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Rewarding performance feedback alters reported time of action

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ABSTRACT

Past studies have shown that the perceived time of actions is retrospectively influenced by post-action events. The current study examined whether rewarding performance feedback (even when false) altered the reported time of action. In Experiment 1, participants performed a speeded button press task and received monetary reward for a presumed "fast," or a monetary punishment for a presumed "slow" response. Rewarded trials resulted in the false perception that the response action occurred earlier than punished trials. In Experiments 2 and 3, the need for a speeded response and reward were independently manipulated in order to decouple the cognitive and reward components in the feedback signal. When tested independently, neither variable affected the judged time of action. We conclude that meaningful feedback (fast or slow) is only used when made salient by reward, to modulate the judged time of an action.

1. Introduction

Friedman's theory of temporal memory proposes that a temporal report is reconstructed from relevant contextual information rather than directly perceived (Friedman, 1990). A number of studies on the perceived time of action supports this view, illustrating that temporal report is not a direct perceptual readout of the action system but is inferred from surrounding events (e.g., Banks & Isham, 2009, 2010; Haggard & Clark, 2003; Haggard, Clark, & Kalogeras, 2002; Isham, Banks, Ekstrom, & Stern, 2011; Moore & Haggard, 2008). The factors which alter temporal reports vary. For example, Isham et al. (2011) showed that post-action information, rather than pre-action attributes, dictated the report time of when an action occurred. In their study, participants pressed a button in a race against a competitor and received a tone feedback indicating whether they "won" or "lost" the race: "win" trials were reported as earlier and "loss" trials as having occurred later, consistent with false feedback, but not with the true time of action. The authors concluded that retrospective knowledge of winning or losing modulated the judged time of action.

While Isham et al. (2011) provided evidence in support of the temporal reconstruction hypothesis, it was unclear what component of the feedback contributed to this reconstruction process. Arguably, the single feedback signal in Isham et al. consisted of at least two attributes: Cognitive information about the speed of the button press and emotional valence associated with winning and losing to a competitor. Given that cognitive information and emotional valence were communicated in the same feedback signal, it is unclear to what extent each component affected the temporal report of action onset. It is possible that the temporal shift occurred at a conscious level such that the temporal report was adjusted to be consistent with the cognitive interpretation (i.e. "I won, so I must have pressed earlier"), or that emotional valence might have played a role in altering the operating mechanisms of an internal clock (Treisman, Faulkner, Naish, & Brogan, 1990; Tse, Intriligator, Rivest, & Cavanagh, 2004). For instance, it has been observed that a winning experience heightens emotional arousal (e.g.

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Anderson & Brown, 1984; Dickerson, 1984; Wulfert, Franco, Williams, Roland, & Maxson, 2008; Wulfert, Roland, Hartley, Wang, & Franco, 2005), which in turn could have made the winning event appear longer lasting than the losing event (Angrilli, Cherubini, Pavese, & Manfredini, 1997). This would lead to the impression that the winning keypress occurred further back in time than the losing action.

The goal of the current study was to determine whether the temporal shift reported in Isham et al. (2011) was adjusted based on a cognitive interpretation or emotional valence in response to the feedback signal. To do so, we modified the protocol used in Isham et al. (2011) such that the emotional valence and cognitive interpretation were decoupled and independently tested: emotional valence was manipulated using monetary reward and cognitive interpretation by feedback regarding speed of response. In Experiment 1, both emotional and cognitive components were included to see if the same temporal shift as Isham et al. would be observed. Subsequently, the individual components were tested separately in Experiments 2 and 3. If the temporal shift were dictated by one attribute and not the other, then the temporal shift should only be observed in one of the latter two experiments. However, if both elements were necessary in modulating the temporal shift, then the effect should only be observed in Experiment 1 where both cognitive and emotional attributes were present.

2. Experiment 1

2.1. Monetary feedback for speed of action

The purpose of Experiment 1 was to examine whether speed-based performance feedback and monetary reward could retrospectively shift the judged time of a keypress. Despite the absence of a live competitor, we predicted the same effect of temporal shift as reported by Isham et al. (2011).

2.1.1. Participants

Fourteen undergraduate volunteers participated in the study (11 females, ages 18–25). The volunteers received partial course credit for their participation as well as a $5.00 reward as part of the experimental manipulation. The protocol complied with the Institutional Review Board at University of California, Davis.

