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Decisions to seek cognitive performance feedback: Potential determinants of feedback value and consequences for learning

Christopher J. Cagna[a,1,2,*], Jamil P. Bhanji[a,1], Da'Quallon Smith[b], Mauricio R. Delgado[a], Elizabeth Tricomi[a]

[a] Department of Psychology, Rutgers University, Newark, 101 Warren Street, Newark, NJ 07102, United States
[b] The London School of Economics and Political Science, Houghton Street, London WC2A 2AE, United Kingdom

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ABSTRACT

Performance feedback is essential for effective learning. Feedback contains both informational and affective properties. Following negative feedback (indicating an incorrect response), the unpleasant experience of being wrong can diminish the value of constructive information that feedback also provides. This can hinder motivation to seek feedback, which can impede learning. Therefore, research into factors that directly shape the subjective value of feedback is critical. The current study investigated potential behavioral and physiological contributors to feedback valuation and to subsequent feedback-seeking behavior. Fifty-nine participants completed a willingness-to-pay associative memory task that measured feedback valuation via trial-wise decisions to either purchase or forgo feedback during a learning phase in service of maximizing a performance-contingent monetary reward during a future test phase. Skin conductance response (SCR) was also measured during feedback decisions. Lower confidence in response accuracy significantly predicted higher likelihood of purchasing feedback during learning. Neither self-reported emotional responses to feedback nor SCR during feedback decisions predicted feedback purchases. Purchase decisions yielding negative feedback significantly predicted better performance during test. These results suggest that confidence during learning significantly impacts performance feedback valuation and should be considered when devising methods to motivate feedback-seeking in settings where learning is critical to success.

1. Introduction

Feedback related to one's performance during a cognitive task is instrumental for gauging task success. We rely on the outcomes of our behavioral responses to determine whether they align with the demands of the task at hand. We then subsequently adapt our behavior accordingly to increase the odds of task success. This performance feedback typically shapes learning via instrumental outcomes that signal correct (positive feedback) or incorrect (negative feedback) responses (Tricomi et al., 2006; Tricomi & Fiez, 2008;

* Corresponding author.
E-mail addresses: christopher.cagna@rutgers.edu (C.J. Cagna), bhanji@psychology.rutgers.edu (J.P. Bhanji), daquallon.smith@gmail.com (D. Smith), delgado@psychology.rutgers.edu (M.R. Delgado), etricomi@psychology.rutgers.edu (E. Tricomi).
[1] These authors share first authorship.
[2] Present address: Center for Traumatic Brain Injury Research, Kessler Foundation, 120 Eagle Rock Avenue, Suite 100, East Hanover, NJ 07936, United States

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Tricomi & DePasque, 2016). Besides providing information beneficial for learning, feedback also contains positive or negative valence, which influences people's emotional responses to it. For example, we often consider positive feedback to be rewarding and informative. Negative feedback, however, while constructive for learning, can be unpleasant to receive (e.g., the "sting" of being wrong). As a result, it is more challenging to highlight the informational value of negative feedback above and beyond the negative emotions it may also cause. This has critical implications for motivating continued pursuit of performance feedback, which is essential for effective performance and learning in diverse settings, including the classroom (Hattie & Timperley, 2007), the workplace (Pelgrim et al., 2012), and rehabilitation (Hart et al., 2019).

1.1. *Feedback valuation and willingness-to-pay*

Performance feedback is not always passively received by an individual. In real life, there are times where we must actively seek out feedback to benefit from its information (Anseel et al., 2015; Ashford et al., 2016; Crommelinck & Anseel, 2013). In these instances, the perceived reward value of the information provided by feedback must outweigh any potential costs associated with receiving the feedback (e.g., the negative affect that may result from making an error). In other words, the *subjective value* of prospective feedback information must be sufficient to motivate feedback-seeking. Subjective value refers to the perceived worth of a stimulus, outcome, or goal (Kable & Glimcher, 2007, 2009; Peters & Büchel, 2010; Rangel et al., 2008). When we decide whether to pursue a goal, cost-benefit computations integrate the prospective reward value of the goal with the costs of obtaining it. The resulting net subjective value then guides subsequent goal-directed behavior. A positive subjective value - in which the prospective reward outweighs the prospective costs - elicits motivated behavior towards the goal. Conversely, a negative subjective value - in which the costs outweigh the reward - motivates avoidance of the goal. Subjective value is often empirically assessed via "willingness-to-pay" (WTP) experimental tasks (Kable & Glimcher, 2007, 2009; Rangel et al., 2008). WTP is the voluntary exchange of a valued commodity (e.g., money) for the receipt of a stimulus (Peters & Büchel, 2010). WTP tasks present participants with choices to obtain an outcome by paying a cost for it. People are willing to pay a higher cost to obtain more highly-valued outcomes. Thus, WTP paradigms capture subjective value with two measures: the decision outcome (purchase/decline) and the magnitude of cost exchanged for the stimulus. These paradigms, therefore, also provide a means for assessing how people assign subjective value to performance feedback and how this valuation, in turn, affects their motivation to seek feedback.

1.2. *Theoretical considerations for feedback-seeking*

A recently developed theory of information value provides a possible framework for how individuals perceive the benefits and costs associated with seeking feedback. Sharot and Sunstein (2020) posit that when deciding whether to obtain information, people estimate three forms of "utility" the prospective information will provide. They are as follows: "instrumental utility" (whether the information will aid in selecting action that gains rewards and/or avoids punishment), "hedonic utility" (the likely effects of the information on affective state), and "cognitive utility" (the personal relevance of the information to their own cognitive representations of themselves and the world around them; Kelly & Sharot, 2021; Sharot & Sunstein, 2020). Individuals assign weighted estimates of either direction (positive, negative, or zero) to each of these utilities. These estimates are then integrated into a net information value, whose sign motivates pursuit of the information (if positive), avoidance of the information (if negative), or indifference to the information (if zero). When applied to feedback-seeking decisions, this framework would predict that people estimate the instrumental (learning) and hedonic (affective) utilities of feedback during the decision. The positive or negative sign of the resulting net feedback value then determines whether feedback pursuit or feedback avoidance occurs. Thus, in this framework, people should be more likely to seek out performance feedback when it is expected to be both useful for learning and indicative of good performance (e.g., positive feedback indicating a correct response). Feedback that is expected to be useful for learning but indicative of suboptimal performance (e.g., negative feedback indicating an error) is less likely to be pursued, given the positive and negative weights, respectively, that are integrated into the net feedback value. Therefore, in the case of expected negative feedback, the positive instrumental utility estimate would have to outweigh the negative hedonic utility estimate to motivate pursuit of negative feedback.

