Time Pressure

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People sometimes emit frequently practiced responses that were previously effective in achieving desired outcomes but are no longer appropriate in the current context. While dual-process theories attribute these action slips to goal-independent, associative processes, we propose that errors in the expectancies about action outcomes contribute to their occurrence. To investigate this, we first replicated an influential study by Hardwick et al. (2019), demonstrating the occurrence of action slips following extensive stimulus–response training when individuals are required to respond rapidly. Building on this foundation, we conducted two additional experiments using a similar procedure, incorporating a measure of outcome expectancies under time pressure. Our findings provide compelling evidence for errors not just in selected responses but also in expected outcomes of these responses, particularly in early time intervals. These results highlight the possible role of goal-directed processes in action slips under time pressure, advancing our understanding of the cognitive mechanisms underlying suboptimal behavior.

Keywords: habits, action slips, dual-process theory, goal-directed processes

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People frequently exhibit behavior that appears to be inconsistent with their stated goals. For instance, despite expressing a desire to prioritize health, social interaction, or environmental responsibility, individuals may engage in actions that contradict these intentions, such as consuming unhealthy food, behaving aggressively, or littering. Dual-system theories have often been used to explain these seemingly contradictory behaviors. According to these theories, human behavior is governed by two distinct mental systems (Evans & Stanovich, 2013; Kahneman, 2011; Wood & Rünger, 2016). The first system, often referred to as the fast and intuitive system, supports behavior guided by learned associations between mental representations of stimuli and actions (i.e., stimulus–response [S–R] associations). This behavior is often referred to as stimulus-driven or "habitual" action. The second system is typically described as slow, deliberate, and goal-directed, involving the selection of actions based on inferences about their potential to achieve desired outcomes.

The existence of the habitual system and its role in supporting stimulus-driven actions has been a subject of considerable debate (De Houwer et al., 2018, 2023). Notably, research on action slips has often been posited as providing compelling evidence in this regard (Hardwick et al., 2019; Wood et al., 2022). Action slips occur when individuals engage in behaviors that were previously effective but are no longer appropriate for the current context (de Wit et al., 2012). For example, someone driving to a new workplace may mistakenly take a wrong turn, following the familiar route they used to take to their previous workplace. According to dual-systems theories, such behaviors may be attributed to a stimulus-driven process, whereby a stimulus (e.g., the intersection) triggers the activation of an association between the mental representations of that stimulus and a response (e.g., turning left). Consequently, this response is automatically elicited without considering the outcome of the action.

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Pieter Van Dessel served as lead for data curation, formal analysis, and visualization. Pieter Van Dessel and Yannick Boddez contributed to investigation, methodology, project administration, supervision, validation, and writing–original draft. Pieter Van Dessel and Jan De Houwer contributed to funding acquisition. Pieter Van Dessel, Yannick Boddez, Agnes Moors, Eike K. Buabang, and Massimo Köster contributed to conceptualization. Jan De Houwer, Agnes Moors, Eike K. Buabang, and Massimo Köster contributed to writing–review and editing.

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It is typically assumed that these stimulus-driven processes arise from the automatic formation of S–R associations through associative learning which involves the repeated pairing of a stimulus and a response (Thorndike, 1931). In an extensive operant conditioning procedure, a response is followed consistently and numerous times by a valued outcome when a particular stimulus is present (Wood & Rünger, 2016). Through this extensive reinforcement, a strong S–R association is thought to form, while the association between the response and the outcome weakens, eventually diminishing the representation of the behavior's outcome or its activation (Dickinson, 1994; Tricomi et al., 2009). Because the S–R associations are believed to strengthen through prolonged training, the likelihood of action slips caused by these stimulus-driven processes is particularly high following extensive repetition.

Notably, establishing convincing evidence that action slips involve actions that disregard action outcomes has been challenging (De Houwer et al., 2018; Watson et al., 2022). Hardwick et al. (2019) put forth a compelling argument in an influential article, suggesting that the difficulty lies in the fact that stimulus-driven actions are frequently overshadowed by goal-directed processes. Specifically, the goal-directed system may override stimulus-driven actions, allowing goals to still influence behavior. However, they further argue that it is crucial to note that dual-process theories often propose that goal-directed processes operate relatively slowly (Moors et al., 2017). Hence, they argue that stimulus-driven responses may become apparent when examining responses generated under the constraint of limited time.

To test this idea, Hardwick et al. (2019) conducted an experiment in which participants received either moderate or extensive training to emit specific responses (pushing one of four buttons) when presented with specific visual stimuli (four geometric figures) to obtain a wanted outcome (feedback about the correctness of the action). In a subsequent reversal phase, two of the S–R mappings were reversed. During the test phase, participants were required to respond to the four figures within different time intervals. The findings revealed that in the early time intervals, participants in the extensive training group made more errors by emitting the original response to the remapped stimuli, indicating action slips, compared to other types of errors. Based on these results, the authors concluded that the initial extensive training had facilitated the formation of S–R associations, which became evident when participants responded to these stimuli under specific time constraints.

Whereas the findings of Hardwick et al. (2019) have been considered as compelling evidence for the role S–R associations in action slips, particularly within the framework of dual-process theories of human behavior, it is important to note that their strength in supporting these ideas may not be as robust as previously argued. In line with recent theoretical proposals (Kruglanski & Szumowska, 2020; Moors et al., 2017), an alternative explanation for the results posits that they can be attributed to goal-directed processes rather than relying solely on S–R associations (Buabang et al., 2023; De Houwer et al., 2023). From this perspective, action slips may arise from a goal-directed mechanism wherein participants select a response based on the mistaken expectation that it will lead to a desired outcome, despite changes in the S–R mapping.