2.1.2. Design

A 3(Game outcome/Reward) × 2(pitch) mixed design was used. Game outcome refers to the combination of speed-based feedback and reward given to the participants. A 550 Hz tone, a 300 Hz tone, or a silence was delivered 60 ms after the keypress to indicate a "win", a "loss", or no feedback. Unbeknownst to the participants, each of the possible outcomes did not reflect the true reaction time, and was randomly presented by the computer with an overall probability of 33.3%. In the "winning" (fast/rewarded) condition, participants were told they pressed the button relatively faster than their own average and were monetarily rewarded ($0.12). In the "losing" (slow/punished) condition, participants were told that they pressed the button relatively slower than their own average, resulting in a monetary loss ($0.05). Of note, monetary gains and losses have been verified as reliable indicators of positive and negative valence in emotion studies (Sakuragi & Sugiyama, 2009). We chose an uneven reward scheme for "wins" vs. "losses" because we found from pilot studies that participants felt frustrated early on if the accumulation of "losses" were greater than "wins". Thus, to motivate participants to engage in the experiment, the rewarded amount for winning was greater than the penalized amount for losing. In the control condition, no feedback and no monetary reward were given. Pitch refers to the tone assigned to indicate a "win" vs. a "loss"; half of the participants received a high pitch tone as the winning tone and the remaining half a low pitch tone.

Monetary chips were exchanged immediately after the speeded button press and tone feedback and prior to the temporal report. It is possible that this process may have distracted participants from their primary temporal report task. Importantly, however, any attentional effects due to the time it took to exchange chips would have been equivalent in the "win" and "lose" conditions and thus, our primary interest in the difference in report in those two conditions would not be affected (see also Experiment 3). Similarly, any shift in visual attention between the visual cue (red square) and the clock that could have distracted participants and caused variability in their temporal report would be equivalent under all experimental conditions and would therefore not differentially affect the comparisons of interest.

2.1.3. Apparatus

A routine in Matlab Psychophysics Toolbox Version 3 (Brainard, 1997; Kleiner, Brainard, & Pelli, 2007; Pelli, 1997) was used to present the clock, the cue, game outcome, and to record the actual time of these events as well as the actual time of keypresses. The experiment was conducted on a MacBook Pro computer.

The clock was 90 mm in diameter with 60 evenly spaced tic marks numbered from 0 to 59. The position of the clock was at the upper left corner of the computer screen. In each trial, a cursor on the computer screen, observed from a distance of 60 cm, moved in the clockwise direction around the clock face, completing two rotations in 6.1 s (see Fig. 1).

The cue was a red square (100 × 100 pixels, subtending 1.90°) presented briefly for 50 ms. The delivery time of the cue was randomly selected from 26 time options within the temporal range of 2500–5000 ms after the trial onset (i.e., an increment of 100 ms between 2500 and 5000 ms yields 26 temporal values). The response button was the keyboard key "A". The actual time of keypress was recorded by the Matlab script.

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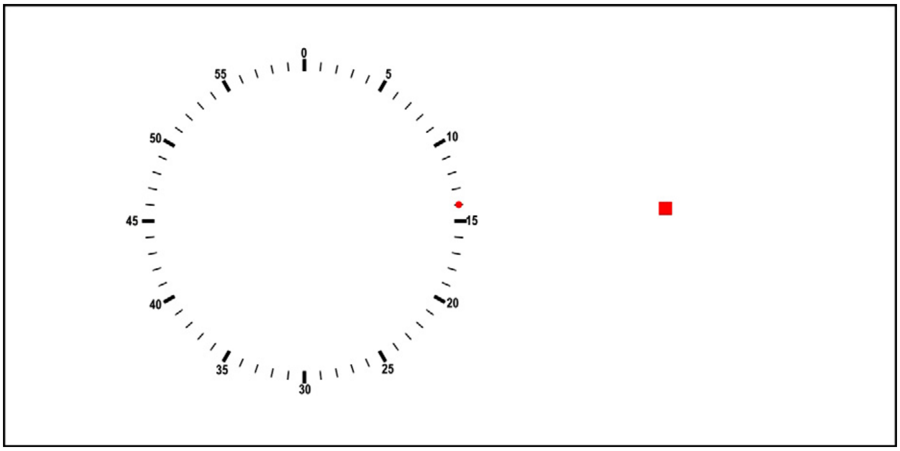

