Supplementary Results

Experiment 3.

Participants exhibited increased rates of temporal learning on the PIP-r, where reinforcements were introduced, compared to non-reinforced cues on the PIP-n, but yielded an initial increase in error that they had to overcome. We sought to determine whether the demonstrated error and increased learning rates could be manipulated by reinforcement magnitude. We also sought to ensure that the effects we were observing were the result of the reinforcement context and not due to cognitive load or spurious group differences. We hypothesized that increased reinforcement magnitude (higher reward) would result in increased temporal error and learning rates. To test this hypothesis, we recruited 40 additional naive participants to complete the PIP-magnitude (PIP-m; **Fig S5**). In the PIP-m, participants reproduced 1000ms, 3000ms, and 5000ms intervals of time and were reinforced with either monetary gains (rewarding trials), monetary losses (punishing trials), or nothing (neutral trials) scaled to the duration of time tested (up to ±$1, ±$3, ±$5, or nothing).

Using learning curves, participants showed significantly lower error at the last appearance (appearance 16) when compared to the first appearance for all cues on the PIP-m (**Fig S5A**; two-way mixed ANOVA; $F(1,76) = 22.36$, $p = 1.02e\text{-}05$***), consistent with the temporal learning behavior on the PIP-n and PIP-r. We then compared mean slope and intercept values between the PIP-r and the PIP-m for the 1000ms criterion duration to explore the effects of higher magnitude of reward (up to $3 on PIP-r compared to up to $1 on PIP-m). We found that participants on the PIP-m exhibited a significantly less steep slope (**Fig S5B**; mixed ANOVA; $F(1,61) = 5.479$, $p = 0.023$*) and significantly lower intercept (**Fig S5C**; mixed ANOVA; $F(1,61) = 4.111$, $p = 0.047$*) value compared to the PIP-r, demonstrating decreased temporal error and learning rate on the PIP-m compared to the PIP-r. This result indicated that the initial increase in error is likely due to the presence and magnitude of reinforcer. It also provided evidence for our hypothesis that higher reward (greater magnitude of reinforcement) on the PIP-s would generate greater temporal errors, as temporal errors are being reinforced at a greater magnitude.

We then compared the RPEs on the previous trial with PPEs on the current trial for the PIP-m, and we found a significant association between RPEs on the previous trial and PPEs on the current

trial for positively reinforced cues (**Fig S5, Experiment 3;** linear regression model; $F(1,579) = 8.871$, $p = 0.003$**). Interestingly, however, we did not see a relationship between RPEs on PPEs on negatively reinforced cues on PIP-m (**Fig 6, Fig S5, Experiment 3;** linear regression model; $F(1,590) = 0.276$, $p = 0.5995$). We also calculated 'RPEs' for neutral cues based on what participants would have accrued if the cues were positively reinforced. We compared these fictive 'RPEs' on the previous trial with actual PPEs on the current trial, and we found a significant association for the neutral cues on the PIP-m (**Fig S5, Experiment 3**; linear regression model; $F(1,577) = 9.487$, $p = 0.002$**). These results are consistent with our findings from the PIP-r, demonstrating a consistent effect of reinforcement on time perception that scales to the magnitude of reinforcer.