Following this perspective, the likelihood of action slips may increase after extensive practice of the original S–R mappings because there are more events that support the incorrect outcome expectancies that can be retrieved during information sampling in action preparation. In this context, "sampling" refers to the process of selecting relevant information from memory to guide action preparation. This process is thought to be probabilistic (e.g., using Bayesian principles; Sanborn & Chater, 2016), meaning that not all relevant information is necessarily accessed and considered when planning an action. Instead, a subset of information is sampled, and this subset may be biased by factors such as prior experience and expectations. Importantly, action slips can be more prone to happen under time pressure because having more time allows for more accurate inferences by enabling participants to more extensively consider information that supports correct outcome expectancies for action selection (e.g., due to more extensive Bayesian sampling: Gershman et al., 2015). This alternative interpretation challenges the notion that the observed action slips are (solely) driven by S–R associations and highlights the potential role of goal-directed processes in explaining these findings.

Buabang et al. (2023) conducted a study to provide an initial test of this idea. In their study, participants were initially trained to push a left or right button in response to the presentation of pairs of doors in specific colors (red, blue, green, or yellow) which would yield a diamond or a rock (a valued outcome linked to receiving more money), either through extensive or moderate practice. Following a reversal phase where the response mappings for certain colored doors were reversed, participants entered a test phase. During this phase, participants were not only required to perform the learned actions under time pressure but also to report their expectancies regarding the outcomes of these actions under time pressure. The results indicated that participants in the extensive practice condition not only made more action slips for the remapped stimuli than participants in the moderate training condition but also made more errors in self-reported expectancies of the action outcomes for these stimuli.

In the current study, we extend this test to the procedure of Hardwick et al. (2019). Examining the concept of goal-dependent action slips within this procedure holds relevance for generalizability, particularly because of the established role of this procedure in demonstrating S–R associations in action slips. Notably, this procedure differs from Buabang et al. (2023) in three significant ways. First, while Buabang et al. had only two possible responses, the current procedure encompasses more than two response options. This allows to distinguish between errors constituting action slips and random guessing errors because errors can be compared for all the different responses. Second, the current procedure investigates responses under varied time constraints (rather than a single time constraint as in the procedure of Buabang et al.), which allows to assess the effect of time on action slips. Finally, rather than introducing an additional stimulus like a diamond or rock as in the procedure of Buabang et al., the relevant outcome in our procedure is feedback about the correctness of actions. This adaptation addresses one potential source of complexity criticized by Wood and Mazar (2023).

We first conducted an online replication experiment using the materials provided by Hardwick et al. (2019; Experiment 1). The aim of this step was to confirm the robustness of the observation of action slips for remapped stimuli in early time intervals. Additionally, we aimed to evaluate the effectiveness of our online procedure implementation, which differs from the offline approach used by Hardwick et al. Moreover, we tested an alternative index of action slips compared to Hardwick et al., who mainly looked at the selection of the original response for remapped stimuli above chance level. Specifically, we probed whether participants make more errors indicating the original response for remapped stimuli than errors indicating an incorrect response for nonremapped stimuli.

Subsequently, we designed two preregistered experiments with a similar procedure to Experiment 1, except that the test phase assessed outcome expectancies rather than stimulus-based responses. During each test trial, participants were presented with a geometric figure accompanied by a response key button. Under time pressure, participants were required to indicate outcome expectancies, more specifically, whether they expected to receive correct or incorrect feedback if they were to emit this response. We expected that participants would exhibit a higher rate of errors in outcome expectancies for remapped stimuli presented with the original response key compared to errors for nonremapped stimuli presented with an incorrect response key, particularly in the early time intervals. This pattern of results would suggest that participants are also more prone to make errors in expecting a positive outcome for original responses to remapped stimuli in early time intervals, supporting the idea that action slips in early time intervals can reflect errors in outcome expectancies.

Experiment 1: Replication of Hardwick et al. (2019)

Method

Ethics Approval

This research complied with all relevant ethical regulations. All experiments were conducted under approval of the Ethics Committee at Ghent University (reference: 2019/72). Informed consent was obtained from all participants as part of the enrollment process.

Participants

We conducted a prescreening using volunteers from Prolific Academic to identify and select 10 participants who consistently responded on time and accurately on most trials, ensuring that the subsequent main study would involve participants capable of meeting the necessary timing criteria for the experiment. Participants were asked to complete a practice task adapted from Hardwick et al. (2019), where they responded to pictures of a right hand with a highlighted finger using specific key presses (f, t, y, or j) within a specific response deadline (see the online supplemental materials for more details). The sample size was determined to yield statistical power exceeding 90% to detect a large effect ($d = 1.00$, as observed in Hardwick et al., 2019; Experiment 1) in a one-tailed within-subjects t test examining whether participants emitted the original response to remapped stimuli above chance level in early time intervals. All 10 participants who qualified through the prescreening process successfully completed the main experiment. The final data set for analysis comprised data from these 10 participants (seven women, $M_{age} = 28$, $SD = 6$).

Procedure

The procedure closely followed that of Hardwick et al. (2019), with the distinction that our experiment was conducted online. To minimize selective attrition and ensure consistent participant engagement throughout the experiment, we followed standard recommendations (Zhou & Fishbach, 2016). Specifically, participants were explicitly informed about the duration of the experiment and the requirement to complete different phases, emphasizing the importance of thoughtful participation to facilitate scientific progress.

The experimental tasks involved participants responding to four different geometric figures using specific key presses (f, t, y, or j). Initially, participants completed an acquisition phase, in which each trial required them to press one of four keyboard keys in response to the presentation of one of four different geometric figures (Figure 1). Each trial began with a tone followed by the presentation of a figure, and participants received feedback based on their response accuracy. Feedback was provided to facilitate learning of the correct responses for each figure. For a correct response, an on-screen box corresponding to the button they had pressed turned green and they heard a pleasant sound. For an incorrect response, the on-screen box corresponding to the button they had pressed turned red, they heard a buzzer sound and there was a compulsory delay of 700 ms in addition to the 300 ms intertrial interval. The acquisition phase concluded when participants achieved five consecutive correct responses for each figure.