1.3. *Present study*

Given the importance of feedback information for learning, a critical area of investigation is the factors that enhance the subjective value of feedback and motivate its seeking, an avenue that we pursue in the present study. A sample of Rutgers University – Newark undergraduate students completed a WTP version of a paired-word association task used in previous work (Cagna et al., 2023; Tricomi et al., 2006; Tricomi & Fiez, 2008, 2012). Participants learned word associations via trial-by-trial performance feedback during a learning phase and were later tested on their associative memory during a test phase. Subjective valuation of feedback was assessed via trial-by-trial decisions to purchase feedback whose cost was systematically varied across trials. We also measured skin conductance in response to feedback to assess possible contributions of physiological arousal during feedback valuation to feedback-seeking choice behavior. Skin conductance is a physiological measure widely used in decision-making, emotion, and learning research (Christopoulos et al., 2019; Dawson et al., 2011), given its ability to measure dynamic visceral fluctuations during transient states. As mentioned earlier in the Introduction, emotion and performance feedback are intimately tied as well. Emotional states can influence feedback-seeking behavior (Ashford et al., 2016) and often factor into decision-making more generally (George & Dane, 2016; Lerner et al., 2015), and received feedback contains both informational and emotional components. Furthermore, emotional states have been shown to influence learning and memory (Tyng et al., 2017). Despite this body of prior evidence, investigations into how SCR might influence feedback-seeking are lacking; thus, we employed this approach as our physiological measure in the current study.

We hypothesized that both the cost of feedback and participants' confidence in their learning phase performance would contribute significantly to decisions to purchase feedback. More specifically, in line with information value theory (Kelly & Sharot, 2021; Sharot & Sunstein, 2020), participants would be more likely to purchase feedback when it was less expensive and when they were less confident in their performance, since the instrumental (i.e., learning) utility of feedback should be greater when participants are not confident about their performance. We also hypothesized that emotional responses to feedback would influence feedback-seeking – namely, that greater self-reported interest to receipt of negative feedback would predict more decisions to purchase feedback. Finally, we hypothesized that an interaction between skin conductance and negative emotional responses to negative feedback would predict feedback-seeking behavior, such that stronger skin conductance in response to negative feedback outcomes would predict a higher likelihood of purchasing feedback, but only when negative-feedback-induced negative emotional responses are low. We note that while our primary hypotheses are motivated by the informational value theoretical framework, they also permit the testing of the alternative possibility of anticipated reward from positive feedback motivating feedback-seeking. More specifically, in this case, we would expect to observe higher likelihood of purchasing feedback when confidence in performance is high due to the desire for information confirming perceived good performance. We would also expect that greater self-reported interest during the receipt of positive feedback would predict more decisions to purchase feedback. Finally, physiologically, we would expect that stronger skin conductance in response to positive feedback would predict higher likelihood of purchasing feedback, but only when positive-feedback-induced emotional responses are high.

2. Materials and methods

2.1. Participants

The target sample size was 60 participants, selected to yield greater than 80 % power to detect a significant effect ($p < .05$) for relationships of medium to large effect size, such as associations between physiological arousal (SCR) to negative feedback and behavior observed in previous work ($r = .37$, Bhanji et al., 2016). A total of 69 Rutgers University - Newark undergraduate students participated in the study. Participants were excluded from data analysis if (a) their percentage of correct responses did not increase by at least 8 % (5 trials) between Phases 1 and 2 or between Phases 1 and 3 of the WTP paradigm (which indicated failure to learn the task; 8 exclusions) or (b) the number of non-zero feedback-elicited SCRs was more than 3 standard deviations lower than the mean across participants (1 exclusion). An additional participant was excluded from data analysis due to data unavailability resulting from technical error. Thus, the final sample comprised 59 participants (Age: $M = 20.04$, median = 19, range = 18–32; Gender: 45 female, 14 male; Race: 17 participants identified as Asian, 15 Black, 15 White, 12 multiracial or other; Ethnicity: across all racial categories, 12 participants identified as Hispanic/Latinx). The research protocol was approved by the Institutional Review Board of Rutgers

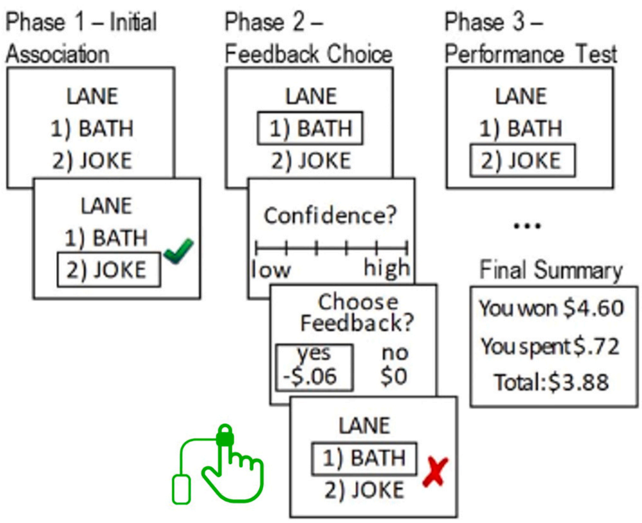

Fig. 1. WTP paired-word association task procedure. Participants first learned correct matches between target words and response options by making a guess and receiving feedback about their choices (Phase 1). They then repeated the same trials (Phase 2), where they were instructed to choose the correct response for each trial and then rate their confidence in their accuracy. Afterwards, they were presented with an opportunity to see feedback about their performance, but at a varying cost. Decisions to purchase feedback resulted in another feedback stimulus and a corresponding cost deduction from future winnings. Decisions to decline feedback resulted in a "No Feedback" stimulus and no cost deduction. SCR recordings were collected during feedback delivery after decisions to purchase/decline it. During the final phase (Phase 3), participants were tested on their associative memory, during which neither feedback nor opportunity to receive feedback were provided. Participants earned a monetary bonus at the end of the task equivalent to the amount of money won during the test phase ($.09 USD per correct response) minus the total cost of feedback purchased during Phase 2.