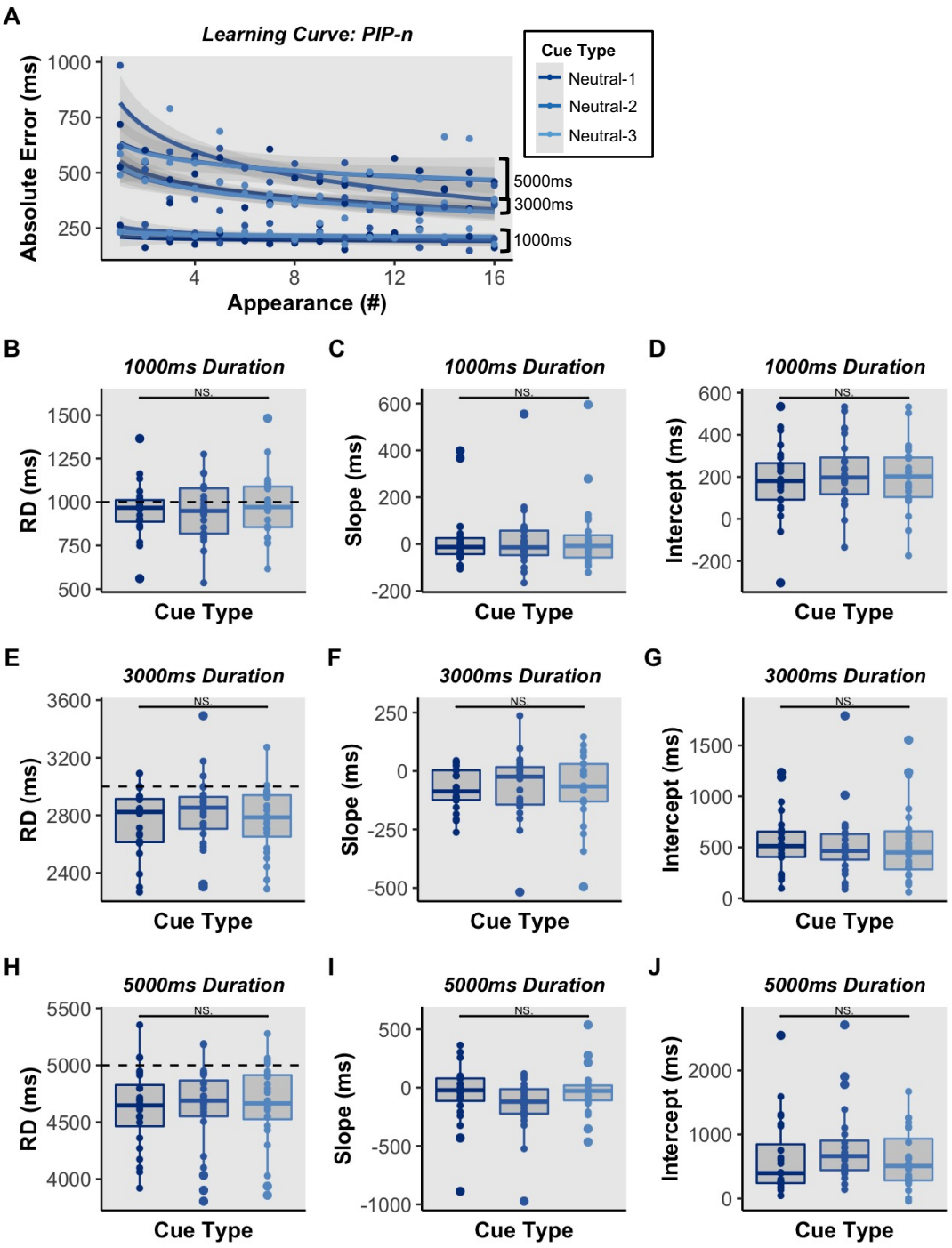

Fig S1. Interval timing is similar across all neutral cues on PIP-n. A. Mean learning curves for all neutral cues on PIP-n. **B.** No significant differences between mean reproduced duration (RD) for 1000ms neutral cues. **C.** No significant differences between mean learning rate (slope) for 1000ms neutral cues. **D.** No significant differences between mean intercept for 1000ms neutral cues. **E-G.** For 3000ms duration. **H-J**. For 5000ms duration. *NS. indicates not significant based on one-way mixed ANOVA.*