Subsequently, participants engaged in extensive practice to strengthen the learned S–R mappings. Before each block, participants were informed of their previous response times and challenged to improve their speed in the next block. They completed five blocks of 100 trials, with reaction time feedback provided after each block. Trial-based accuracy feedback was the same as during acquisition. Participants returned on the following day to complete another five blocks of 100 trials with the same S–R contingencies as before. On the third day, they completed an additional five blocks of 100 trials of the task.

Following this, participants were informed that the correct key presses for some figures had changed, and they needed to learn the new correct responses. During this reversal phase, the correct response keys for two figures (the remapped stimuli) were switched, and participants continued until they achieved five consecutive correct responses for all four figures.

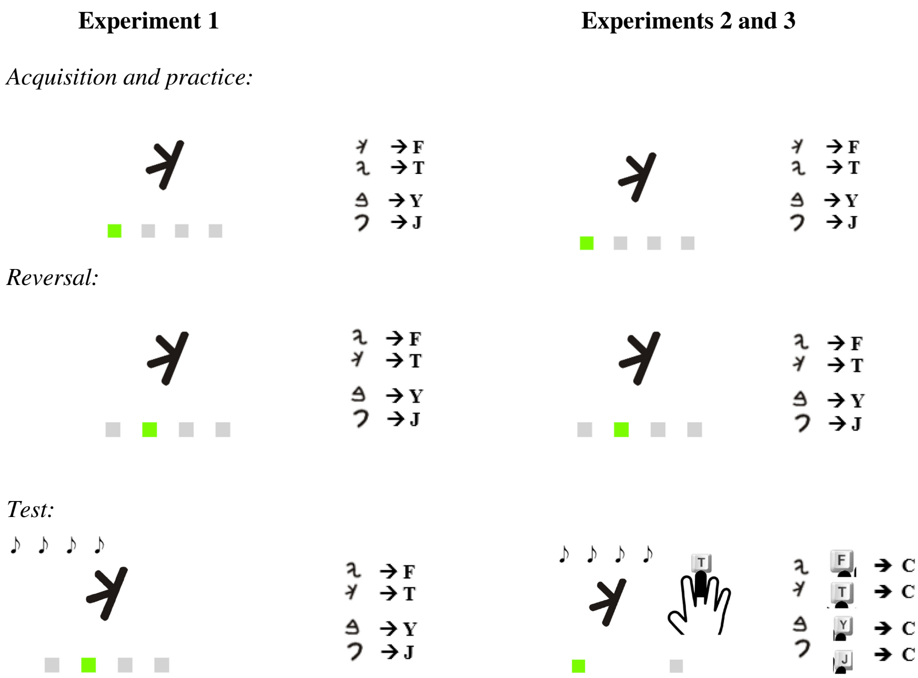
After the reversal phase, participants proceeded to the test phase, which encompassed five blocks of 100 trials. Participants were informed that they would perform the same task again, but with the added requirement of responding at an exact point in time. They were presented with four tones equally spaced in time (400 ms apart), and their task was to synchronize their response with the fourth tone. The geometric figure appeared randomly within the 0–1,200 ms time interval of the four tones, providing participants with varying time constraints for initiating the correct response.

Results

For both remapped and nonremapped stimuli, participants exhibited performance above chance level (25%), in all time intervals after 400 ms, $ts > 3.27$, $ps < .005$, $ds > 1.03$. More importantly, consistent with the results of Hardwick et al. (2019), participants emitted more original responses to remapped stimuli than expected by chance in the early time intervals of 400–500 ms ($M = 32.6\%$, $SD = 9.2\%$), $t(9) = 2.61$, $p = .014$, $d = 0.82$, and 500–600 ms ($M = 38.1\%$, $SD = 12.3\%$), $t(9) = 3.36$, $p = .004$, $d = 1.06$.

We conducted an analysis of variance (ANOVA) to analyze the difference in the proportion of incorrect responses between two

Figure 1
Illustration of the Procedure of All Experiments



Note. Participants first completed an acquisition phase and then practiced the stimulus–response contingencies in 15 blocks of 100 trials (spread over 3-day sessions). They then completed a reversal phase in which two stimulus–response contingencies were changed. Finally, they completed five blocks of 100 test trials with time pressure. In Experiment 1, the test trials required a simple response to the geometric figures. In Experiments 2 and 3, the test trials required indicating whether a specific response would generate correct or incorrect feedback. See the online article for the color version of this figure.

conditions: one where participants exhibited action slips by giving the original response for remapped stimuli, and the other where they inaccurately responded for nonremapped stimuli (averaging the proportion of the three incorrect responses). The ANOVA included stimulus type (nonremapped, remapped stimulus) and time interval (0–300 ms, 300–700 ms, and 700–1,100 ms) as factors. We observed a main effect of time, $F(1.45, 13.06) = 32.39$, $p < .001$, $\eta_p^2 = .78$, indicating fewer errors in the last time interval (0–300 ms: $M = 24.7\%$, $SD = 4.9\%$; 300–700 ms: $M = 29.5\%$, $SD = 5.6\%$; 700–1,100 ms: $M = 11.6\%$, $SD = 6.6\%$), a main effect of trial type, $F(1, 9) = 59.31$, $p < .001$, $\eta_p^2 = .87$, indicating more errors for remapped stimuli (remapped: $M = 29.6\%$, $SD = 6.9\%$; nonremapped: $M = 14.2\%$, $SD = 1.7\%$), and an interaction effect of Time × Trial Type, $F(1.66, 14.94) = 23.14$, $p < .001$, $\eta_p^2 = .72$. This interaction indicated more errors for remapped than nonremapped stimuli in the second ($M_{\text{difference}}$ $M_d = 27.2\%$, $SD = 9.3\%$) and third interval ($M_d = 20.5\%$, $SD = 12.8\%$), but not in the first time interval ($M_d = -1.5\%$, $SD = 8.0\%$). Follow-up *t* tests showed more errors for remapped than nonremapped stimuli across all time intervals following 400 ms, $ts > 2.94$, $ps < .009$, $ds > 0.93$ (Figure 2).