Fig. 1. The clock has 60 tick marks (left). A red dot circulates around the clock face and competing two rotations in 6.1 s. A red square (right) was randomly presented 2500–5000 ms after the onset of the clock. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2.1.4. Procedure

Prior to the actual experiment, participants were asked to press a button in response to the cue 15 times. The participants were informed that the computer subsequently calculated the average reaction time. During the experiment, each participant completed 90 trials. Individual participants were seated in front of the laptop computer. Each trial began with the start of the clock that completed two rotations. At any time during the rotations, a single red square was presented. The participants were asked to respond to the red square target by pressing the "A" key on the keyboard as fast as they could (i.e., they were told that reaction time was important). It was emphasized that a faster reaction time compared to the average reaction time measured prior to the experiment would result in a "fast" tone and a slower reaction would result in a "slow" tone. If no tone was given (i.e., the control condition), the participants were informed that the computer simply did not provide any feedback. This feedback tone was presented 60 ms after the participant responded. Additionally, after each "fast" response, participants were given a poker chip (valued at $0.12) and after each "slow" the participants returned a different poker chip (valued at $0.05). If the computer did not sound, no chips were exchanged. At the end of the trial, the participants reported the time of their keypress by reporting numbers from the clock face. After completion of the experiment, all participants received $5.00 compensation irrespective of the number of poker chips gained or lost.

2.1.5. Results

The relative time of action (i.e., the difference between actual time of keypress and reported time of keypress) was subjected to a 3 game outcome (win, loss, or control) × 2 pitch (high or low) mixed ANOVA. There was no main effect for pitch, $F(1, 12) = .060$, $p = .811$, $\eta^2 = .005$, nor an interaction between pitch and outcome, $F(2, 24) = .722$, $p = .496$, $\eta^2 = .057$. The lack of a significant main effect and interaction suggested that tone pitch did not have an effect on the judged time of action and the factor was therefore collapsed in subsequent analyses.

The primary focus of the current experiment was to examine the effect of game outcome on temporal judgment when performance on a speeded response task was rewarded (Fig. 2a). There was a main effect of game outcome, $F(2, 24) = 4.107$, $p = .029$, $\eta^2 = .255$. Pairwise comparison analysis conducted on the winning ($M = -423$, $SE = 32$) and losing ($M = -379$, $SE = 37$) conditions showed that the winning keypress was judged as having occurred earlier than the losing keypress, $t(1, 13) = 2.3$, $p = .02$. These results are consistent with the findings by Isham et al. (2011) and demonstrated that an emotionally meaningful (i.e. rewarded or punished) feedback signal regarding the time of action produced a differential shift in the judged time of action.

To further explore the reliability of these group results, we calculated the binomial probability of getting 12 out of 14 participants with earlier reported times for "win" compared to "lose" trials (Fig. 3a). The prior likelihood of participants showing one or the other pattern of result was set to .5 (i.e., random). The calculated probability of getting 12 out of 14 participants with faster "win" times than "lose" times was .006; thus, it is highly unlikely that our group statistic was spurious.

Although the primary analysis of interest in this study was between "win" and "lose" trials, we additionally compared the control (no-tone) condition ($M = -453$, $SE = 36$) against the "win" and "lose" conditions as an additional measure of the directionality of the shift in judged time of action. Past findings showed that the presence of a non-informative post-action tone shifted the judged time of action in its direction (i.e., to be later) (e.g., Banks & Isham, 2009; Haggard & Clark, 2003). Thus, the winning and losing conditions in this experiment would be expected to result in later temporal reports than the control trials based solely on the presence of a sensory tone. Any modulation for an "earlier" report should therefore be closer to temporal reports in the control condition. The results demonstrated that control trials resulted in significantly earlier reports than losing trials ($p < .05$), but did not differ from winning trials ($p > .05$). That winning trials resulted in sim-

