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Longer duration intertrial intervals without visual stimuli have reinforcement value and increase the rate of reinforcement and punishment learning in computer-based discriminations in humans

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ABSTRACT

In two experiments, we examined the motivational value of the duration of intertrial intervals and/or task delays on responding in a computer-based task in humans. In both experiments, four color stimuli with different response contingencies were displayed. Participants freely decided if they want to make a response or not towards each stimulus. The outcome that followed was either a putatively pleasant visual feedback (a "smiley face" display) or a blank screen, which was contingent on whether a response was made or withheld differently for different color stimuli. Our key manipulation was whether this blank screen outcome was longer or shorter than the visual feedback, that is whether the blank screen outcome made the next trial start sooner, later, or with the same delay as earning the visual feedback. We found 1) increased reinforced responding for encouraging visual feedback and 2) faster reinforcement and punishment learning to respond or withhold responding for this visual feedback if there was a longer duration blank screen outcome on trials in which people did not earn the visual feedback. This effect appeared to be driven more by the absolute length of the blank screen stimulus rather than whether it increased the delay until the start of the next trial more than the visual feedback. Additional research is needed to investigate boundary conditions that may determine when these blank screens do/do not have this motivational effect. Our findings suggest that manipulating task delay may be a way to increase motivation in laboratory studies in humans and possibly minimize individual differences in motivation due to differing sensitivity to demand characteristics in individual participants. However, additional research is needed to eliminate alternative explanations for this effect, such as an effect in which longer blank screen presentations led to better learning by preventing poorer learning that can be observed after massed trial presentations.

1. Introduction

Reinforcement and punishment are studied in humans and non-human animals. However, the reinforcers traditionally used in humans generally differ from those in non-human animals. In non-humans, the traditional reinforcers include food, water, drugs of

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abuse or the avoidance of shock (Berridge, 1996; Kearns, 2019; Lu et al., 2003; Sangha et al., 2020). In humans, some studies use small amounts of money (ex: Lin et al., 2012; Murayama et al., 2010; Rasmussen & Newland, 2008) and a small subset uses viewing of pleasant/arousing pictures or small quantities of food or drink as reinforcers (ex: Andreatta and Pauli, 2015; Buskist and Miller, 1981; Navarick, 1986; Steele et al., 2019). However, in humans, the most common reinforcers for good performance are generally arbitrary points or tokens (exchangeable for nothing) or simple feedback that the response was correct, such as a smiley face or "Correct!" on a computer screen (ex: Albertella et al., 2019; Anderson, 2016; Ma & Abrams, 2022). This distinction suggests that animal procedures primarily use reinforcers that are inherently reinforcing to animals, while human research largely depends on demand characteristics (often defined as a desire to please the experimenter or to "do well in the experiment") to reinforce behavior.

One common aspect to experiments in non-human animals is a delay in the start of the intertrial interval (ITI; meaning the next trial starts later) after incorrect responses in discrimination procedures, (ex: Beran et al., 2009; Bussey et al., 2008; Caglayan et al., 2021; Fisher et al., 2017; Flemming et al., 2011; Pickens et al., 2017), with this delay sometimes termed a "time-out". This could be conceptualized as negative reinforcement if long delays until the next trial are aversive and making correct responses avoids these delays. However, the reinforcement value of these delays is understudied. In non-human experiments with task delay contingencies, the task delays after incorrect responses are commonly accompanied by a tangible reinforcer (like food or drug) after correct responses (ex: Beran et al., 2009; Bussey et al., 2008; Caglayan et al., 2021; Fisher et al., 2017; Flemming et al., 2011; Pickens et al., 2017). Even in cases where the correct response is not immediately paired with tangible reward, there can be a reward period at the end of the session such that avoiding a time-out delay leads to a shorter overall delay to the eventual reward period (ex: Perdue et al., 2015). In humans, the change in task delay often accompanies the receipt of tokens, points, or encouraging feedback (such as "correct!" on the screen) after correct responses so the altered task delay itself might not be reinforcing on its own, but might give information about whether or not a response was correct and demand characteristics might be reinforcing the behavior if "doing well in the task" is the real reinforcer.

However, there is some evidence that avoidance of longer delays between trials may have reinforcement value that is additive to or amplifies the reinforcement value of other reinforcers. For example, one study in humans in which correct responses were reinforced with money found that longer duration time-outs after incorrect responses were associated with higher accuracy than shorter duration time-outs (in participants who experienced multiple time-out lengths) (Zimmerman & Baydan, 1963). This paralleled a similar finding in which generally longer time-outs after incorrect responses (excluding a long 120-sec time-out that disrupted response rates) were associated with higher accuracy in a discrimination procedure in pigeons reinforced with food for correct responses (Ferster and Appel, 1961). Likewise, imposing contingencies in which free-operant responses can lead to both food and time-outs (in which responses initiated a period in which environmental stimuli indicated that no reinforcement could be earned for the twenty seconds after the response, although the initial response could still be reinforced) led to dramatic decreases in response rate when the cues for this time-out punishment were present (McMillan, 1967).

Here, we aimed to determine whether altered ITIs would have reinforcement value that would alter responding for a pleasant visual stimulus (a "smiley face" visual feedback after certain responses or withholding of responses). In particular, trials led to either the visual stimulus outcome or a blank screen outcome before the ITI, which was also indicated with a blank screen and lasted for a 1-sec fixed duration. As the blank screen outcome was indistinguishable from the blank screen during the ITI and there was no signal that indicated that the blank screen outcome ended and the ITI began, the blank screen outcome appeared to simply be a longer ITI. We manipulated the duration of visual stimulus and blank screen outcomes and our key manipulation in both experiments was whether the visual stimulus outcome was longer, shorter, or the same duration as a blank screen presented otherwise prior to the ITI. If the visual stimulus feedback had a shorter duration than the blank screen outcome, then earning the blank screen outcome would delay the start of the next trial. If people in this condition had response patterns that earned more visual stimulus feedback (responding to stimuli that earned the visual stimulus and withholding responses to stimuli if responses prevented the visual stimulus) than people in conditions where the duration of the visual stimulus and blank screen outcome were the same, this would indicate that the longer delays prior to the next trial in the absence of the visual feedback had motivational value that added to or amplified the value of the visual feedback. If the visual feedback had a longer duration than the blank screen outcome, then earning the visual stimulus would delay the start of the next trial. If people in this condition had response patterns that earned fewer visual stimuli than people in conditions where the duration of the visual stimulus and blank screen outcome were the same, this would indicate that the shorter delays prior to the next trial in the absence of the visual feedback had motivational value that counteracted or dampened the value of the visual feedback.