Discussion

The results of this experiment support the main findings of Hardwick et al. (2019), confirming that action slips—defined as responses to stimuli that were previously correct but now incorrect—can occur under time pressure. Specifically, participants exhibited a higher proportion of original responses to remapped stimuli than chance level within the 400–600 ms time intervals. Additionally, we observed that participants emitted more original responses to remapped stimuli than incorrect responses to nonremapped stimuli within the 400–1,200 ms time intervals. Notably, these consistent results were observed in an online study setting.

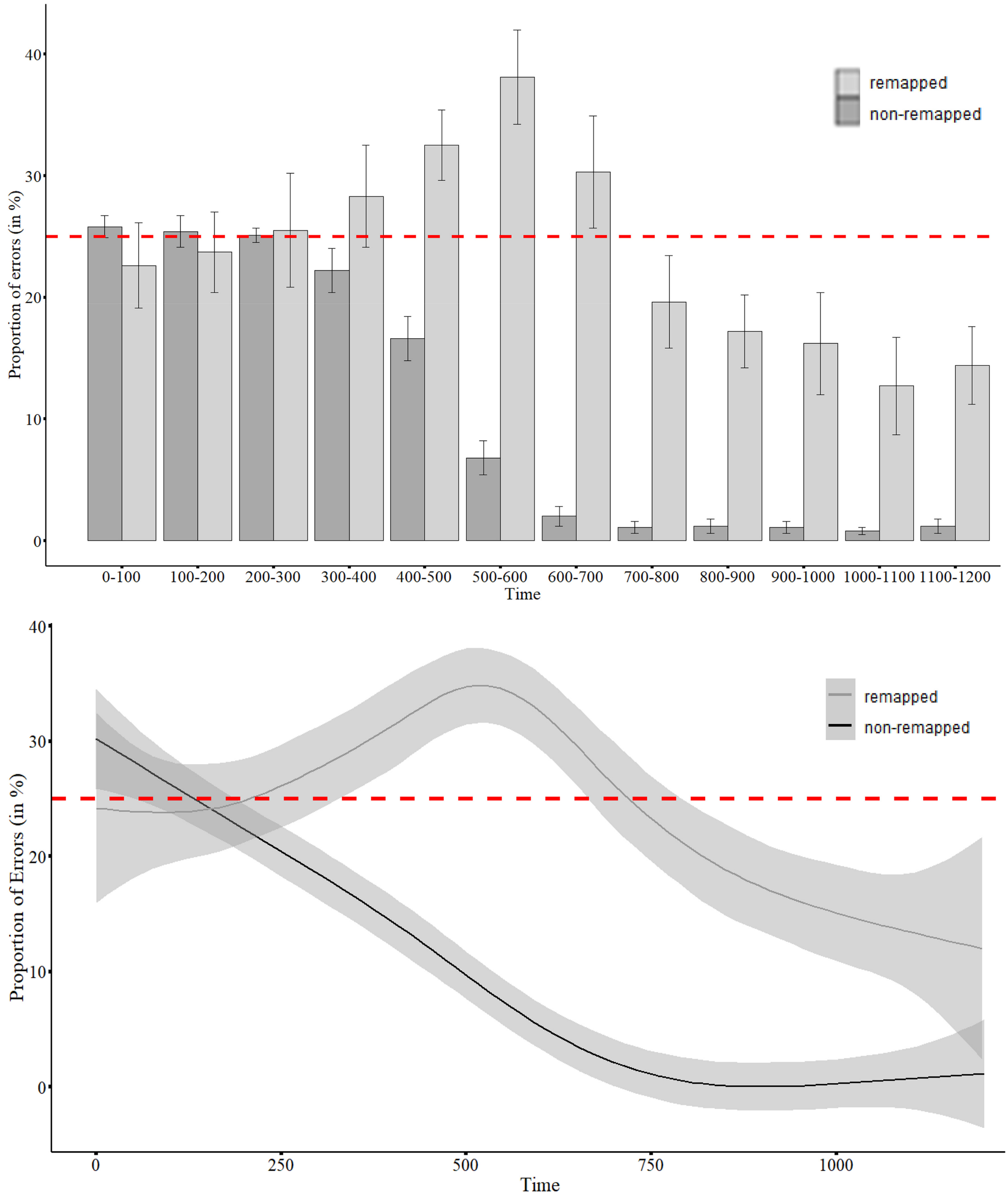
Experiments 2 and 3

Method

Participants

In line with the methodology of Experiment 1, a prescreening experiment was conducted to identify participants who could meet the timing requirements of the experiment. For Experiment 2, 11 participants were initially invited to participate in the main experiment. This sample size was chosen to afford approximately 90% statistical power to observe an effect size of $d = 0.93$ (the smallest effect observed in Experiment 1) in within-subjects *t* tests comparing the proportion of errors for remapped and nonremapped stimuli. Data from one participant were excluded from the analysis due to not answering within the required time for over 30% of the trials (44% of trials; $M = 12\%$, $SD = 5\%$). The remaining data from 10 participants (seven women, $M_{\text{age}} = 26$, $SD = 5$) were included in the final analyses.

Figure 2
Proportion of Incorrect Responses in Experiment 1



Note. These figures compare the mean proportion of original responses for remapped stimuli (action slips) with the mean proportion of inaccurate responses for any nonremapped stimulus in all time intervals. The top figure displays the errors within timed bins, with error bars representing the standard error of the mean. The bottom figure features continuous lines illustrating the proportion of errors over time. Shading denotes the standard error of the mean. In both figures, the dashed line represents chance-level performance of 25%. See the online article for the color version of this figure.