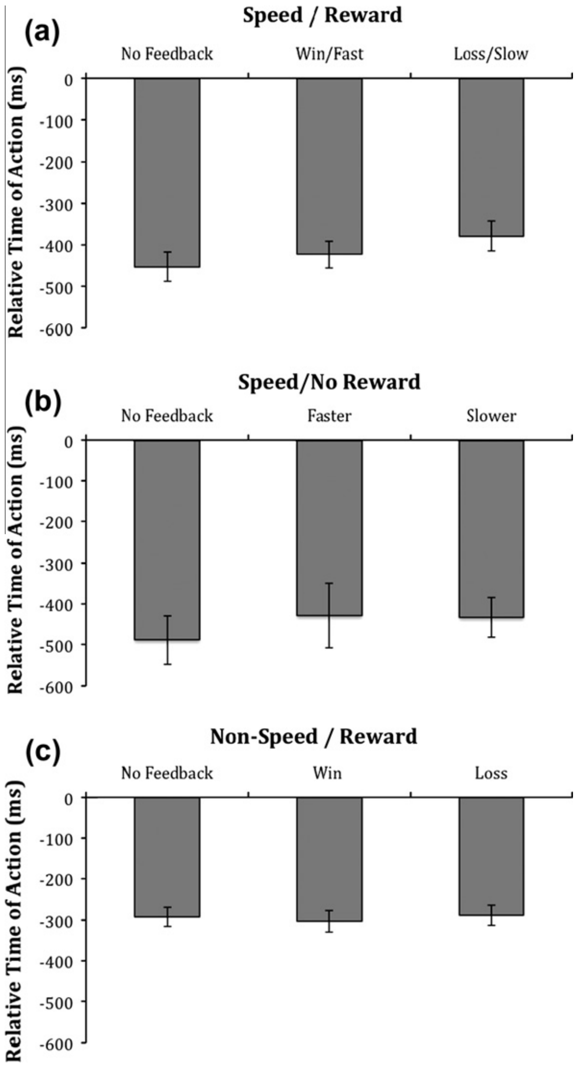

Fig. 2. The relative time of action (the difference between reported time and actual time of keypress) is represented as a function of feedback: (a) Experiment 1 – reward was given in association with speed-based feedback. (b) Experiment 2 – speed-based feedback was given in the absence of reward. (c) Experiment 3 – reward was given in the absence of feedback. *Note*: the negative relative time value indicates reported time was earlier than actual time of action.

ilar reports as the control trials (and that both were earlier than losing trials) suggests that receipt of a "winning" feedback signal resulted in a relative backward shift in the reported time of keypress.

To further emphasize the temporal difference between a presumed "winning" keypress and a presumed "losing" keypress, linear regression analyses were performed on the *z*-scores of the reported and actual times of keypress separately for the "winning" and "losing" conditions. In this manner, the analyses ensured that the difference in the reported time of winning and losing keypresses was not confounded by the actual time of keypress. Results showed that the reported time of action shifted linearly with the reaction time (R^2 = .23 and .20 for winning and losing trials, respectively), $p < .05$. As shown in Fig. 4, the slopes of the best-fitted lines for the reported time of winning and losing were approximately .45 for both trials (these are very similar to the slope values reported by Isham et al.; .48 for winning trials and .47 for losing trials). The fact that the slope values were not 1 or 0 suggests that the reported time of action was not exclusively dependent on reaction time nor was it exclusively independent of it. While the reported time of action scaled with reaction time, the difference in intercept values (.01 and .08 for fast/rewarded and slow/punished, respectively) suggested that reported time of action was an adjusted value based on our feedback manipulation, but was still anchored to the true reaction time. These findings thus provided support for both Friedman's theory of temporal reconstruction and the working hypothesis that the judged time of action is influenced by extra-sensory factors: participants relied on both the actual time of keypress and extra-sensory information to determine when they pressed the button.

These findings here demonstrate that a feedback signal that provided cognitive information that the response was fast and an emotional component associated with winning money produced an earlier judged time of action report. However,