University. All participants provided informed consent before beginning any experimental procedures, and all were compensated with academic course credit and monetary winnings obtained during the task. This study was pre-registered through the Open Science Framework prior to data collection (https://doi.org/10.17605/OSF.IO/NC2JV).

2.2. Experimental paradigm

All participants completed a WTP version of a feedback-based paired-word association task that has been used in prior work (Cagna et al., 2023; Lempert & Tricomi, 2015; Tricomi & Fiez, 2008, 2012). The task was administered on a computer via PsychoPy (Version 1.90.3; Peirce et al., 2019) in a lab testing room. Participants were told that they would be completing a word-matching task, in which they could potentially win money depending on their performance during the final “bonus” round of the task – nine cents ($.09 USD) per correct answer, up to a maximum of approximately $6 USD. The task consisted of three phases that each included 60 trials (Fig. 1).

For each trial during Phase 1, participants were presented with a target word at the top of the screen, along with two words underneath it, for four seconds. The words were matched for string length (4 to 8 letters) and were semantically dissimilar from each other (Tricomi & Fiez, 2012). Participants were instructed to select the word they thought was the correct associate with the target word. Correct pairings were randomized, so response selection during this phase was essentially a guess. Correct responses yielded positive feedback displayed as a green checkmark for two seconds. Incorrect responses yielded negative feedback displayed as a red “X” for the same amount of time. Participants were instructed to learn the correct word matches from the feedback they received.

During Phase 2, participants received the same 60 sets of word pairs in a randomized order and were instructed to select the correct word based on the feedback they received from Phase 1. As with the previous phase, each trial lasted four seconds. Participants then rated their confidence in their response accuracy on a scale from 1 to 6 [1 = 50 % confidence (a guess) and 6 = 100 % confidence (certainty their response was correct)], with 10 % increments in between. Participants were then presented with an opportunity to receive feedback about their response accuracy again. However, unlike the previous phase where feedback was automatically provided, participants had to purchase feedback if they wished to see it again during this phase. They were presented with the question, “Do you want feedback?”, which appeared along with the options to either purchase it at a varying cost that was randomized across trials ($.00, $.02, $.04, or $.06 USD; 15 trials each) or to decline it. This screen and the preceding confidence rating screen terminated with the response. If 6 s passed without a response, a message appeared prompting participants to “please respond.” This manipulation measured subjective valuation of performance feedback, since participants had to factor both the potential benefit of receiving performance feedback again (better learning of word pairs, and thus, better performance and a greater monetary reward during the final phase) with the monetary cost of receiving feedback. If feedback was purchased, another feedback stimulus corresponding to response accuracy appeared for two seconds. If feedback was declined, an image with the words “No Feedback” appeared for two seconds. To assess physiological arousal in response to performance feedback valuation, SCRs were measured during a time window 1–4 s after feedback stimulus onset (positive feedback, negative feedback, or no feedback), when stimulus-elicited SCRs are expected (Benedek & Kaernbach, 2010). A four-second blank screen with a centered fixation dot followed every trial, to better isolate feedback-related SCRs.

Phase 3 tested participants’ associative memory of the word pairs. Participants received the same 60 sets of word pairs in a randomized order a final time, and were instructed to select the correct word match for each target word. Since this was a test phase, no feedback was presented during this phase. At the end of this phase, participants were presented with the total number of trials they answered correctly, the total amount they spent on feedback purchases during Phase 2, and their net winnings. If a participant failed to respond to a specific word pair in any of Phase 1, 2 or 3 then those trials were excluded from analysis (5.11 % of stimuli). Net winnings were calculated by subtracting the aggregate cost of Phase 2 feedback purchases from Phase 3 gross earnings ($.09 per correct trial). Participants were then awarded this amount at the completion of the experiment (M = $3.72 USD, SD = $0.72). This arrangement of feedback costs and potential material benefits per trial meant that it would be materially beneficial on any trial to spend one cent on feedback if it increased probability of responding correctly in Phase 3 by more than 11.1 % (e.g., raising probability from 50 % to 61.1 % would raise the expected value of the payoff from 4.5 cents to 5.5 cents).

2.3. Post-task affective measure of feedback

After completing the WTP task, participants rated their emotional responses to the positive and negative feedback they received during Phase 2 (on trials where they purchased feedback) of the task using items from the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988). First, participants rated their general affective response to the feedback they received during Phase 2 by indicating on a 7-point Likert scale how negative or positive they felt when they received feedback indicating they were incorrect (negative feedback outcomes) or correct (positive feedback outcomes). Values ranged from “extremely negative” to “extremely positive.” Next, using specific positive and negative affective states from the PANAS, participants rated how much of each state they felt when receiving either positive or negative feedback. Specifically, negative affective states included the “upset,” “frustrated,” and “distressed” items from the PANAS, and positive affective states included the “excited,” “enthusiastic,” and “proud” items. We also assessed interest-related responses to positive and negative feedback with the “interested,” “determined,” and “attentive” items of the PANAS. Values for each rating ranged from 1 (not at all) to 7 (extremely). We retrospectively assessed emotional responses to feedback to both reduce potential participant fatigue throughout the task and minimize the number of events that could have potentially interfered with learning during each Phase 2 trial (since participants were also making confidence ratings and feedback purchase decisions for each trial), which could have impacted test performance during Phase 3.