For Experiment 3, we invited 20 participants based on the results of the prescreening experiment. This sample size was chosen to afford 90% statistical power to observe a more moderate effect size of $d = 0.70$ in the within-subjects t tests. The aim of this increase in sample size was to examine the reliability of the absence of significant effects in time intervals after 1,000 ms, as observed in Experiment 2. We excluded the data from one participant who reported experiencing issues with the main experiment. We did not have to exclude any additional participants' data due to not answering in time for more than 30% of trials ($M = 12\%$, $SD =$ 5%). Analyses were performed on the data of 19 participants (11 women, $M_{\text{age}} = 26$, $SD = 4$).

To ensure transparency and reduce potential bias in the data analysis process, the target sample size, experiment design, hypotheses, and data-analytic plans were preregistered prior to data collection. There were no deviations from preregistration except that we excluded the data from the two participants noted above and that we conducted additional *t* test analyses for exploratory purposes. These analyses are outlined in the online supplemental materials.

Procedure

The protocol closely resembled that of Experiment 1, including the completion of acquisition trials, 15 blocks of practice trials distributed over three consecutive days, and reversal trials. However, a notable modification was made to the test phase trials. Participants were informed that a response key button would be presented alongside each figure, and their task was to imagine that they had pressed this button. The objective was for participants to quickly indicate whether they would receive correct or incorrect feedback if they had actually pressed this button (i.e., to report their outcome expectancy), by pressing the "c" key for correct or the "n" key for not correct. Similar to Experiment 1, participants were required to make this response precisely at a predetermined moment synchronized with the fourth tone presentation.

This outcome expectancy test phase consisted of five blocks, each consisting of 100 trials. Half of the trials presented accurate response key buttons, while the other half presented a different response key button. For each figure, there were only two response keys that could be presented: (a) the accurate response key and (b) the key corresponding to the original response for remapped trials or the key corresponding to another response (i.e., the response for the other nonremapped stimulus) for nonremapped trials.

The procedure for Experiment 3 closely mirrored that of Experiment 2, with one notable variation introduced during the test phase. In Experiment 3, we delayed the presentation of the first tone by 200 ms, and we extended the timeframe for displaying the figure within the 0–1,400 ms time interval. This adjustment aimed to investigate whether outcome expectancy action slips might be significantly reduced in later time intervals, building on the observed pattern in Experiment 2 where intervals after 1,000 ms showed nonsignificant differences between error rates for remapped and nonremapped stimuli. Additionally, this change allowed participants more average preparation time for their responses, potentially reducing random guesses and enhancing statistical power due to reduced variance.

Results

Experiment 2

To examine outcome expectancy errors, all analyses focus on trials where stimuli were presented with an inaccurate response. We first examined overall performance. For nonremapped stimuli presented with the inaccurate response, participants more often reported expecting incorrect than correct feedback, exhibiting performance above chance level (50%), in all time intervals after 400 ms, $ts > 2.32$, $ps < .046$, $ds > 0.74$. In contrast, for remapped stimuli presented with the inaccurate (original) response, performance was higher than chance only in the later time intervals of 800–1,100 ms, $ts > 3.39$, $ps < .009$, $ds > 1.07$.

To examine the hypothesis that participants would display higher rates of outcome expectancy errors for remapped compared to nonremapped stimuli in early time intervals, we conducted a 2 (stimulus type: nonremapped, remapped stimulus) × 3 (time interval: 0–300 ms, 300–700 ms, 700–1,100 ms) ANOVA on error rates in inaccurate response trials. The ANOVA revealed a main effect of time, $F(1.27,\ 11.47) = 7.54$, $p = .014$, $\eta_p^2 = .46$, indicating fewer errors in the last time interval (0–300 ms: $M = 45.7\%$, $SD = 22.7\%$; 300–700 ms: $M = 43.4\%$, $SD = 15.8\%$; 700–1,100 ms: $M =$ 24.3%, $SD = 11.9\%$), a main effect of trial type, $F(1,\ 9) = 7.97$, $p = .020$, $\eta_p^2 = .47$, indicating more errors for remapped stimuli (remapped: $M = 41.9\%$, $SD = 15.6\%$; nonremapped: $M = 33.7\%$, $SD = 15.1\%$), and an interaction effect of Time × Trial Type, $F(1.93,\ 17.34) = 15.57$, $p < .001$, $\eta_p^2 = .63$. This interaction indicated more outcome expectancy errors for remapped than nonremapped stimuli in the second ($M_d = 11.9\%$, $SD = 12.4\%$) and third interval ($M_d = 16.7\%$, $SD = 9.4\%$), but not in the first time interval ($M_d = -4.1\%$, $SD = 12.8\%$). Follow-up *t* tests showed more errors for remapped than for nonremapped stimuli in all time intervals following 400 ms, $ts > 2.96$, $ps < .016$, $ds > 0.93$, except for the 600–700 ms interval, $t(9) = 1.67$, $p = .13$, $d = 0.53$, and the intervals after 1,000 ms, $ts < 1.96$, $ps > .082$, $ds < 0.66$ (Figure 3).