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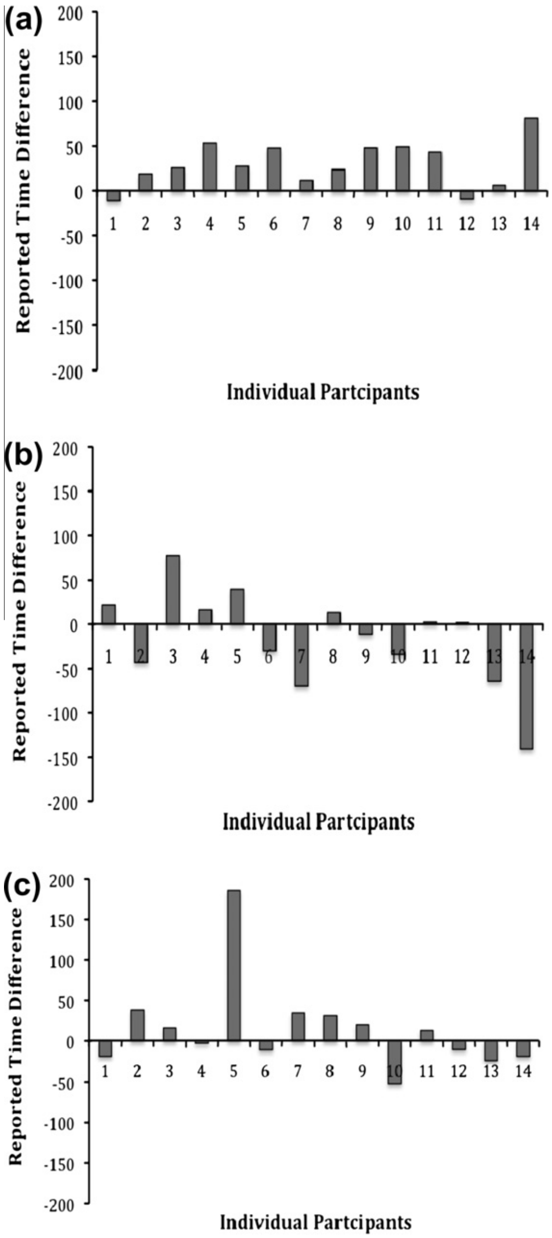

Fig. 3. The difference between relative time of action reported for positive and negative outcomes across individual participants. The more positive the difference, the earlier the reported time of action for positive outcome. (a) Experiment 1 – reward was given in association with speed-based feedback. (b) Experiment 2 – speed-based feedback was given in the absence of reward. (c) Experiment 3 – reward was given in the absence of feedback.

the result could be attributed to either the reward (and its associated emotional valence) *or* speed-based performance feedback. Thus, we next independently test whether each component is necessary and sufficient to modulate the judged time of an action. Experiment 2 examined the effect of performance feedback in the absence of reward, while Experiment 3 tested whether reward would suffice at modulating the judged action time in the absence of speed-related feedback.

3. Experiment 2

3.1. Testing the sufficiency of performance feedback

The goal of this experiment was to test whether speed-related feedback modulated temporal report when reward was absent, which presumably also minimized the contribution of emotional valence. If modulation were observed, it would imply that feedback regarding the speed of the button press in the absence of reward and the associated emotional valence, was

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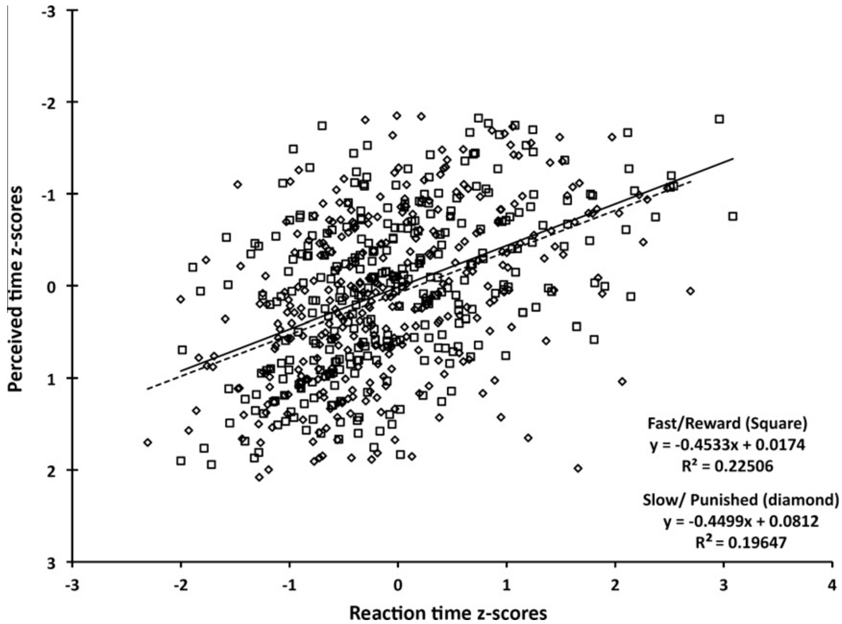