In the current paper, we report the results of two experiments examining this question. In both experiments, we measured reinforcement by contrasting responses to a stimulus where responding led to visual stimulus feedback (Reinforced for responding) compared to a stimulus that led to no visual feedback regardless of responding (Nonreinforced). In both experiments, we measured punishment by contrasting responses to a stimulus that delivered visual feedback *unless* a response was made (an Omission stimulus) compared to a stimulus that predicted free delivery of visual feedback regardless of responding (which we term the "Free" stimulus). In Experiment 1, the blank screen outcome was 0 or 3 sec longer than the visual feedback. In Experiment 2, the blank screen outcome could either be 3 s longer, 3 s shorter, or the same duration as the visual feedback. All groups in both experiments had the same contingencies for visual stimuli, and only differed in how long each stimulus lasted and how much the next trial was delayed. Thus, differences in performance between groups could be attributed to the reinforcement value of the task delays or length of the blank screen presentation. We aimed to determine whether people were more motivated to earn visual feedback if the feedback was associated with a shorter delay to the next trial and people were less motivated for visual feedback if this feedback was associated with a longer delay to the next trial. Our results suggest that longer blank screen presentations are more effective in reinforcing behavior and make reinforcement and punishment learning occur faster, but this is related to the absolute length of the blank screen presentation rather than its relative duration compared with the visual stimulus feedback.

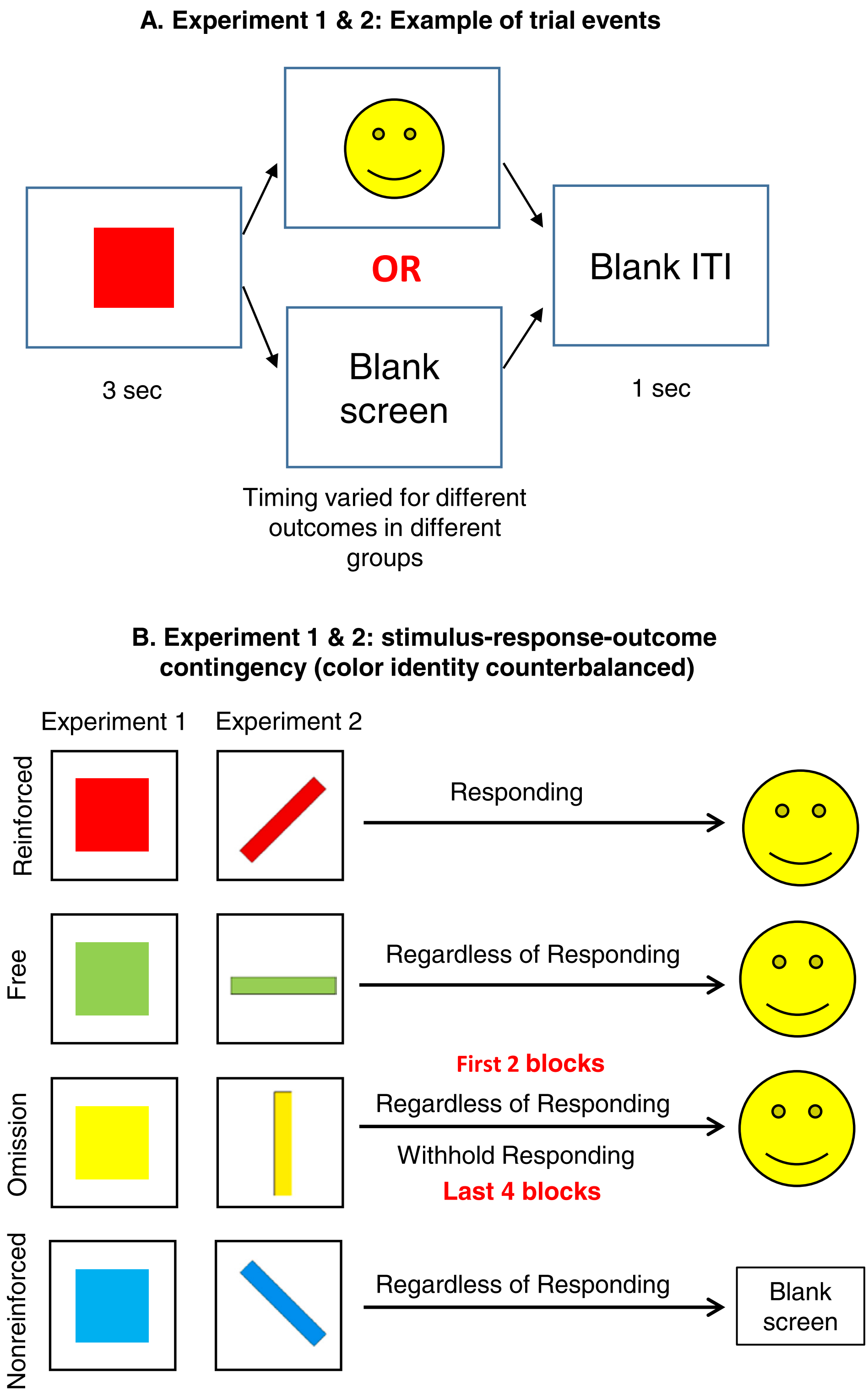

Fig. 1. Diagram of the task structure. A. The order of trial events. B. Contingencies for the four types of trials. For all trial types, the blank screen was presented if the smiley face was not (ex: if no response was made to the reinforced stimulus).