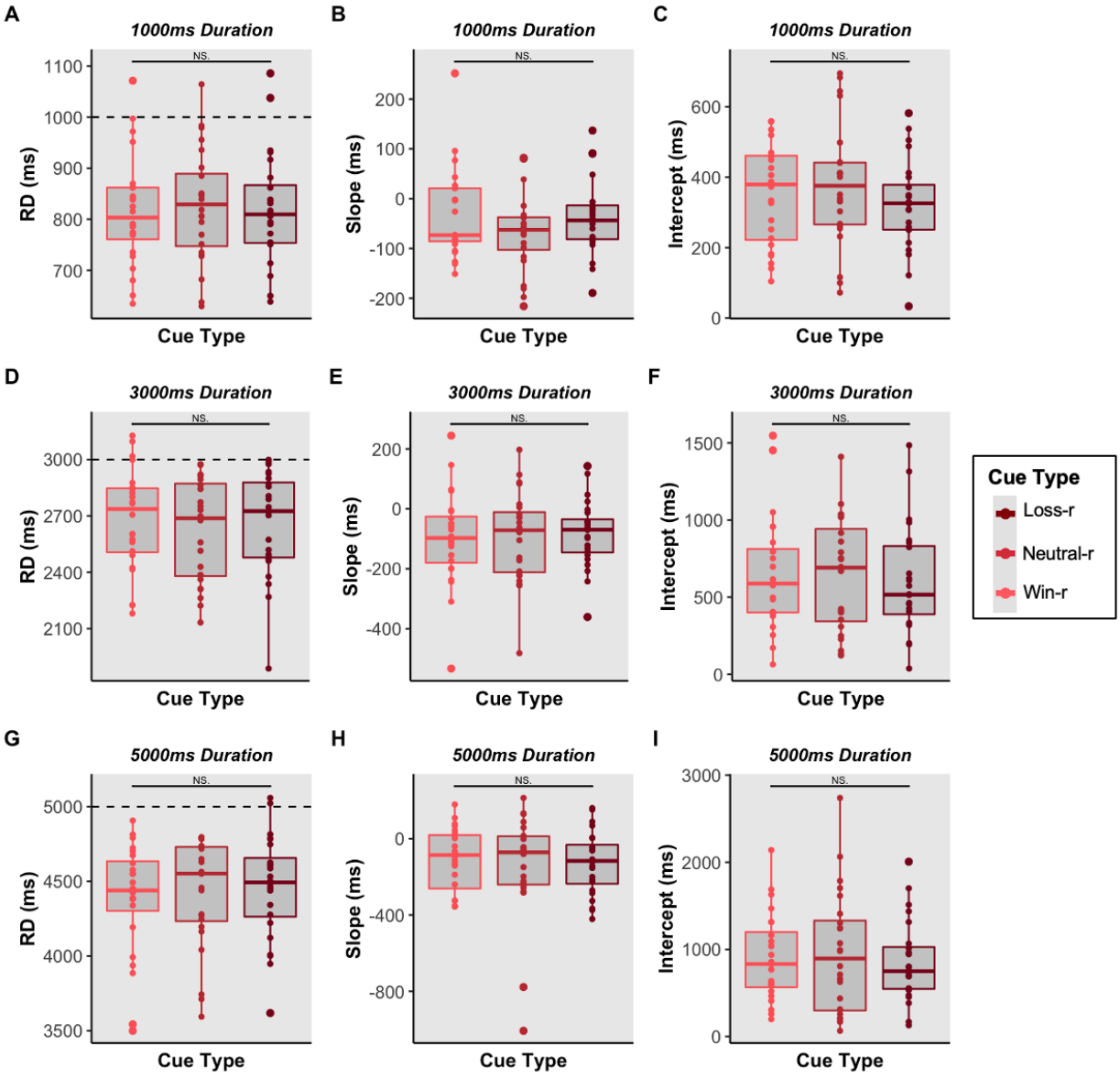

Fig S2. Interval timing is similar across all cues on PIP-r. A. No significant differences between mean reproduced duration (RD) for 1000ms cues. **B.** No significant differences between mean learning rate (slope) for 1000ms cues. **C.** No significant differences between mean intercept for 1000ms cues. **D-F.** For 3000ms duration. **G-I**. For 5000ms duration. *NS. indicates not significant based on one-way mixed ANOVA.*