2.4. SCR data acquisition and preprocessing

A BIOPAC MP150 system conductance module and AcqKnowledge software (Biopac Systems, Goleta, CA, USA) were used to acquire SCR data. Preprocessing and continuous decomposition analysis (CDA) of the SCR data were performed using Ledalab software version V3.4.9 (Benedek & Kaernbach, 2010). This model-based analysis method estimates an individual skin conductance response shape, deconvolves the response, and decomposes the signal into continuous tonic and phasic components. The phasic component of this signal estimates sympathetic nervous system responses (Benedek & Kaernbach, 2010). In this study, we aimed to estimate responses to feedback events (positive, negative, no feedback). Thus, the response window was defined as 1–4 s after onset of the feedback event after the feedback purchase decision. The response window definition was consistent with the window used in validation of the decomposition method by Benedek and Kaernbach (2010). The area under the phasic driver within the response window was used as the trialwise measure of SCR to feedback (in microsiemens, μS) (Benedek & Kaernbach, 2010). SCR amplitudes less than the minimum threshold of .01 μS were entered as zero, following prior work (Benedek & Kaernbach, 2010; Bhanji et al., 2016). Following the preregistered analysis plan, participants whose total count of trials with non-zero SCRs was more than 3 standard deviations lower than the mean across participants were excluded from analysis ($n = 1$). The remaining participants exhibited non-zero SCRs in 70.91 % of trials on average ($SD = 19.92$ %, range: 16.67 % to 100 %). Thus, there was some concern that this threshold may include individuals who fail to show consistent SCRs. For this reason, SCR analyses were repeated in a subset of participants who demonstrated non-zero SCRs on at least 75 % of trials, referred to here as "consistent-SC-responders" ($n = 23$, 16 female, 7 male). This threshold was based on prior studies examining SCR to outcomes of decisions involving monetary incentives (Brooks & Sokol-Hessner, 2024; FeldmanHall et al., 2016). SCR analyses were repeated in consistent-SC-responders, and results were largely consistent with the full group. Results of the consistent-SC-responders analysis is described in the Supplementary Materials. Responses were then natural log-transformed to correct for positive skew, then mean SCRs to positive feedback, negative, and no feedback were computed for each participant by averaging across trials corresponding to each feedback type. Gender was included as a covariate in analysis of individual differences in SCR relating to feedback seeking and performance.

2.5. Pre-registered behavioral data analysis: Feedback-seeking behavior

RStudio (v. 2022.02.0; R Foundation for Statistical Computing; Vienna, Austria) was used for data analysis. Trial-by-trial feedback purchase decisions served as our measure of feedback subjective value. To test our hypotheses that feedback cost and reported confidence would each negatively predict feedback purchase decisions, we used the *lme4* package in RStudio to formulate two generalized logistic mixed models (GLMM) that each tested the influences of these factors on trial-by-trial decisions to purchase feedback. Feedback purchase decision (0 – decline; 1 – purchase) was entered as a binary outcome variable in each model. Feedback cost was entered as a fixed effect in its respective model, while the same was done for confidence in its model. Random intercepts and slopes for feedback cost and confidence, each by participant, were also included in their respective models. Notably, the confidence model also allowed for the testing of the pre-registered alternative hypothesis that high confidence could predict feedback purchase decisions, as it is possible that a desire for positive reinforcement from positive feedback could also motivate decisions to seek it.

In all GLMM analyses, individual predictor significance was assessed by likelihood ratio tests comparing the full model with the predictor to a reduced model without that predictor (Barr et al., 2013). Supplemental paired-samples t tests were also conducted for each model. For the feedback cost model, we compared the number of times feedback was purchased on 0-cent trials and on 6-cent trials. For the confidence model, we compared mean confidence ratings between trials where feedback was purchased and trials where feedback was declined.

To test our hypothesis that higher self-reported interest-related emotional responses (i.e., "interested," "determined," and "attentive" items) to negative feedback would be associated with a greater amount of money spent on feedback, we conducted a simple linear regression using a standard general linear model (GLM). The mean amount of money spent per trial on feedback purchases (WTP) was calculated for each participant and entered as the outcome variable. Responses for each of the interest-related items in response to negative feedback were collapsed to form a composite score for each subject that was entered into the model as the regressor of interest. For regression using WTP as the outcome, we conducted a robust linear regression, due to the non-normal distribution of model residuals (Field & Wilcox, 2017). We used the *lmRob* function in the *robustbase* package in RStudio with the same aforementioned model structure (Maechler et al., 2024).

2.6. Pre-registered behavioral data analysis: Task performance

We also tested the effects of WTP for feedback during Phase 2 on task performance during Phase 3, using a standard GLM with Phase 3 percent correct as the outcome and WTP (mean amount of money spent per trial) per participant as a predictor. Performance in Phase 2 was included as a control variable. A supplemental analysis examined trial-level performance with a GLMM, in which Phase 3 trial accuracy was entered as a binary outcome variable (0 – incorrect, 1 – correct). Feedback purchase decision was entered as our fixed effect of interest, while Phase 2 trial accuracy and feedback cost were entered as covariate fixed effects. Phase 2 trial accuracy was specifically included to control for prior performance and thus focus on change in performance between Phases 2 and 3. Random intercepts and slopes for purchase decision and feedback cost, each by participant, were included.

2.7. Pre-registered SCR data analysis

With respect to potential physiological correlates, we expected that higher SCR to negative feedback outcomes would correlate with more decisions to purchase feedback when participants reported lower levels of feedback-related distress (i.e., negative emotional responses to feedback). We conducted a robust multiple regression (due to the aforementioned non-normal distribution of model residuals), in which mean purchase amount was entered as the outcome variable (using the ***robustbase*** R package; Maechler et al., 2024). A composite score of negative affective states in response to negative feedback was computed and entered into the model as a regressor of interest, as was mean SCR during trials answered incorrectly (negative feedback) during Phase 2. The interaction between these two variables was also included. Exploratory analysis of SCR used robust repeated-measures ANOVA and paired comparisons with the WRS2 package (Mair & Wilcox, 2020), due to the non-normal distribution of SCR. For comparison of SCR means between conditions, we report robust tests of 20 % trimmed means, which is recommended by Mair and Wilcox (2020) because it achieves comparable power to a standard t-test while remaining robust to non-normal sample distributions, outliers, and heteroscedasticity. For comparison, we also include the standard paired t-test statistic and p-value for each comparison of SCR means.