2. Methods

2.1. Experiment 1

2.1.1. Participants

Participants were all undergraduate students at Kansas State University (male and female, between 18 and 29 years old), who were recruited to participate in the study for course credit. Eighty undergraduate students participated. These students were assigned to two groups: group Smiley-Advantage and group Neutral (n = 40/group).

2.1.2. Procedure

Experiments were conducted on Dell Inspiron 5567 or 5570 computers using E-Prime 3.0 (Schneider et al., 2002).

During the experiment, participants first read through and signed an informed consent form followed by a brief demographics questionnaire. Then they were seated in front of a computer and asked to read through the instructions and could start the session when they were ready by pressing the 'Q′ button. The instructions said:

> 'Welcome to the experiment!
>
> You will see blue, green, red or yellow squares.
>
> You have a limited amount of time during each square to decide whether to press the "SPACE BAR"
>
> You will receive a smiley face and the next trial will start sooner if you are doing well.
>
> At least one of the squares means something different from the other three.
>
> After reading the instructions, press the "Q" button to start the experiment'

In this experiment, the stimuli were colored squares (blue, green, red, and yellow). Each square was presented for 3 s and participants were able to respond by pressing the space bar during the shape. Responses during each of the 4 squares had different effects on the likelihood of the square being followed by smiley face visual feedback vs. a blank screen (see Fig. 1A for the sequence of trial events). One square was a Reinforced cue that required a response for the visual feedback. Responses during this cue earned visual feedback 100 % of the time and trials with no response earned the blank screen 100 % of the time. One square was the Nonreinforced cue that did not predict visual feedback on any trials. This cue predicted the blank screen 100 % of the time regardless of whether a response was made. One square was the Free cue, which predicted visual feedback 5 out of 6 times regardless of responding and predicted the blank screen 1 out of 6 times regardless of responding. Responses during the Free cue had no effect on which outcome was earned. Finally, one square was the Omission cue. During the first 2 trial blocks, the Omission cue had the same contingencies as the Free cue (predicting visual feedback 5/6 of the time and a blank screen 1/6 of the time regardless of responding). This contingency led to a relatively high rate of responding on both the Free and Omission cue, so that there would be some responding to punish in the last 4 blocks. In blocks 3–6, responding on the Omission cue was punished by withholding the smiley face visual feedback if a response was made. The Omission cue predicted visual feedback 5/6 of the time and a blank screen 1/6 of the time if no response was made. However, this cue predicted the blank screen on 100 % of the trials where a response was made (see Fig. 1B for demonstration of contingencies for the stimuli). For each of the two groups, there were 4 counterbalanced versions of the task such that each of the colored squares had one of the four relationships with the visual stimulus (ex: the red square was the Reinforced, Nonreinforced, Free, or Omission stimulus in 25% of the people in each group).

The colored shapes were presented for the entire 3 s regardless of responding, but only the first response (or the absence of a response) was recorded. The square presentation did not terminate once a response was made because this outcome would make the visual feedback or blank screen appear sooner. If responses terminated the colored squares, an alternative strategy to shorten the experimental session would be to ignore the identity of the visual stimulus and simply respond as quickly as possible to each square to terminate the shapes quickly, even if this led to earning some task delays based on longer smiley face or blank screen outcomes.

In both groups, the smiley face visual feedback lasted 0.75 s. In Smiley-Advantage group, the blank screen presented in the absence of visual feedback lasted 3.75 s, which meant earning a blank screen delayed the next trial 3 s longer than earning the smiley face visual feedback. In Neutral group, the blank screen presented in the absence of visual feedback lasted 0.75 s, which meant earning a blank screen caused the same delay until the next trial as earning the smiley face visual feedback. Regardless of the cue or visual feedback/blank screen, there was a 1-sec ITI in which a blank screen was presented. As the blank screen outcome was indistinguishable from the blank screen during the ITI, the blank screen outcome appeared to the participants as a longer ITI. In the Smiley-Advantage group, the two outcomes appeared to be a 0.75-sec visual feedback followed by a 1-sec ITI with a blank screen and a 4.75-sec ITI with a blank screen. In Neutral group, the two outcomes appeared to be a 0.75-sec visual feedback followed by a 1-sec ITI with a blank screen and a 1.75-sec ITI with a blank screen.

The experiment consisted of 6 blocks, with 48 trials in each block. Each block contained 12 presentations of the Reinforced, Nonreinforced, Free, and Omission stimuli. For each stimulus, responses had the contingencies described above. A forced break for at least 30 s was enforced between blocks, and participants could start the next block when they were ready by pressing the 'Q′ button. After the participants completed the task, they were asked a series of questions about the relationship between their responses and the smiley face visual feedback. These were open-ended questions on a paper survey and they proved to be difficult to analyze and interpret, so we do not report these data and we did not include this survey in Experiment 2. Finally, participants were debriefed.

2.2. *Experiment 2*

2.2.1. *Participants*

Participants were all undergraduate students at Kansas State University (male and female, between 18 and 29 years old), who were recruited to participate in the study for course credit. Ninety-seven undergraduate students participated. These students were assigned to four groups: Short, Smiley-Advantage, Smiley-Disadvantage, and Long.