Fig. 4. Distribution of the judged time *z*-scores of the fast/rewarded (square data points) and slow/punished (diamond data points) trials as a function of reaction time *z*-scores. Best fitted lines of fast/reward and slow/punished trials show that the reported time of keypress was adjusted in accordance with the presumed outcome; a rewarded press was reported as significantly earlier (more negative slope value; solid best-fitted line) than a punished keypress (less negative slope value; dashed best-fitted line), $p < .05$.

sufficient to produce a shift in the reported time of action. If, however, there was no modulation, it would suggest that the cognitive feedback regarding speed of button press alone was not sufficient to produce a shift temporal report.

3.1.1. Participants

Fourteen undergraduate volunteers participated in the study (13 females, ages 18–25). The volunteers received partial course credit for their participation. The protocol complied with the Institutional Review Board at University of California, Davis.

3.1.2. Design

As in Experiment 1, a 3(Game outcome) × 2(pitch) mixed design was used. However, in contrast to Experiment 1, no monetary reward/punishment was given in this experiment. Game outcome thus consisted of "fast", "slow," and control (no feedback).

3.1.3. Apparatus

The clock apparatus and data acquisition apparatus was the same as described in Experiment 1.

3.1.4. Procedure

The procedure was the same as in Experiment 1 but no monetary reward or punishment was given. It was emphasized that a faster reaction would result in a "fast" tone, a slower reaction would result in a "slow " tone, and a silence provided no feedback. As in Experiment 1, the tones were randomly presented and did not reflect the true reaction time performance. After a trial ended, the participants reported the time of their keypress by reading the numbers from the clock face.

3.1.5. Results

The relative time of action was calculated as the difference between the actual time and subjective time of when the button was pressed; the larger the difference in the negative direction, the earlier the judged time of action.

The relative time was subjected to a 3 outcome (fast, slow, control) × 2 pitch (high, low) analysis of variance. No main effect of pitch, $F(112) = .011$, $p = .918$, $\eta^2 = .001$, nor an interaction effect between pitch and game outcome, $F(2, 24) = .823$, $p = .451$, $\eta^2 = .064$, was observed. However, there was a marginal main effect of game outcome, $F(2, 24) = 2.594$, $p = .095$, $\eta^2 = .178$. Pairwise comparison between the no-tone control condition and the "fast" and "slow" conditions showed that the no-tone keypress ($M = -488$ ms, $SE = 61$) was judged as earlier than a "fast" ($M = -429$, $SE = 83$; $p = .058$) or a "slow" ($M = -433$, $SE = 50$; $p = .035$) keypress. This was in contrast to Experiment 1 where "fast/win" trials were earlier than "slow/lose" trials and equivalent to the control condition (see above). This result also replicated previous results (e.g., Banks

& Isham, 2010), which showed that a no-tone condition was judged as earlier than other conditions that were coupled with tones because a tone pulled the temporal report forward in time.

Importantly, there was no difference in the reported time between "fast" and "slow" keypresses, $p = .901$ (Fig. 2b). These results are also in opposition to those in Experiment 1. Post-interviews suggested that some participants did not consistently pay attention to the tone since they were not emotionally invested in the task. However, the null effect may not have been due to insufficiency of the cognitive signal, per se, but because the cognitive feedback signal was not fully processed when it was devoid of meaningful context. This suggests that reward may have been critical for eliciting the temporal distortion observed in Experiment 1 because of its role in increasing the emotional relevance of the cognitive feedback signal.

4. Experiment 3

4.1. Testing the sufficiency of reward

Complementary to Experiment 2, Experiment 3 examined the effect of reward independent of speed-based performance. It is possible that emotional valence was the necessary manipulation for producing the shift in judged time reported in Experiment 1. To test this hypothesis, we manipulated reward in the absence of a speeded action. In contrast to the previous two experiments, participants in the current experiment were not instructed to press a button as rapidly as possible in response to the cue, but instead were told to press at any time of their choosing. Upon keypress, they were given feedback as to whether they won or lost money on that trial; importantly, feedback contained no information about the speed of response. If the judged time of action was modulated in this experiment, it would suggest that reward, and any associated emotional factors, was the critical factor affecting the judged time of action.