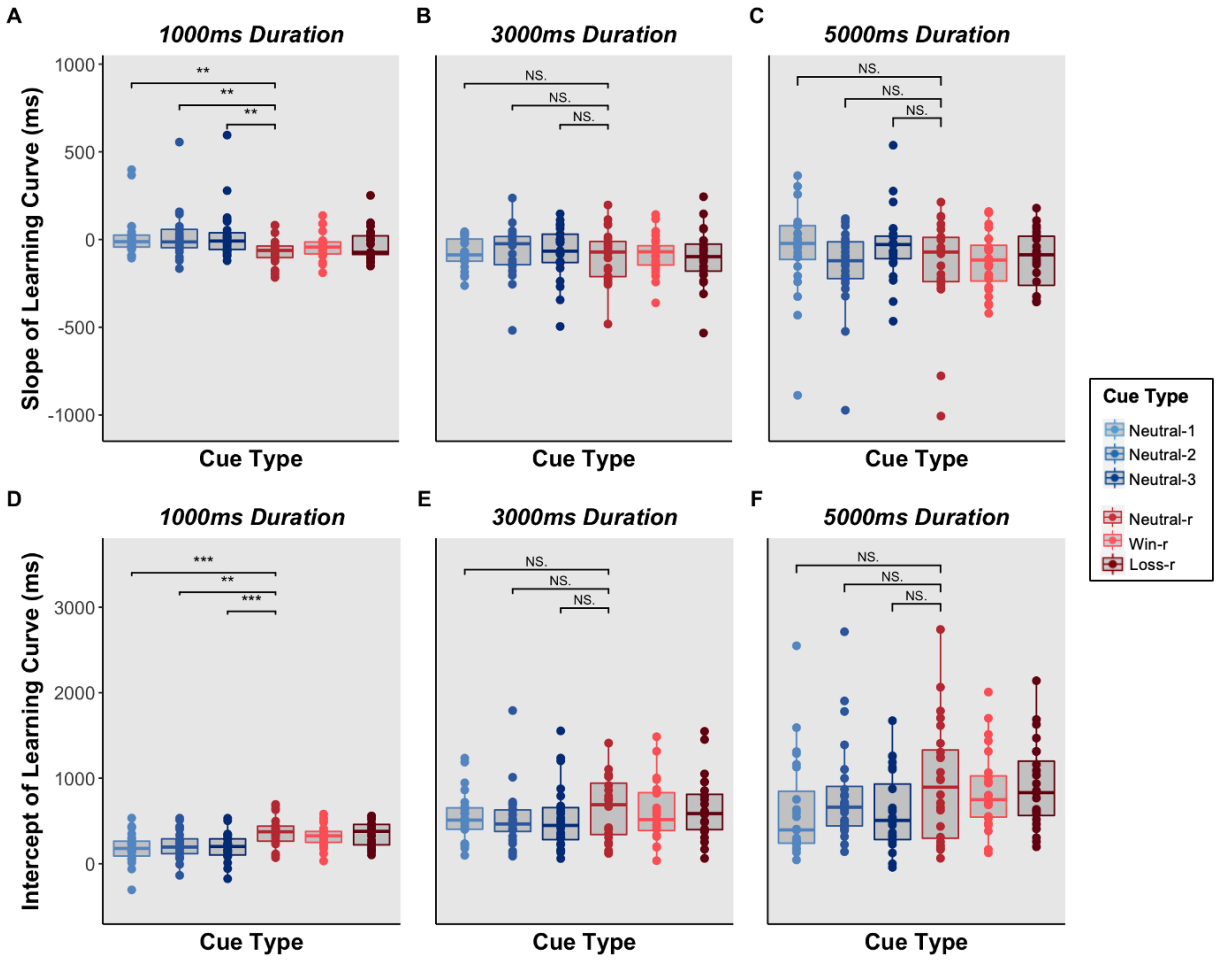

Fig S3. Learning rates differ between reinforced and non-reinforced cues for the 1000ms duration, but not the 3000ms and 5000ms durations. A. Comparing the slopes of the learning curves from the neutral cues on the PIP-n (blue) to the neutral cues on the PIP-r (red) for the 1000ms duration. **B.** for the 3000ms duration. **C.** for the 5000ms duration. **D.** Comparing the intercept of the learning curves from the neutral cues on the PIP-n (blue) to the neutral cues on the PIP-r (red) for the 1000ms durations **E.** for the 3000ms duration. **F.** for the 5000ms duration. *Significance based on p < 0.05*, 0.01**, 0.001***. NS. indicates not significant based on one-way two-sample t-tests.*