2.2.2. *Procedure*

The procedure in Exp. 2 was exactly the same as that in Exp. 1, with 4 exceptions. First, the 4 colored squares used as stimuli in Exp. 1 were replaced with 4 colored lines in different orientations (a green line at 0 degrees, a red line at 45 degrees, a yellow line at 90 degrees, and a blue line at 135 degrees). Each colored line was always associated with the same orientation, so there were only 4 different stimuli (*not* 4 colors crossed with 4 orientations to make 16 possible stimuli, see Fig. 1B for demonstration of contingencies for the stimuli). Second, there were 4 groups in a 2 × 2 between-subjects design, with 2 possible durations of the smiley face visual feedback (0.5 s or 3.5 s) and 2 possible orientations of the blank screen presented in the absence of the visual feedback (0.5 s or 3.5 s). This made 4 groups: group Short (Smiley=0.5 s, Blank = 0.5 s, so earning visual feedback vs. blank screens did not affect the delay to the next trial), group Smiley-Advantage (Smiley=0.5 s, Blank = 3.5 s, so earning a smiley made the next trial start sooner than if a blank screen was earned), group Smiley-Disadvantage (Smiley=3.5 s, Blank = 0.5 s, so earning a smiley made the next trial start later than if a blank screen was earned), and Long (Smiley=3.5 s, Blank = 3.5 s, so earning visual feedback vs. blank screens did not affect the delay to the next trial). As in Experiment 1, the blank screen outcome was indistinguishable from the blank screen during the ITI, so the blank screen outcome appeared to be a longer ITI. For instance, in the Smiley-Advantage group, the two outcomes appeared to be a 0.5-sec visual feedback followed by a 1-sec ITI with a blank screen and a 4.5-sec ITI with a blank screen. Third, we did not conduct the post-test survey about people's understanding of the relationship between stimuli. Fourth, we amended the instructions to reflect that the stimuli were lines rather than squares and to avoid stating that smiley face stimuli would be associated with the next trial starting sooner. The instructions said:

> 'Welcome to the experiment!
>
> You will see blue, green, red or yellow lines.
>
> You have a limited amount of time during each line to decide whether to press the "SPACE BAR"
>
> Your behavior may affect the delay until the next trial.
>
> At least one of the lines means something different from the other three.
>
> After reading the instructions, press the "Q" button to start the experiment'

2.3. *Data analysis*

Our measure was the number of trials with a response to each of the 4 stimuli during the 6 trial blocks. We analyzed this in two ways. First, we analyzed the absolute response rates (not a difference score) with the number of trials with a response for each of the stimuli. This analysis includes information about overall response rates so that the absolute levels of responding to each of the stimuli could be assessed. However, we designed the experiment to examine the reinforcement and punishment motivational value of the task delays, with built-in controls. For reinforcement, we used a difference score of responses on the Reinforced minus responses on the Nonreinforced stimulus. The two stimuli had the same outcome on trials with no response (a blank screen 100% of the time), but only the Reinforced stimulus led to a different outcome (the smiley face visual feedback) if a response was made. For punishment, we used a difference score of responses on the Free minus responses on the Omission stimulus. The two stimuli had the same outcome on all trials in blocks 1 and 2 and on trials with no response in blocks 3–6 (smiley face visual feedback on 5/6 trials), but only the Omission stimulus led to a different outcome if a response was made in blocks 3–6 (a blank screen 100% of the time).

Data were analyzed by Statistica 5.1 software (Tulsa, OK). The factors used in the statistical analyses are described in the Results section for each ANOVA and significant effects ($p < 0.05$) in the different ANOVAs were followed by post-hoc Tukey's HSD tests. We only report and perform post-hoc test on the highest-order interactions including factor Group (for example, if a three-way interaction of Group X Stimulus X Trial Block and a two-way interaction of Group X Stimulus were significant, we only report and perform post-hoc tests on the three-way interaction).

3. Results

3.1. *Experiment 1*

The data for one participant from the Smiley-Advantage group were removed from the analysis, as the participant was caught sleeping during the experiment. We also excluded 9 participants (3 from the Smiley-Advantage group and 6 from the Neutral group), as they exhibited a strong preference between the Free vs. Omission stimuli in the first 2 blocks (a difference of five or more responses/ block between the 2 stimuli) and responses on these stimuli had identical contingencies during these blocks (free visual feedback