Experiment 3

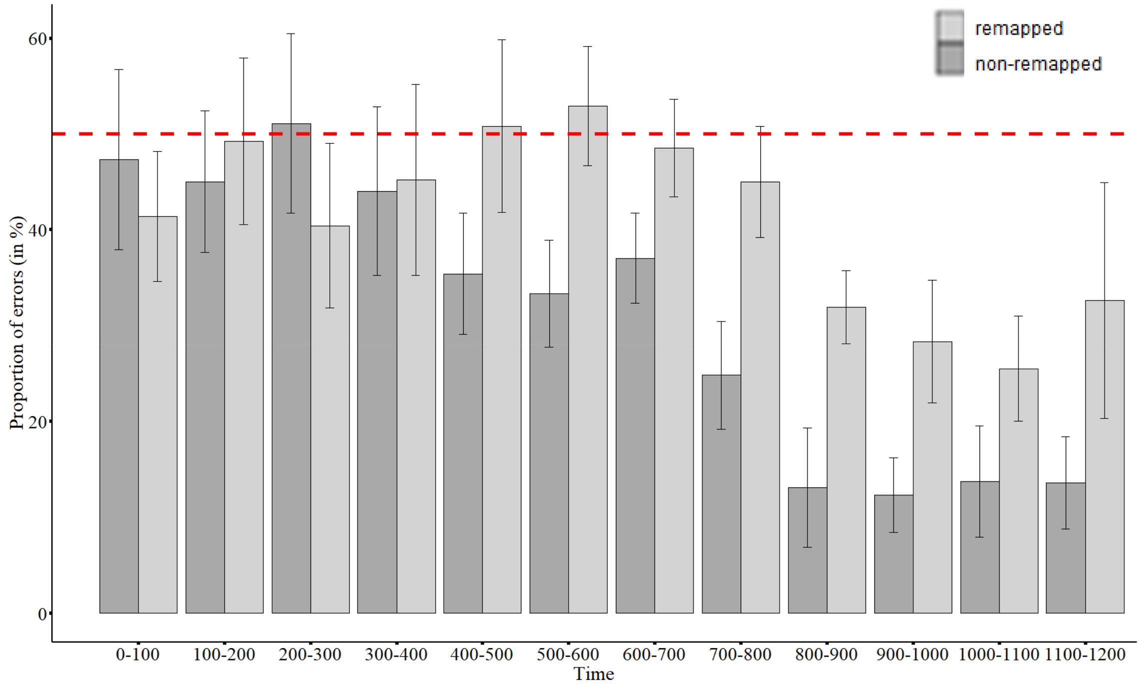
For nonremapped stimuli presented with the inaccurate response, participants exhibited performance above chance level in all time intervals after 600 ms, $ts > 2.73$, $ps < .014$, $ds > 0.62$. In contrast, for remapped stimuli presented with the inaccurate (original) response, performance was higher than chance in all time intervals after 700 ms, $ts > 2.24$, $ps < .038$, $ds > 0.51$.

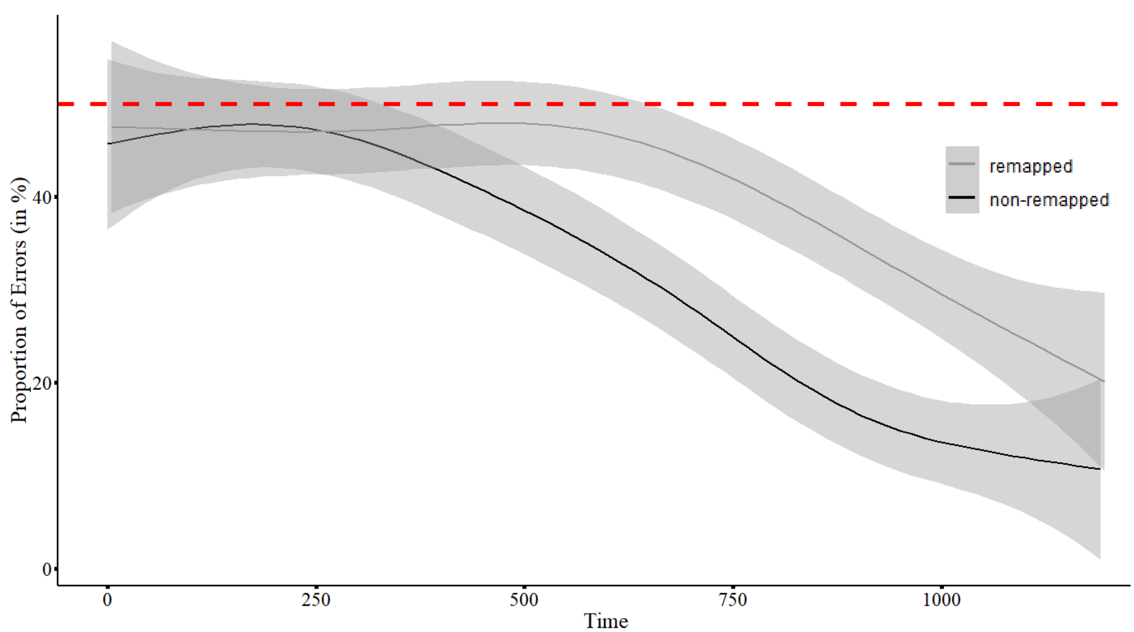
We conducted a 2 (stimulus type) × 2 (time interval: 0–300 ms, 400–700 ms, 700–1,000 ms, and 1,100–1,400 ms) ANOVA which revealed a main effect of time, $F(1.27,\ 11.47) = 36.66$, $p < .001$, $\eta_p^2 = .67$, indicating fewer errors in the third than in the first two time intervals and even fewer errors in the last time interval (0–300 ms: $M = 44.5\%$, $SD = 19.3\%$; 400–700 ms: $M = 45.5\%$, $SD = 15.8\%$; 700–1,000 ms: $M = 27.6\%$, $SD = 14.5\%$; 1,100–1,400 ms: $M = 12.5\%$, $SD = 10.0\%$), and trial type, $F(1,\ 18) =$ 29.69, $p < .001$, $\eta_p^2 = .62$, indicating more errors for remapped stimuli (remapped: $M = 36.9\%$, $SD = 11.9\%$; nonremapped: $M =$ 28.1%, $SD = 12.6\%$), but no interaction effect of Time × Trial Type, $F(2.44,\ 43.97) = 1.06$, $p = .37$, $\eta_p^2 = .06$. Post hoc tests indicated more outcome expectancy errors for remapped than nonremapped stimuli in the second ($M_d = 10.2\%$, $SD = 17.7\%$), third ($M_d = 13.0\%$, $SD = 14.8\%$), and fourth interval ($M_d = 7.8\%$, $SD = 14.7\%$), but not in the first time interval ($M_d = 4.4\%$, $SD =$ 12.4%). Follow-up *t* tests showed more errors for remapped stimuli than for nonremapped stimuli in all time intervals following 600 ms, $ts > 2.26$, $ps < .036$, $ds > 0.66$, except for the 1,100–1,300 ms intervals, $ts < 1.38$, $ps > .18$, $ds < 0.37$ (Figure 4).