3. Results

3.1. Feedback-seeking behavior: Pre-registered analyses

Likelihood ratio tests indicated significant contributions of feedback cost [$X^2(1) = 53.88, p < .001$] and confidence [$X^2(1) = 20.59, p < .001$] to model fit of the feedback purchase data. Parameter estimates of these effects supported our hypotheses. Participants were more likely to opt to purchase feedback on trials where it was less expensive ($b = -1.16$, $b_{SE} = 0.13$; Fig. 2A). A supplemental t-test supported this finding as well, indicating feedback was purchased in a greater proportion of trials for 0-cent ($M = .75$, $SD = .33$) compared to 6-cent ($M = .16$, $SD = .24$) trials [$t(58) = 12.98, p < .001, d = 1.69$]. Additionally, participants displayed higher likelihoods of purchasing feedback on trials where they reported lower confidence in their response accuracy ($b = -.25$, $b_{SE} = .05$; Fig. 2B). This was also supported by a supplemental paired-samples t test that indicated significantly lower confidence ratings for trials where feedback was purchased ($M = 76.80$ %, $SD = 10.90$) compared to when it was declined [$M = 82.68$ %, $SD = 11.78$; $t(54) = 4.34$, $p < .001$, $d = 0.69$]. Including a cost by confidence interaction term did not improve model fit [$X^2(1) = 0.09, p = .76$], meaning that the relation between confidence and feedback purchase was not significantly moderated by feedback cost (Fig. 2C). These findings support our hypothesis that lower, rather than higher, confidence in performance motivates feedback-seeking behavior.

We predicted that decisions to purchase feedback might be driven by emotional responses to feedback. However, interest-related emotional responses to negative feedback did not predict the amount of money spent on feedback during Phase 2 ($R^2 = .00005$; $b = 0.002$, $b_{SE} = 0.02$, $t = 0.13$, $p = .90$). We also did not find a significant effect of the interaction between SCR during negative feedback and self-reported negative emotional responses to negative feedback ($R^2 = .03$; $b = 0.49$, $b_{SE} = 0.96$, $t = 0.51$, $p = .61$). Moreover, there was neither a main effect of negative feedback SCR ($b = 0.48$, $b_{SE} = 1.06$, $t = 0.45$, $p = .65$) nor of emotional response to negative feedback ($b = 0.009$, $b_{SE} = 0.25$, $t = 0.04$, $p = .97$) on the amount of money spent on feedback. These results suggest that one's emotional and physiological responses to the performance feedback they receive may not necessarily be enough to motivate its purchase. Other factors, such as the cost of feedback and confidence in performance, may weigh more heavily in these decisions to seek feedback.

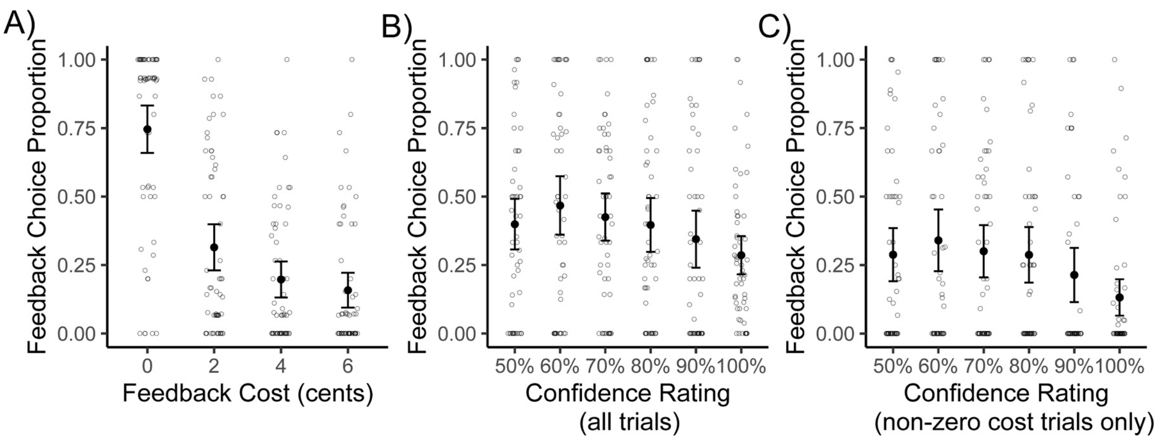

Fig. 2. Feedback choice explained by feedback cost and confidence rating. Mean proportion of feedback choice binned by A) feedback cost, and B) confidence rating on each trial. Panel C also shows feedback choice binned by confidence rating, but is based only on trials where feedback cost was greater than zero. Empty circles represent, for an individual participant, the proportion trials where feedback was chosen. Black points and error bars show the mean across participants and 95 % confidence interval. Means and error bars are shown here for visualization, but statistical tests are based on trialwise generalized mixed effects models.

3.1.1. Additional description of feedback-seeking on zero and non-zero cost trials

For descriptive purposes, we further examined feedback-seeking on trials where there was no cost for choosing to receive feedback, as well as all trials where the cost of feedback was greater than zero (Table 1). The association of low confidence with feedback purchase was also examined based only on trials where the cost of feedback was greater than zero (Fig. 2C).