4.1.1. Participants

Fourteen undergraduate volunteers participated in the study (7 females, ages 18–25). The volunteers received partial course credit for their participation as well as a $5.00 reward as part of the experimental manipulation. The protocol complied with the Institutional Review Board at University of California, Davis.

4.1.2. Design

As in Experiment 1, a 3 Game outcome ("win", "loss", control) × 2 Pitch (high, low) mixed design was used. In contrast to Experiment 1, game outcome was not judged on the basis of speed. Thus, game outcome consisted of "winning" (tone indicated monetary gain), "losing" (tone indicated monetary loss), and control (no tone and no monetary exchange).

4.1.3. Apparatus

The clock apparatus was the same as described in Experiment 1.

4.1.4. Procedure

The procedure was the same as in Experiment 1 with the exception that the participants' earnings were not evaluated based on speed. Instead, the participants were asked to press the "a" key at any time of their choosing after the red square was shown. It was emphasized that their winnings were based on some random algorithm programmed on the computer. Tones and monetary rewards were given in the same manner as in Experiment 1.

4.1.5. Results

The relative time of action (i.e., the difference between actual time and subjective time of when the keypress was made) was subjected to a 3 game outcome ("win", "loss", control) × 2 pitch (high, low) mixed ANOVA. Consistent with other experiments in the current study, there was no main effect for pitch, $F(1, 12) = .534$, $p = .479$, $\eta^2 = .043$, nor an interaction between pitch and outcome, $F(2, 24) = .250$, $p = .781$, $\eta^2 = .020$. The lack of main effect and the interaction suggests that tone pitch did not influence the judged time of action.

The critical manipulation in this study tested whether reward when dissociated from speed-based performance would have the same impact on judged time of action as when reward was related to speed-based performance (Fig. 2c). The ANOVA results showed no main effect for game outcome, $F(2, 24) = .211$, $p = .812$, $\eta^2 = .017$. This suggests that reward alone was insufficient to modulate the perceived time of action.

Additional pairwise comparisons between a "win" ($M = -269$, $SE = 48$), a "loss" ($M = -286$, $SE = 25$), and control ($M = -284$, $SE = 25$) were also not significantly different, $p > .05$. We speculate the lack of an effect between control and the reward conditions in this experiment may be due to the fact that the de-emphasis on a speeded response effectively changed the paradigm from one of cued-action to one of self-generated action. Since participants were asked to press the button at a time of their choosing (i.e., when they were feeling lucky) after they detected the stimulus cue (but not directly in response to it). Given this flexibility of when to act, it is likely that the response was preplanned instead of driven by the cue and therefore participants were less susceptible to the modulation by the sensory tone. Nevertheless, despite the insignificant difference between the control condition and reward conditions, the most important finding was the null difference between the two reward conditions. This suggests that reward outside of the context of a speeded response task did not modulate the perceived time of action.

4.2. Discussion

Evidence from a number of studies suggests that despite the presence of a timing device (e.g. a clock), the temporal report of a self-generated action varies across individuals and manipulations. Of these studies, a small subset have extended their investigation beyond the sensory experience (e.g., Ebert & Wegner, 2010 – authorship; Haggard, Clark, & Kalogeras, 2002 – intentionality; Isham et al., 2011 – feedback about a speeded task in the context of competition; Moore & Haggard, 2008 – probability of post-action tone). The current study further examined the effects of cognitive interpretation and emotional valence on the modulation of temporal report in a speed task. To test these effects, the cognitive influence was manipulated via performance feedback (fast vs. slow) and the emotional valence was manipulated by way of monetary reward.

4.2.1. General findings

A combined effect of both cognitive and emotional components was observed in Experiment 1. Participants reported the onset time of their keypress to be earlier when feedback indicated the action was faster and accompanied by reward compared to when feedback indicated a slower action and resulted in a monetary loss. However, when these two elements were decoupled, the temporal shift was not observed. In Experiment 2, when the tones indicated being fast or slow, but no monetary reward was given, participants may not have used the meaning of the tone to interpret the time of action. In Experiment 3, when the tone did not indicate whether the response was fast or slow, but instead was associated with a monetary win or loss, also no temporal shift was observed. Collectively, our data suggest that both cognitive and emotional valence must be present in order to produce a temporal shift in the reported time of action. We argue that the monetary reward provided the emotional incentive to use the cognitive information regarding speed to adjust the reported time of action.