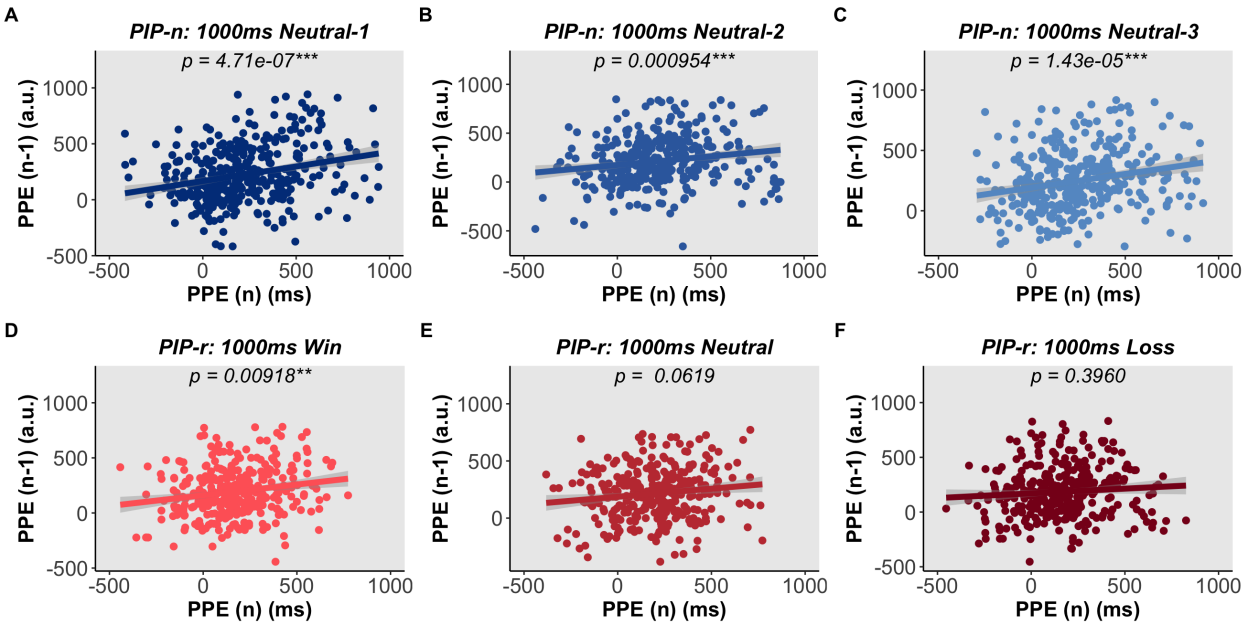

Fig S4. Performance prediction errors on previous trials (n-1) are associated with performance prediction errors on the current trial (n), except for the 1000ms loss cue on the PIP-r. A. Linear regression models show the results of the association between performance prediction errors of the previous trial (n-1) of the same type and performance prediction errors on the current trail (n) for the 1000ms neutral-1 cue on the PIP-n. **B-L.** for the other cues presented on the PIP-n and PIP-r. *Significance based on p < 0.05*, 0.01**, 0.001***. Shading = SEM.*