3.1.2. Additional description of subjective confidence ratings

To assess how well subjective confidence ratings reflected actual performance, we calculated mean subjective confidence for objectively correct versus incorrect Phase 2 trials. Subjective confidence ratings were higher on objectively correct trials ($M = 84.1$ %, 95 % CI = [81.1, 86.9]) compared to objectively incorrect trials ($M = 69.1$ %, 95 % CI = [66.1,72.0], $t(58) = 13.24$, $p < .001$, $d = 1.72$). To explore the possibility that objective accuracy might contribute to feedback purchase over and above the contribution of subjective confidence, we added an objective accuracy term to the model predicting feedback choice by confidence. Objective accuracy did not significantly improve model fit [$X^2(1) = 0.04$, $p = .83$].

3.2. Task performance: Pre-registered analyses

Greater spending on feedback contributed to better learning performance. Specifically, Phase 2 feedback spending for each participant positively related to Phase 3 performance (controlling for Phase 2 performance; $b = 3.30$, $b_{SE} = 1.14$, $t = 2.89$, $p = .006$; correlation between amount spent and performance improvement: $\rho = .45$, 95 % CI = [.21, .64]; Fig. 3). However, a supplemental mixed effects analysis indicated that decisions to purchase feedback on a given trial did not significantly predict better performance during the test phase, after accounting for the independent contributions of Phase 2 response accuracy and feedback cost to Phase 3 response accuracy [$X^2(1) = 2.55$, $p = .06$, $b = 0.25$, $b_{SE} = 0.13$]. Given these findings, we considered the possibility that feedback valence might interact with feedback purchase decisions to promote better subsequent performance. Specifically, negative feedback (i.e., purchase decisions that yielded feedback signaling an incorrect response), more than positive feedback, may increase test phase performance due to corrective information contained in negative feedback (whereas positive feedback may be more confirmatory). This effect would have been obscured in the previous model that collapsed across feedback valence. To test this, we re-ran the previous model, but with the inclusion of an additional fixed effect that estimated the contribution of the interaction between Phase 2 response accuracy and feedback purchase decision. Results of this model suggested that this interaction did significantly improve model fit compared to the model without the interaction [$X^2(1) = 17.254$, $p = .00003$]. Specifically, participants' Phase 3 performance significantly benefited from Phase 2 purchase decisions that yielded negative feedback ($b = -0.81$, $b_{SE} = 0.19$, $t = -4.17$, $p < .001$). Collectively, these results suggest that negative feedback, in this task, improved participants' performance between phases. This pattern should be expected because we could not measure improvement on trials that were correct in Phase 2, only decreased performance.

3.3. Physiological responses, subjective affective responses, and motivation: Exploratory analyses

Exploratory analyses examined (a) whether differences in task feedback (positive, negative, no feedback) elicited different physiological responses (SCR), (b) whether physiological responses correlated with subjective affective responses to positive or negative feedback (interest-related: attentive, determined, interested ratings related to positive/negative feedback; and distress-related: distress, frustrated, upset emotion ratings related to negative feedback), and (c) whether WTP or task performance related to

Table 1
Descriptive statistics for sub-groups of participants who never/always chose feedback, split by trials where feedback had zero cost versus trials where feedback had nonzero cost.

	n	Confidence Rating (50 %–100 %)	Subjective Distress for Negative Feedback (1-7)	Subjective Interest for Negative Feedback (1-7)	Subjective Interest for Positive Feedback (1-7)	Performance Improvement from Phase 2 to 3
Zero Cost Trials						
Never Chose Feedback	5	86.3 % [62.3,96.8]	1.67[1.07,2.40]	4.00[3.33,4.60]	4.87[4.20,5.93]	−7.28 %[−15.18,−1.33]
Always Chose Feedback	19	78.3 % [74.3,82.9]	2.89[2.39,3.35]	4.56[3.96,5.14]	5.00[4.39,5.63]	7.03 %[.54,12.83]
All Participants	59	80.8 % [77.7,84.0]	2.76[2.49,3.03]	4.20[3.89,4.55]	4.69[4.36,5.00]	3.76 %[−.02,.7.70]
Nonzero Cost Trials						
Never Chose Feedback	12	77.4 % [70.1,84.5]	2.28[1.64,2.92]	3.81[3.06,4.47]	4.33[3.44,5.08]	
Always Chose Feedback	1	94.2 %[na]	1.67[na]	6.67[na]	7[na]	
All Participants	59	80.5 % [77.8,83.5]	2.76[2.49,3.03]	4.20[3.89,4.55]	4.69[4.36,5.00]	6.49 %[4.51,8.38]

Note: Means and [95 % CI] are shown for each sub-group of participants. Confidence ratings were measured trial-by-trial, but subjective distress/interest ratings were retrospectively completed after the task concluded.

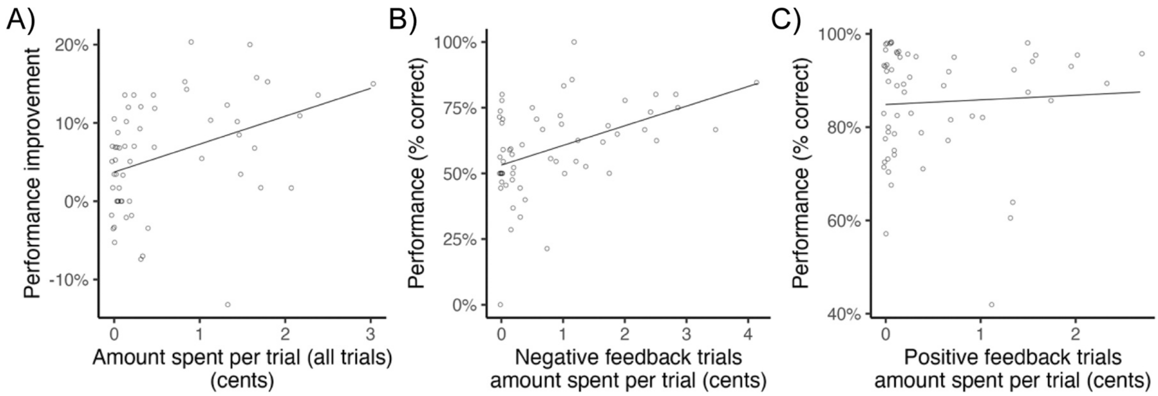

Fig. 3. Learning performance explained by the amount spent on feedback. A) Across all trials, participants who spent more for feedback in Phase 2 improved more in Phase 3 (ρ = .45). The vertical axis shows the change in performance (% correct responses) between Phase 2 and Phase 3 (positive values indicate improvement). B) and C) On trials that were answered incorrectly in Phase 2, feedback spending related to better performance on corresponding trials in Phase 3 (ρ = .41), but this association did not exist for trials that were answered correctly in Phase 3 (ρ = .06). The vertical axes in (B) and (C) show the absolute performance (% correct responses) in Phase 3. Each point represents one participant. Points are jittered by 1 % of the horizontal axis range for visibility.