Another important note is that of the direction of the temporal shift in Experiment 1. It was possible that the earlier reported time of the "winning" trials reflected a backward temporal shift for these trials, or that a forward temporal shift occurred in the "losing" trials. According to previous studies (e.g., Banks & Isham, 2009; Haggard & Clark, 2003; Haggard et al., 2002), judged time of action is often shifted forward toward the time of the subsequent event (e.g., a tone), and keypress in the control condition (no tone) is judged as the earliest since there is no binding or integration between the time of action and post-action event. Assuming this as the standard effect, we would have expected the feedback tone to temporally attract all trials forward, and away from the time of keypress that did not elicit a tone (i.e., control condition). However, this was not true for the "winning" trials in Experiment 1. Given that the "fast" trials in Experiment 2 (which was perceptually identical to the "winning" trials in Experiment 1) were judged to have occurred later than the control trails and as the same time as the "slow" trials, we speculate that a form of backward shifting, as facilitated by a cognitive interpretation "I won, therefore, I must have pressed earlier," must have contributed to the temporal judgment of "winning" trials in Experiment 1. This hypothesis however is beyond the scope of the current study and further examination is required to address the mechanisms of the shifting direction.

Our findings are significant in several ways. First, the results are consistent with those reported by Isham et al., illustrating that winning, when placed in a non-social context still facilitated a shift in the temporal report of a winning or losing action. This shift in the temporal report is cognitively driven and is consistent with the idea that temporal perception is malleable and can be influenced by events surrounding the action. More generally, this supports the perspective that temporal memory is a reconstructive process rather than directly experienced (Friedman, 1990). On this basis, our results challenge the validity of temporal report as a measure for awareness (Libet, Gleason, Wright, & Pearl, 1983). Although previous studies (e.g., Banks & Isham, 2009, 2010) have also previously made this argument, the current findings further demonstrate that the temporal report of an action onset is not exclusively predictive, but is, at least in part, retrospectively inferred, and contextually-driven (see also Moore & Haggard, 2008).

4.2.2. The role of reward and emotional valence

One of the main goals of this study was to examine the role of emotional valence as manipulated by reward on the reported time of action onset. When decoupled from the cognitive component, reward and presumably emotional valence, did not independently modulate the temporal report (Experiment 3). Although insufficient on its own, reward did play some role in the modulation of the judged time of action in Experiment 1. There are two possibilities for how reward might have affected the temporal report. First, reward could have served to motivate performance (i.e., participants tried harder to be fast so that they would be rewarded). Thus effort may have been critical for creating a situation where temporal report was shifted. However, a post-hoc comparison between the reaction times in Experiment 1 ($M = 572$, $SD = 36$; $N = 13$) and Experiment 2 ($M = 570$, $SD = 43$; $N = 14$) showed no difference between these two experiments, $t(1, 25) = .084$, $p = .386$. This indicates that the amount of effort and motivation were equivalent in the two tasks yet there was an effect of feedback in Experiment 1, but not in Experiment 2.

Alternatively, we propose that reward might be necessary for providing a meaningful context for the speeded performance. That is, reward may have provided an emotionally salient context for action performance that then caused participants to use feedback information to adjust their temporal report. This explanation is also consistent with the findings in

Isham et al. (2011) when participants competed against a human competitor. Although, there was no monetary reward in the Isham et al. study, it is likely that having won the race equates to being rewarded (e.g., monetary and social reward share the same neural circuitry; Izuma, Saito, & Sadato, 2008). Therefore, we concluded that monetary reward in the current study and winning a competition in Isham et al. commonly elicited an emotional response that increased the saliency of the fast/slow feedback signal: We hypothesize that emotional relevance was necessary to motivate the use of cognitive strategies to interpret performance based on feedback. Without the meaningful consequence of monetary reward (or social competition in Isham et al., 2011), the speeded feedback signal was too weak to initiate the post-hoc operation of adjusting the temporal report about the action.

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