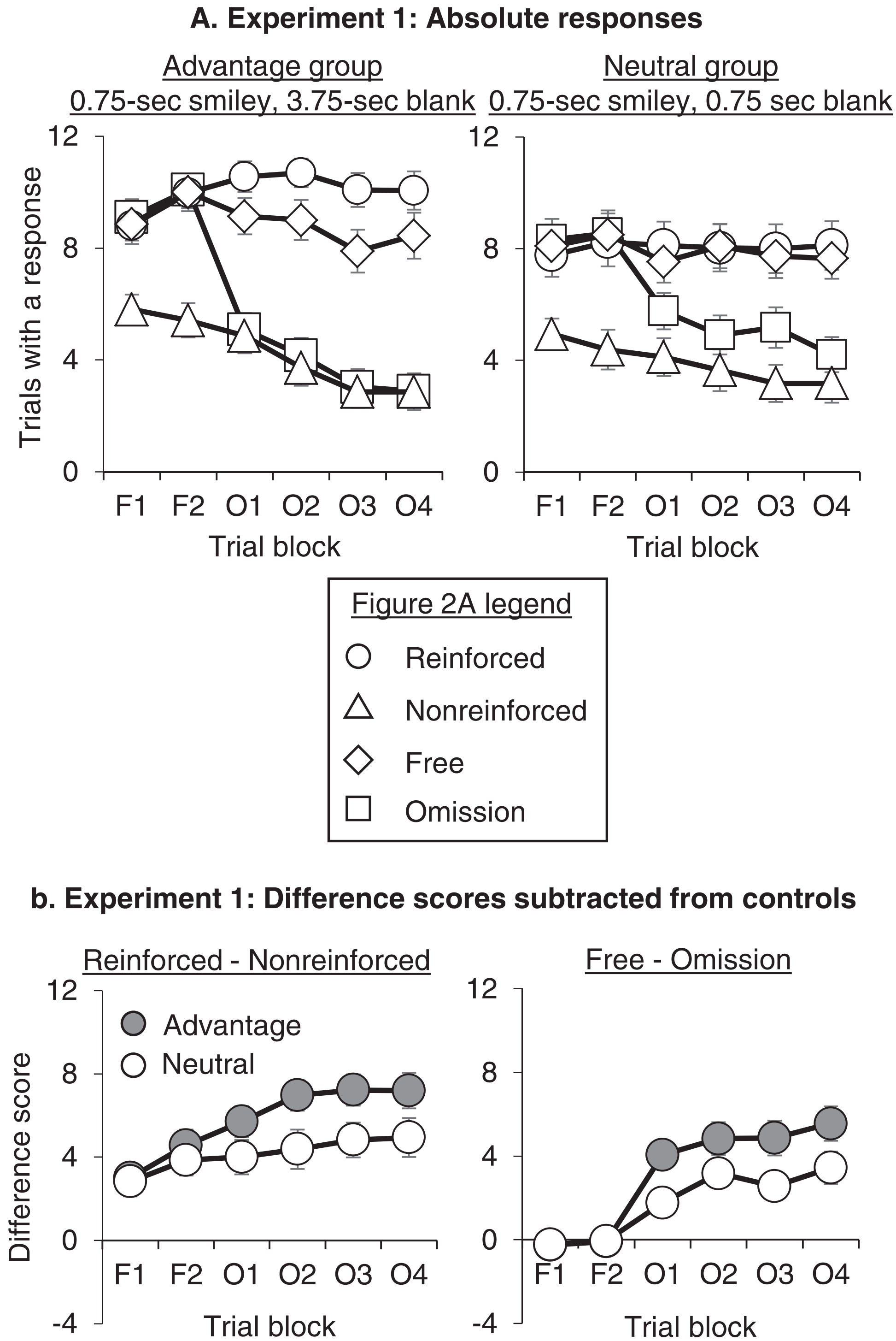

Fig. 2. Behavioral data from Experiment 1. A. Mean number of trials with a response (mean+SEM, out 12 trials in each trial block). Left = data from the Smiley-Advantage group. Right = data from the Neutral group. B. Mean difference scores (mean+SEM) of trials with a response on the Reinforced and Omission stimuli/trials corrected for trials with a response from their control stimuli/trials (Nonreinforced and Free, respectively). Left = difference score of trials with a response on the Reinforced minus Nonreinforced stimuli/trials (higher score mean a greater reinforcement effect). Left = difference score of trials with a response on the Free minus Omission stimuli/trials (higher score mean a greater punishment effect). F1 and F2 = trial blocks 1 and 2 when the Free and Omission stimuli were both under Free conditions where 5/6 trials ended in a smiley face visual stimulus regardless of responding. O1-O4 = trial blocks 3–6 when responses on the Omission stimulus led to the blank screen 100% of the time (an Omission contingency) and no response on this stimulus led to the smiley face visual stimulus 5/6 times.