individual differences in self-esteem (Rosenberg, 1965), mastery learning goals (Elliot & McGregor, 2001), theory of intelligence (Dweck, 2000), or task motivation (Ryan, 1982).

3.3.1. Physiological responses to feedback are influenced by valence

54 participants exhibited SCRs for all feedback types: positive, negative, and no feedback trials. In these participants, feedback type had a significant effect on SCR (robust ANOVA: $F(2,66) = 4.812$, $p = 0.011$; standard ANOVA: $F(2,106) = 5.24$, $p = .007$; Fig. 4). Pairwise comparisons showed that (a) SCR to positive feedback was significantly greater than negative feedback (20 % trimmed mean difference =.069, 95 % CI = [.024, .115], $p = .001$, paired $t(53) = 3.036$, $p = .004$), (b) SCR to negative feedback was significantly lower than no feedback according to the robust, but not the standard, comparison (20 % trimmed mean difference = −.056, 95 % CI = [−.113, −.001], $p = .019$, paired $t(53) = -1.590$, $p = .118$), and (c) SCR to positive feedback did not significantly differ from SCR to no feedback (20 % trimmed mean difference =.034, 95 % CI = [−.015, .084], $p = .08$, paired $t(53) = 1.754$, $p = .085$). There was no association between negative feedback SCR and WTP. Exploratory analysis showed a negative association between negative feedback SCR and task performance improvement (ρ = −.28, 95 % CI = [−.51, .00], $p = .042$), but this association was non-significant when including gender as a covariate in a robust regression ($p = .06$).

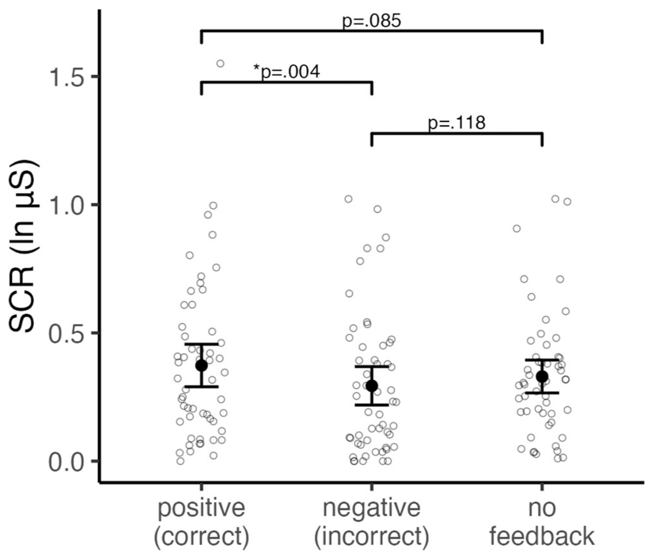

Fig. 4. SCR by feedback type. Gray dots represent individual participant SCRs following each type of feedback. Black points and error bars show the mean across participants and 95 % confidence interval around each mean. Uncorrected p-values from standard paired t-test between conditions.

3.3.2. Physiological responses to feedback are not significantly related to subjective emotional responses to feedback

Negative feedback SCR did not significantly correlate with subjective interest ratings for negative feedback (ρ = .21, 95 % CI = [−.06, 0.46], p = .117) or subjective distress for negative feedback (ρ = .05, 95 % CI = [−.32, .23], p = .726). Positive feedback SCR did not significantly correlate with subjective interest ratings for positive feedback (ρ = .02, 95 % CI = [−.25, .29], p = .879) or subjective positive affect for positive feedback (ρ = .08, 95 % CI = [−.19, .35], p = .726).

3.3.3. Individual differences in task performance and WTP for feedback

Table 2 shows correlations between WTP for feedback, task performance (improvement from Phase 2 to Phase 3), task motivation (measured by the Intrinsic Motivation Inventory: Ryan, 1982; yielding reports of perceived competence in the task, perceived task importance, and task enjoyment), self-esteem (Rosenberg, 1965), learning goals (Elliot & McGregor, 2001), and theory of intelligence (Dweck, 2000).

4. Discussion and conclusions

Utilizing a WTP feedback-based paired-associate paradigm, the present study revealed the significant role of confidence in the subjective valuation of performance feedback and the subsequent motivation to pursue it. Participants opted to purchase feedback when they were less confident about their learning accuracy. Emotional responses to feedback, as well as physiological arousal during feedback purchase decisions, however, did not predict participants' willingness to buy feedback. Thus, confidence in one's cognitive performance may be a major factor in value-based decisions about seeking feedback and could serve as a target for motivating feedback-seeking in environments where learning is integral to success.

Participants were more likely to purchase feedback on trials for which they reported lower confidence in their response accuracy during learning. This result replicates what has been found in other work using this WTP task (Cagna et al., 2023) and is consistent with other reports of confidence influencing value-based decision-making and learning (Boldt et al., 2019; Folke et al., 2017). It has been shown that individuals tend to seek information to verify response accuracy when they are unsure about whether they made the right choice during initial response selection (Desender et al., 2018, 2019; Kelly & Sharot, 2021). We show a similar result in the current study. During Phase 2, participants rated their confidence in their response accuracy immediately after choosing what they thought was the correct word match. Immediately afterwards, they were faced with a decision to seek feedback. Thus, participants' own confidence in their performance was likely still quite salient while deciding whether to seek feedback. An interesting future direction would be to increase the amount of time between confidence rating and feedback purchase decision to test the robustness of the confidence effect.