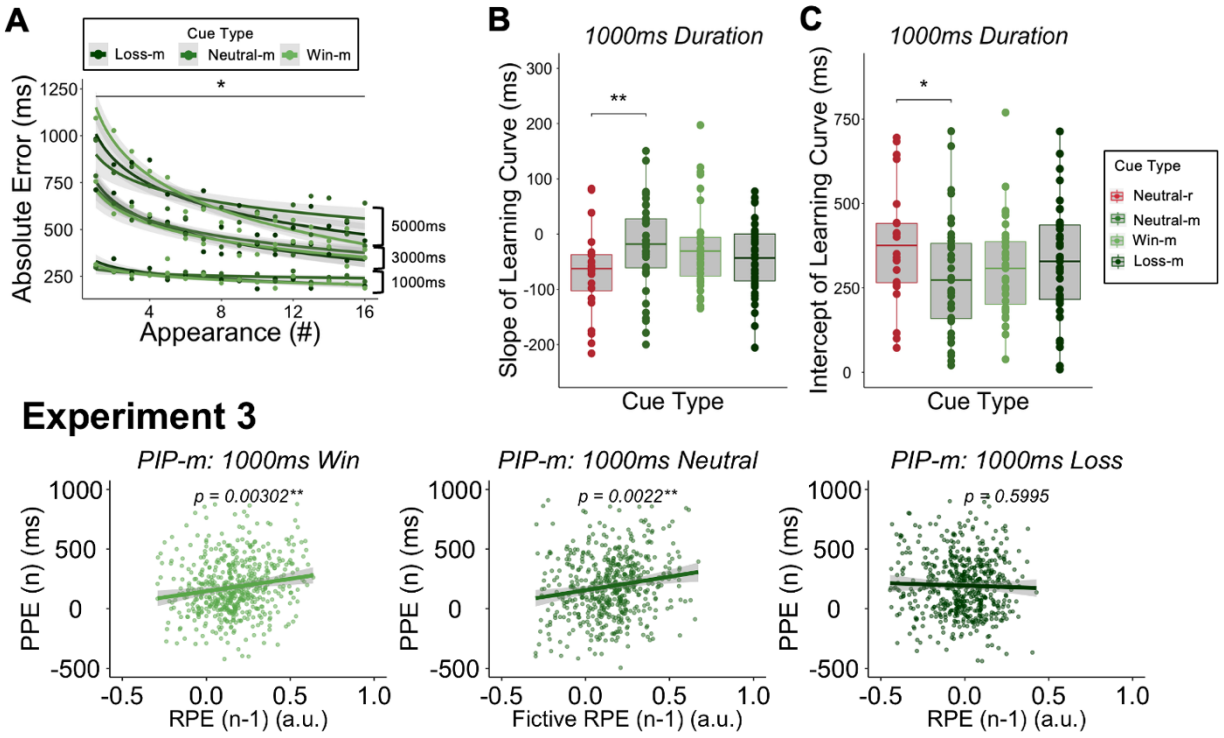

Fig S5. Altering the magnitude of reinforcement available further potentiates the effects of positive reinforcement on 1000ms cues. A. Mean learning curves for all neutral cues on PIP-m (PIP-magnitude), where the amount of reinforcement available scaled from $1-$5 based on cue type. **B.** Comparing the mean slope of the learning curves for the 1000ms cues between the PIP-r and PIP-m show significantly lower slope on the PIP-r, indicating a faster learning rate in response to greater reinforcement magnitude ($3 versus $1). **C.** When comparing mean intercept values between the 1000ms cues on the PIP-r and PIP-m, a significantly higher intercept was found on the PIP-r compared to the PIP-m revealing greater error in response to greater reinforcement magnitude ($3 versus $1). **Experiment 3.** Linear regression models show the results of the association between reward prediction errors (RPEs) of the previous trial (n-1) of the same type and performance prediction errors (PPEs) on the current trail (n) for the 1000ms cues on the PIP-m, which reveal the same pattern of associations as other reinforced cues. *Significance based on p < 0.05*, 0.01**, 0.001***. Shading = SEM.*