Discussion

The results of two preregistered experiments provide support for the idea that people make errors in expecting positive outcomes of the original response for remapped stimuli (outcome action slips)

Figure 3
Proportion of Outcome Expectancy Errors in Experiment 2



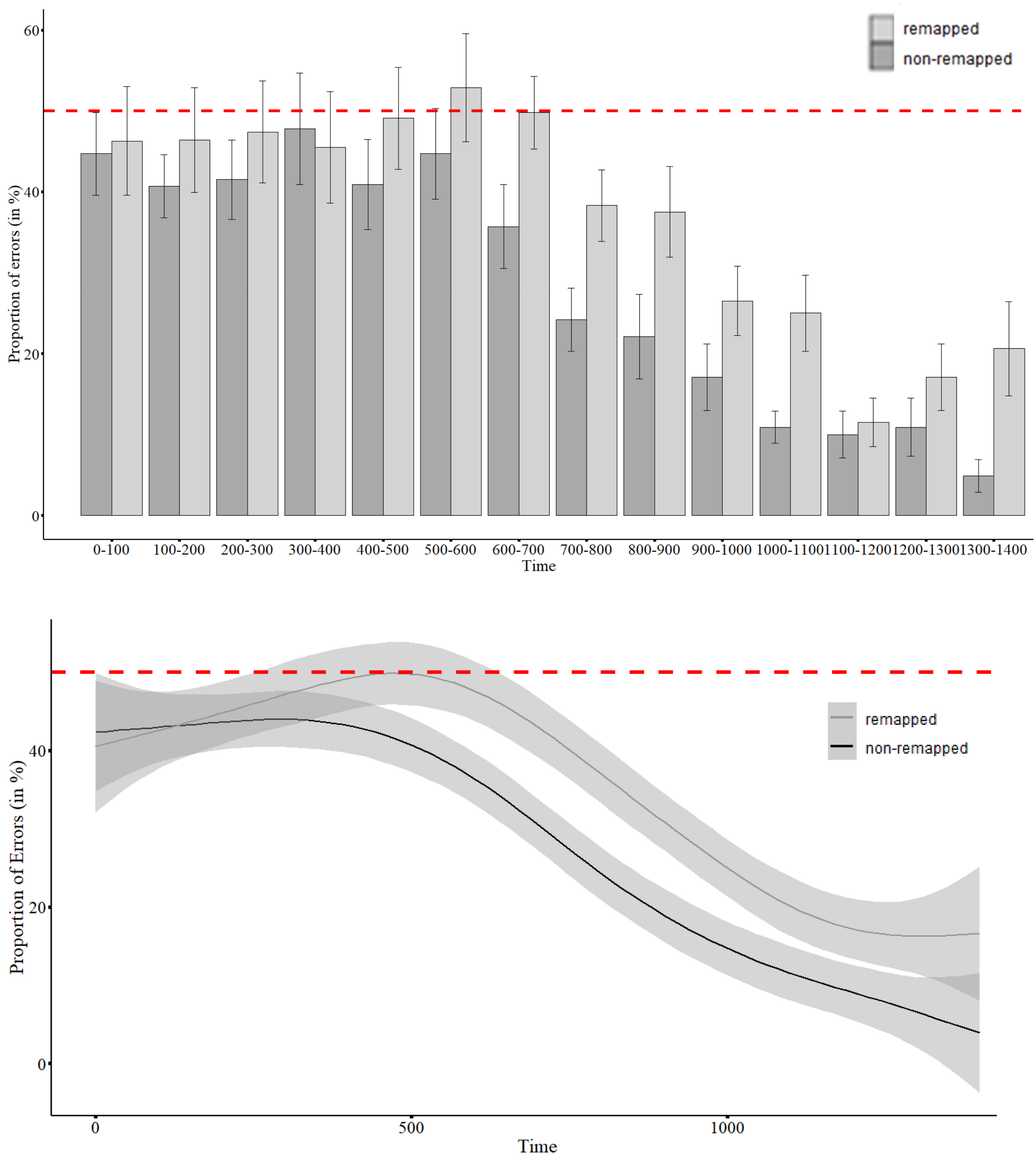


Note. These figures compare the mean proportion of outcome expectancy errors indicating the original response as correct for remapped stimuli (outcome expectancy action slips) with the mean proportion of outcome expectancy errors indicating an incorrect response as correct for nonremapped stimuli in all time intervals. The top figure displays the errors within timed bins, with error bars representing the standard error of the mean. The bottom figure features continuous lines illustrating the proportion of errors over time. Shading denotes the standard error of the mean. In both figures, the dashed line represents chance-level performance of 50%. See the online article for the color version of this figure.

under time pressure. Participants exhibited a higher rate of errors in outcome expectancies for remapped stimuli presented with the original response key buttons compared to errors for nonremapped stimuli presented with an incorrect response. This pattern was consistently observed in early time intervals (600–1,000 ms), whereas it was less discernible in later time intervals.

Figure 4

Proportion of Outcome Expectancy Errors in Experiment 3



Note. These figures compare the mean proportion of outcome expectancy errors indicating the original response as correct for remapped stimuli (outcome expectancy action slips) with the mean proportion of outcome expectancy errors indicating an incorrect response as correct for non-remapped stimuli in all time intervals. The top figure displays the errors within timed bins, with error bars representing the standard error of the mean. The bottom figure features continuous lines illustrating the proportion of errors over time. Shading denotes the standard error of the mean. In both figures, the dashed line represents chance-level performance of 50%. See the online article for the color version of this figure.