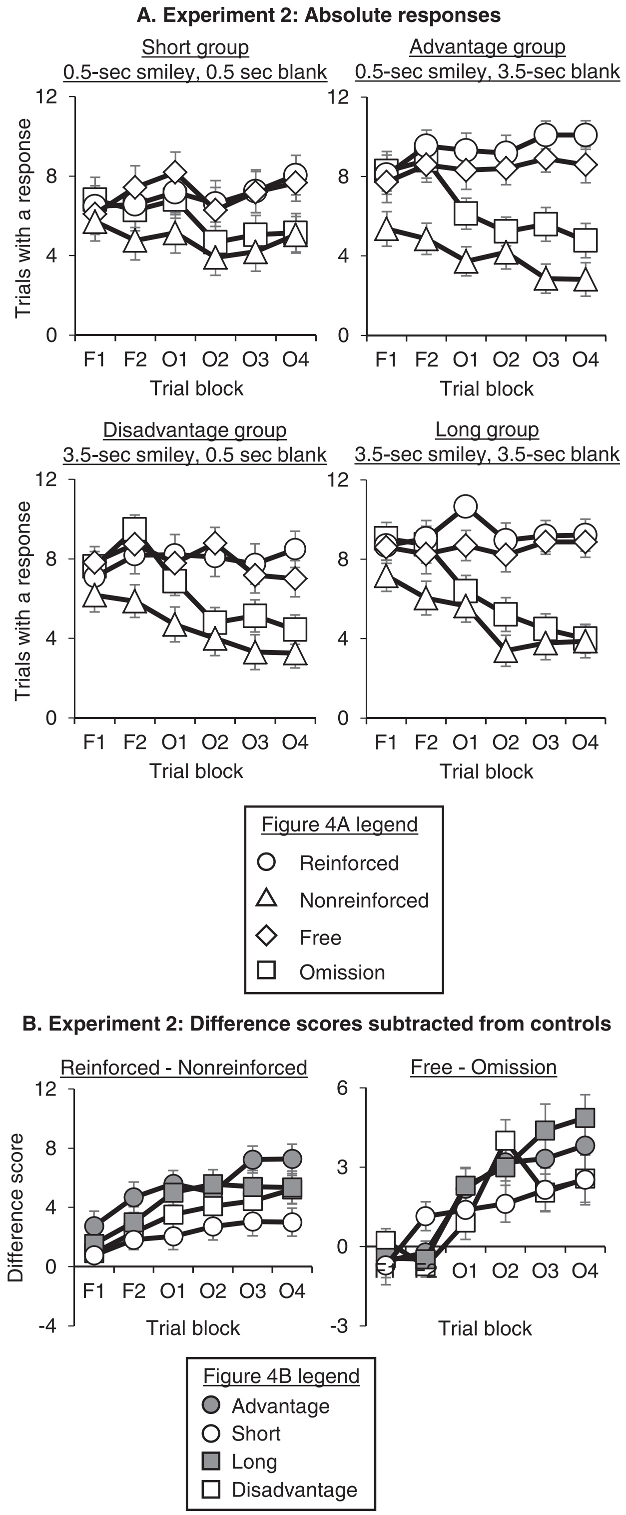

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Fig. 3. Behavioral data from Experiment 2. A. Mean number of trials with a response (mean+SEM, out 12 trials in each trial block). Top Left = data from the Short group. Top Right = data from the Smiley-Advantage group. Bottom Left = data from the Smiley-Disadvantage group. Bottom Right = data from the Long group. B. Mean difference scores (mean+SEM) of trials with a response on the Reinforced and Omission stimuli/trials corrected for trials with a response from their control stimuli/trials (Nonreinforced and Free, respectively). Left = difference score of trials with a response on the Reinforced minus Nonreinforced stimuli/trials (higher score mean a greater reinforcement effect). Left = difference score of trials with a response on the Free minus Omission stimuli/trials (higher score mean a greater punishment effect). F1 and F2 = trial blocks 1 and 2 when the Free and Omission stimuli were both under Free conditions where 5/6 trials ended in a smiley face visual stimulus regardless of responding. O1-O4 = trial blocks 3–6 when responses on the Omission stimulus led to the blank screen 100% of the time (an Omission contingency) and no response on this stimulus led to the smiley face visual stimulus 5/6 times.

regardless of responding). Because our experiment was designed to investigate the reinforcement value of different ITIs, we did not exclude people for low responding as this would bias our results towards a higher estimate of reinforcement value. These exclusions meant that our analysis includes 36 people in the Smiley-Advantage group and 34 people in the Neutral group.

We found that a shorter delay associated with the smiley face visual feedback compared with the blank screen (or alternatively a longer blank screen presentation) led to stronger reinforcement effects and faster punishment learning. First, we examined the absolute response rate for each of the 4 stimuli (Fig. 2A). We found that the Smiley-Advantage group (with the longer blank screen presentations and shorter visual feedback presentations compared to the blank screen presentations) had higher responding than the Neutral group (with short blank screen presentations that were equal in duration to the visual feedback) on the Reinforced stimulus in the later blocks of the task. We analyzed these data with a mixed-factor ANOVA with the between-subjects factor of Group (Smiley-Advantage or Neutral) and the within-subjects factors of Stimulus (Reinforced, Nonreinforced, Free, and Omission) and Trial Block (the 6 trial blocks). We found a significant interaction of Group X Stimulus X Trial Block (F(15, 1020)= 2.5, $p < 0.01$). Post-hoc tests performed on the Group X Stimulus X Trial Block interaction found that the Smiley-Advantage group had significantly higher responding on the Reinforced stimulus on trial blocks 3–6 (or O1-O4) ($p < 0.05$). There was also lower responding in the Smiley-Advantage group compared to the Neutral Group on the Omission stimulus in trial block 5 (or O3). The two groups did not differ on any other stimulus in any trial block.

We also analyzed the data using difference scores to determine if the trial delays associated with the visual feedback vs. the blank screens had a selective effect on responding during the stimuli associated with reinforcement or punishment. Using these difference scores, we found that the group in which the blank screen was longer than the smiley face visual feedback (the Smiley-Advantage group) exhibited a faster increase in reinforced responding, a faster decrease in punished responding and a higher terminal rate of reinforced responding. To examine selective effects of reinforcement, we used a difference score of responses on the Reinforced minus responses on the Nonreinforced stimulus (Fig. 2B, left). The two stimuli had the same outcome on trials with no response (a blank screen 100% of the time), but only the Reinforced stimulus led to a different outcome (the smiley face visual feedback) if a response was made. We analyzed these data with a mixed-factor ANOVA with the between-subjects factor of Group and the within-subjects factor of Trial Block. We found a significant interaction of Group X Trial Block (F (5, 340)= 2.5, $p < 0.05$). Post-hoc analyses of the Group X Trial Block interaction found higher responding in the Smiley-Advantage group than the Neutral group in trial blocks 4–6 (or O2-O4) ($p < 0.05$). These post-hoc analyses also found that difference scores significantly increased from trial block 1 (or F1) to trial blocks 3–6 (or O1-O4) in the Smiley-Advantage group ($p < 0.05$), but in the Neutral group difference scores were not significantly higher than those in trial block 1 until trial block 6 (suggesting that people were slower to adjust to reinforcement in this group). To examine selective effects of punishment, we used a difference score of responses on the Free minus responses on the Omission stimulus (Fig. 2B, right). The two stimuli had the same outcome on trials with no response (smiley face visual feedback on 5/6 trials), but only the Omission stimulus led to a different outcome (a blank screen 100% of the time) if a response was made. We analyzed these data with a mixed-factor ANOVA with the between-subjects factor of Group and the within-subjects factor of Trial Block. We found a significant interaction of Group X Trial Block (F(5, 340)= 2.5, $p < 0.05$). Post-hoc analyses of the Group X Trial Block interaction found a trend towards higher responding in the Smiley-Advantage group than the Neutral group in trial blocks 3 and 5 (both $p = 0.06$) but no differences between the two groups that reached significance. However, that difference scores significantly increased from trial block 1 (or F1) to trial blocks 3–6 (or O1-O4) in the Smiley-Advantage group ($p < 0.05$), but in the Neutral group difference scores were only significantly higher than those in trial block 1 in trial blocks 4–6 (signifying that people were slower to adjust to punishment in this group).

3.2. Experiment 2

The data for individual participants were removed from the analysis due to discovery that they were older than 29 years old (1 participant) or malfunctions in the experimental program (2 participants). We also excluded 5 participants (1, 2, and 2 in the Smiley-Advantage, Smiley-Disadvantage, and Long groups, respectively) as they exhibited a strong preference between the Free vs. Omission stimulus in the first 2 blocks (a difference of five or more responses/block between the 2 stimuli). We did not exclude people for low responding. As a result, the final data included 89 participants (with 21–23 participants/group in 4 groups).