General Discussion

Understanding the processes underlying automatic and fast responding to stimuli is a fundamental topic of interest in psychological science. One particular phenomenon of interest is that of action slips, which refers to emitting the originally correct response for a stimulus despite a change in the correct response. It has been proposed that action slips may arise from stimulus-driven processes involving the activation of mental associations between a response and the context in which it is emitted. It has also been proposed that these slips may become more apparent after extensive practice when actions are performed under time pressure. In support of this notion, Hardwick et al. (2019) demonstrated the presence of action slips in early time intervals following extensive practice of S–R mappings.

Outcome Expectancies and Action Slips

In the current study, we first replicated the key findings of Hardwick et al. (2019) using their materials but in an online implementation, further establishing the robustness of their results. Building upon this foundation, we aimed to investigate an alternative hypothesis suggesting that action slips under time pressure might also be linked to errors in outcome expectancies. Drawing on the influential study by Hardwick et al. (2019), we employed similar materials in two experiments that examined whether errors in outcome expectancies could also be observed under time pressure.

Our findings provide support for the alternative hypothesis, demonstrating that, under time pressure, errors in self-reported outcome expectancies for original responses to remapped stimuli occur more frequently compared to errors for nonremapped stimuli, indicating the occurrence of outcome expectancy action slips. These errors were most robustly observed in early time intervals in both experiments (400–1,000 ms). These findings align with and extend the results of Buabang et al. (2023), who also found evidence for the role of outcome expectancies in action slips. Importantly, our study extends this reasoning to the procedure of Hardwick et al. (2019) which has been utilized in a manner supporting claims of dual-process models and that involves more than two possible responses, reducing the likelihood of errors resulting from random guessing by allowing the comparison with other responses.

Implications

The current results highlight the complex nature of fast responding and suggest that action slips may not solely reflect S–R associations but can also involve errors in predicting the expected outcomes of our actions. Under time pressure, participants may incorrectly infer that an original response to a remapped stimulus will be correct, and this might be what drives action slips. In contrast to assumptions of dual-process theories as highlighted by Hardwick et al. (2019), such goal-directed inferential processes are not necessarily slow. Importantly, however, they can produce errors depending on the availability of time (Moors et al., 2017). For instance, one may engage in Bayesian sampling of relevant information to allow for "good enough" inferences within the given time restrictions (Sanborn & Chater, 2016). Under strict time pressure, episodes of previous trials may be sampled and drive automatic inferences about action outcomes that can lead to inaccurate responses to a stimulus. As argued elsewhere, this time-efficient use of goal-directed inferences may be evolutionarily relevant, helping us deal with uncertainty and save energy (Gigerenzer & Brighton, 2009; Parr et al., 2022).

From this perspective, the current findings may invite broader considerations about the real-world implications of time pressure and its connection with other everyday situations. Time-pressure manipulation, as used in this study, cannot only be seen as a model of real-life situations in which people have limited time but also of situations in which people are distracted, tired, or faced with other environmental demands that limit their ability to carefully sample relevant information and engage in more elaborate inferences. Future research may delve further into the potential connections between these suboptimal conditions and errors in performance, to shed light on how these conditions can influence behavior in various (real-world) domains.

Our findings are also relevant to research on volition and action control. Specifically, evidence that action slips can also be caused by goal-directed inferential processes is consistent with the findings of Ach (1910) that people are more likely to make action slips when they are tired or stressed, because such circumstances could, similar to time pressure, impair their ability or motivation to make accurate inferences about action outcomes. It also aligns with prior research indicating that individuals with an action-oriented disposition (i.e., who remain goal-focused even under suboptimal circumstances) are less prone to making action slips (Kuhl & Beckmann, 1994). This could be attributed to their increased likelihood of making accurate goal-directed inferences under challenging circumstances. Furthermore, our research aligns with theoretical perspectives proposing that action slips are rooted in difficulties translating goal intentions into action (Heckhausen & Beckmann, 1990) and connects these difficulties to inaccurate inferences about action outcomes.

Limitations

It might be argued that the outcome expectancy task employed in our study does not directly reveal the automatic outcome expectancies that underlie actual responding. This task required participants not only to predict the outcome of a response to a stimulus but also to process the presented response on the screen and generate a response using a different response button to indicate accuracy. This additional cognitive processing introduces more steps compared to mere outcome prediction. This might explain why accuracy levels in this task reached their peak slightly later than in the S–R task of Experiment 1. However, this may also present a limitation in the sense that we cannot compare the exact timing of action slips and outcome expectancy action slips.

Another limitation is that we did not manipulate the amount of training provided to participants in the current study. We therefore cannot conclude that the (outcome expectancy) action slips are crucially dependent on the amount of training. Notably, however, previous studies have already established that action slips and outcome expectancy errors depend on the extensiveness of the training (Buabang et al., 2023; Hardwick et al., 2019).

It is also important to note that our study did not directly test the idea that outcome expectancy processes underlie action slips. We did not probe action slips and errors in outcome expectancies in the same paradigm and therefore could not assess mediation (as did Buabang et al., 2023). Two primary reasons guided this decision. First, within the current paradigm, evaluating both action slips and errors in outcome expectancies simultaneously would introduce considerable complexity, potentially leading to confusion among participants (Wood & Mazar, 2023). Second, as noted above, measured outcome expectancies do not seamlessly map onto the mental-level construct of outcome expectancies. For instance, outcome expectancies might require translation into a behavioral response, a process influenced by multiple factors.

Because of these limitations, we acknowledge that our results do not provide conclusive evidence that goal-directed processes instead of associative processes underlie action slips. Instead, the current study provides a viable alternative explanation for the results of Hardwick et al. (2019) and, alongside the findings of Buabang et al. (2023), offers supporting evidence for a specific prediction derived from this account.

Conclusion

Our study contributes to the understanding of action slips under time pressure by highlighting the potential involvement of goal-directed processes. By emphasizing the role of outcome expectancies, we shed light on (suboptimal) behavior under time pressure. Future research should continue to explore the underlying mental processes of action slips and further investigate the interplay between S–R associations, goal-directed processes, and outcome expectancies in fast responding to a stimulus.

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