We found that a longer blank screen presentation (in the absence of smiley face visual feedback) led to stronger reinforcement effects and faster punishment learning regardless of whether the smiley face visual feedback was shorter, longer, or the same duration as the blank screen. First, we examined the absolute response rate for each of the 4 stimuli (Fig. 3A). We found that the groups with a longer blank screen presentation (the Smiley-Advantage and Long groups) had higher responding than the groups with a shorter blank screen presentation (groups Smiley-Disadvantage and Short) on the Reinforced stimulus, but there were no effects of how long the smiley face visual feedback was presented. We analyzed these data with a mixed-factor ANOVA with the between-subjects factors of Feedback Duration (smiley face feedback presented for 0.5 or 3.5 s) and Blank Duration (blank screen presented for 0.5 or 3.5 s) and the within-subjects factors of Stimulus (Reinforced, Nonreinforced, Free, and Omission) and Trial Block (the 6 trial blocks). We found significant interactions of Blank Duration X Stimulus ($F(3, 255) = 3.6$, $p < 0.05$) and Stimulus X Trial Block ($F(15, 1275) = 17.6$, $p < 0.01$). No other interactions were significant (all $p > 0.05$). Post-hoc analyses of the Blank Duration X Stimulus interaction found that the 3.5 s blank groups had significantly lower responding on the Reinforced stimulus than the 0.5 s blank groups, but there were no other differences in responding to the other stimuli between the 0.5- and 3.5-sec blank groups.

We also analyzed the data using difference scores. Using these difference scores, we found that the groups in which the blank screen was longer exhibited a higher rate of reinforced responding and a faster decrease in punished responding, but there were no effects or interactions of the duration of the smiley face visual feedback. To examine selective effects of reinforcement, we used a difference score of responses on the Reinforced minus responses on the Nonreinforced stimulus (Fig. 3B, left). We analyzed these data with a mixed-factor ANOVA with the between-subjects factors of Feedback Duration and Blank Duration and the within-subjects factor of Trial Block. We found a significant effect of Blank Duration ($F(1, 85) = 7.0$, $p < 0.01$) and Trial Block ($F(5, 425) = 22.4$, $p < 0.01$). No other effects or interactions were significant (all $p > 0.05$). To examine selective effects of punishment, we used a difference score of responses on the Free minus responses on the Omission stimulus (Fig. 3B, right). We analyzed these data with a mixed-factor ANOVA with the between-subjects factors of Feedback Duration and Blank Duration and the within-subjects factor of Trial Block. We found a significant interaction of Blank Duration X Trial Block ($F(5, 425) = 2.5$, $p < 0.05$). No other effects or interactions were significant (all $p > 0.05$). Post-hoc analyses of the Blank Duration X Trial Block interaction found no significant difference between the groups with 0.5- or 3.5-sec blank screens in any trial block (all $p > 0.05$). However, these post-hoc tests found that the difference score in blocks 3–6 (or O1-O4) significantly differed from that in trial block 1 (or F1) in the 3.5-sec blank screen groups (signifying that people adjusted to the punishment in the first block it was implemented) but only trial blocks 4–6 differed from trial block 1 in the 0.5-sec groups (signifying that people were slower to adjust to punishment in this group).

4. Discussion

Although our results in Experiment 1 suggested that people were sensitive to the duration of the blank screen/ITI, in Experiment 2 we found that people were primarily sensitive to the absolute length of the blank screen rather than whether the length of the blank screen made the next trial start sooner or later. People exhibited greater responding to avoid the longer duration blank screen regardless of whether this made the next trial start sooner. While this was not our expected outcome, our results do support the idea that it is possible to motivate research participants to perform laboratory tasks above and beyond the level that is supported by encouraging feedback (like “smiley face” outcomes) through manipulating the duration of the blank screen presentations or ITI.

The smiley face feedback and/or avoidance of the lengthened blank screen stimulus was clearly reinforcing in our procedure. For both Experiments 1 and 2, the difference scores for all groups were above zero, suggesting that people were willing to make responses to earn the smiley face feedback (or avoid the lengthened blank screen) and willing to withhold responses to earn the smiley face feedback (or avoid the lengthened blank screen). This was true, despite the fact that the instructions in the two experiments differed in what the participants were told about the visual feedback. In Experiment 1, the participants were told “You will receive a smiley face and the next trial will start sooner if you are doing well.”, which was explicit in indicating that the visual feedback would give information about whether the participants were “doing the experiment well”. In Experiment 2, the instructions said nothing about the visual feedback. In both cases, the difference scores suggested that participants were willing to make responses and withhold responses in order to earn the smiley face feedback and/or avoid the lengthened blank screen feedback. However, as we expected participants to be motivated by a desire for the next trial to start sooner, we designed our experiments to assess this hypothesis rather than determining what was driving responding for the smiley face visual stimulus. There are several possible sources of the reinforcement value of the smiley face feedback, including prior associations (ex: being previously paired with pleasant outcomes in life prior to coming to the laboratory) or demand characteristics (ex: belief by the participant that they were “doing the task properly”). It is also possible that behavior was primarily driven by a desire to avoid lengthened blank screen presentations, as the blank screen during the ITI was always 1 sec on trials with the smiley face visual stimulus feedback, and always longer (either 1.5-, 1.75-, 4.5-, or 4.75-sec) on trials when the visual stimulus was not presented.

We cannot entirely exclude the possibility of demand characteristics in the reinforcing/punishing effects of the blank screen outcome duration, as the instructions in Experiment 2 mentioned that “Your behavior may affect the delay until the next trial.” This may have led some participants to believe that the comparatively shorter delays associated with the smiley face feedback (in the Smiley-Advantage group) or comparatively longer delays associated with the smiley face feedback (in the Smiley-Disadvantage group) were designed by the experimenter to alter their behavior. However, similar stronger reinforcement patterns were observed with the longer blank screen duration (in the Long and Smiley-Advantage group) compared to that with the shorter blank screen duration (in the Short and Smiley-Disadvantage group) in Experiment 2, regardless of the comparative duration of the blank screen versus the smiley face feedback. This does not fit with a pattern in which participants took the information in the instructions and tried to fit experimenter’s expectations about the effect of making the next trial start sooner. In addition, as the manipulation of the duration of the “no smiley” feedback occurred with a between-subjects design, it is unlikely that research participants were aware of this manipulation and could use this to infer the desired responses. In essence, if individual subjects had some stimuli associated with short blank screens in the absence of the smiley face and other stimuli associated with long blank screens in the absence of the smiley face, the participants might infer that they were supposed to respond to avoid the longer blank screens, and our between-subjects design avoided this. However, future research will need to be done to determine whether the effects of the blank screen duration’s motivational properties are still due to some demand characteristics.

Additionally, it is worth noting that the manipulation of intertrial duration inevitably altered the overall pace of the experiment, resulting in trials administered at different rates for different groups of subjects. The groups with relatively short blank screen presentations with the smiley duration held constant (Neutral in Experiment 1) or both short blank screen and short smiley face durations (Short in Experiment 2) experienced the trials in an overall more massed manner. The groups with relatively long blank screen presentations with the smiley duration held constant (Smiley-Advantage in Experiment 1) or both long blank screen and long smiley face durations (Long in Experiment 2) experienced the trials in an overall more spaced manner. Thus, greater average spacing between trials represents an alternative explanation for the enhanced reinforcement and punishment learning with longer blank screen duration. Indeed, lengthened spacing between consecutive learning events has been demonstrated to positively affect learning outcome in several learning preparations in several species of non-human animal (Carew et al., 1972; Menzel et al., 2001; Teichner, 1952; Terrace et al., 1975) and in humans (Foos & Smith, 1974; Jacoby, 1978; McDaniel et al., 2013; Rea & Modigliani, 1987). In those studies, learning was found to occur at a faster rate or with greater retention when trials were administered with longer intertrial intervals. This explanation alone has trouble explaining the main effect of the blank screen duration in Experiment 2, as participants in groups Smiley-Advantage and Smiley-Disadvantage received a mix of short and long intervals between trials (long blank screen and short smiley presentations in Smiley-Advantage and vice versa in Smiley-Disadvantage). Neither the reinforcement nor the punishment difference score patterns match the pattern that would be expected if the only factor driving differences was the average intertrial interval across all trials (greatest effect in group Long, intermediate effect in groups Smiley-Advantage and Smiley-Disadvantage, and smallest effect in group Short). In the present study, given the inherent confound between the duration of a particular type of response outcome and the overall spacing of trial administration, the observed effect could be due to a combined influence of trial spacing and the reinforcement effect of lengthened blank screen stimulus. Future studies are needed to distinguish between different sources of influence.

The pattern found in Experiment 2, in which it was the absolute duration of the blank screen rather than its relative duration compared to the duration of the smiley face feedback, was unexpected and suggests that longer presentation of the blank screen may have been aversive for the participants or made the duration seem longer. In that case, in addition to any reinforcing value of the smiley face stimulus (due to previous associations with reinforcing outcomes or demand characteristics), behavior in our task may have been driven by avoidance of these potentially aversive long blank screen presentations. There is prior evidence that visual stimuli can make a duration seem shorter than if a blank screen is presented, for durations including 10.1 s (Suwanaposee et al., 2022), although the prior literature on effects of auditory or visual stimuli suggests that participants often judge "filled" intervals as longer than "unfilled" intervals (see Thomas & Brown, 1974; Wearden et al., 2007 for reviews). Therefore, one possibility is that participants believed that the next trial was starting later if followed a longer interval with a blank screen than if it followed a similar duration interval that contained presentations of visual stimuli. Alternatively, it is possible that participants in certain conditions (like the Long and Short conditions in Experiment 2) were aware that the intervals between trials were equal regardless of the visual stimuli presented, but the blank screen outcomes were aversive regardless and more aversive in the Long condition where they were present for longer durations. Future research will need to be done to determine if our particular visual stimuli make the delay seem shorter than a blank screen, or if participants find the blank screens in our task aversive.

5. Conclusion

In two experiments, we found increased responding for encouraging visual feedback ("smiley faces") and faster reinforcement and punishment learning to respond or withhold responding for this visual feedback if there was a longer duration blank screen outcome on trials in which people did not earn the visual feedback. This effect appeared to be driven more by the absolute length of the blank screen stimulus rather than whether it increased the delay until the start of the next trial more than the visual feedback. This finding is in accord with previous findings that longer time-out periods after incorrect responses increased accuracy in discrimination tasks in human and non-human animals (Ferster and Appel, 1961; Zimmerman & Baydan, 1963) and extends these findings by showing that these effects can be found without requiring a longer delay until the next trial or explicit stimuli in the environment to indicate that the time-out period is separate from the ITI. This finding is also in accord with common practice in many laboratory animal studies, in which delays after incorrect responses are used to motivate behavior (ex: Beran et al., 2009; Bussey et al., 2008; Caglayan et al., 2021; Fisher et al., 2017; Flemming et al., 2011; Pickens et al., 2017). However, as lengthening of the blank screen after incorrect responses inevitably increased the overall spacing between trials, it is possible that our results were due to better learning with spaced than massed training. Additional research is needed to more definitively investigate the factors that cause this effect and boundary conditions that may determine when these blank screens do/do not have this motivational effect. However, our findings suggest that these methods may be a way to increase motivation in laboratory studies in humans and possibly minimize individual differences in motivation due to differing sensitivity to demand characteristics in individual participants.

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CRediT authorship contribution statement

Xiaojin Ma- Data curation, Investigation, Project administration, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Blair Bracciano-** Investigation, Writing – review & editing. **Nicole Hoppas-** Investigation, Writing – review & editing. **Sydney Zimmerman-** Investigation, Writing – review & editing. **Charles L. Pickens**- Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Roles/Writing – original draft, Writing – review & editing.

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