Notably, our confidence findings provide support for Sharot & Sunstein's (2020) theory of information value, but not the alternative explanation of anticipated reward from positive feedback. The latter explanation would predict that individuals would be more motivated to seek feedback when they believe it will be positive (i.e., confirm their accuracy or seek positive affect from positive feedback). If this were the case, we would have expected feedback purchases to be more likely on trials with higher reported confidence. Since better learning of word pairs predicted better performance in our paradigm, it is possible that participants' recognition of feedback as a means of earning more money during the test phase (through better performance) "overrode" the affective risks of potentially receiving negative feedback. This explanation aligns with the "instrumental utility" tenet of the theory of information value (Kelly & Sharot, 2021; Sharot & Sunstein, 2020). As explained in the Introduction, part of this theory posits that people estimate whether prospective information will aid them in obtaining rewards and/or avoiding punishment. If so, then the information is pursued. Thus, in the current study, the monetary incentive for future good performance may have highlighted the instrumental utility of feedback (i.e., corrective information) above and beyond the affective value (or, "hedonic utility") of feedback (i.e., avoiding being wrong) during low-confidence trials. Instrumental utility of feedback information could therefore buffer against biased information-seeking moderated by the expected valence of the information, as has been reported elsewhere (Charpentier et al., 2018). Put simply, sufficiently highlighting the learning utility of feedback to people may motivate them to seek it out, even if doing so risks being told they are wrong.

Decisions to seek feedback were guided by "rational" factors (low confidence, low cost) that tended to increase bonus payments by gaining information while minimizing cost. Neither emotional nor physiological responses significantly factored into decisions to seek feedback. Specifically, self-reported interest in, and negative emotional responses to, negative feedback did not impact feedback purchases. Moreover, physiological arousal (SCR) did not interact with emotional responses to predict feedback purchases, nor did it predict feedback choice behavior on its own. However, SCR did differ for positive compared to negative feedback, and exploratory analysis showed that individuals with greater negative feedback SCR improved less in the task. These results suggest that feedback in this task elicits meaningful changes in physiological arousal, and negative feedback arousal responses may relate to worse learning from negative feedback. One explanation for the lack of association between feedback purchases and physiological or subjective emotional responses is that the instrumental utility (Kelly & Sharot, 2021; Sharot & Sunstein, 2020) of feedback, rather than emotional responses to it, factored more heavily in choices about whether to purchase it or not.

With respect to task performance, greater spending on performance feedback promoted better associative memory performance during test. This beneficial effect on learning was largely driven by feedback purchases that yielded negative feedback. This finding aligns with the established role of negative feedback in shaping learning (Cagna et al., 2023; Dobryakova & Tricomi, 2013; Lempert & Tricomi, 2015; Tricomi & Fiez, 2008, 2012). Furthermore, negative feedback outcomes signal a prediction error between the predicted correct response and the actual correct response. Prediction errors of greater magnitude tend to promote better learning (O'Doherty, 2004; Schönberg et al., 2007; Schultz et al., 1997), as there is a greater degree of corrective information from which to learn. In our

Table 2
Correlations (Spearman's ρ) for task behavior, task feedback-related emotional reports, and trait measures.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. WTP	—													
2. Task performance	.45 * *	—												
3. Negative feedback interest	.02	.09	—											
4. Negative feedback distress	.06	.00	.28 *	—										
5. Positive feedback interest	−.02	.08	.76 * *	.30 *	—									
6. Self-esteem	−.03	−.08	.12	−.21	.28 *	—								
7. AGQ: mastery approach	−.20	.03	.2	.02	.34 * *	.19	—							
8. AGQ: mastery avoid	−.08	.10	.18	.2	.18	−.39 * *	.23	—						
9. AGQ: performance approach	−.07	−.08	.11	−.05	.10	−.01	.02	.04	—					
10. AGQ: performance avoid	.06	.10	.06	−.11	.14	.15	.46 * *	−.03	.16	—				
11. TOI: Entity theory	.04	.29 *	.38 * *	.01	.28 *	.32 *	.36 * *	.13	.13	.34 * *	—			
12. IMI: Competence	.01	.16	.44 * *	.22	.52 * *	−.03	.28 *	.27 *	.32 *	.22	.43 * *	—		
13. IMI: Effort/ Importance	.14	.03	.45 * *	.02	.64 * *	.16	.28 *	.12	.22	.36 * *	.17	.40 * *	—	
14. IMI: Interest/ Enjoyment	−.04	.05	.55 * *	.16	.55 * *	.29 *	.27 *	.08	.09	.15	.31 *	.54 * *	.44 * *	—

Note. WTP: Willingness to pay for task feedback; Task performance: improvement from task Phase 2 to Phase 3; Negative/positive feedback interest/distress are from post-task emotion ratings (see Methods); Self-esteem measured from Rosenberg (1965) inventory; AGQ: Achievement Goals Questionnaire (Elliot & McGregor, 2001) - "mastery approach" measures aim to develop mastery of a task; "mastery avoid" measures aim to avoid failure to master a task; "performance approach" measures aim to demonstrate competence in a task relative to others; "performance avoid" measures aim to avoid failure to demonstrate competence in a task; TOI: Theory of intelligence - higher scores indicate entity theory (belief that intelligence is a fixed trait; Dweck, 2000). IMI: Intrinsic Motivation Inventory (Ryan, 1982) - "competence" measures perceptions of one's performance in the target WTP for feedback task; "effort/importance" measures effort put into the target task; "interest/enjoyment" measures intrinsic interest in the target task. * indicates $p < .05$. * * indicates $p < .01$ (uncorrected).

study's WTP task, since prediction errors are more apparent during negative, relative to positive, feedback, it is sensible that participants' performance improved from these outcomes, in particular.

The current study contains some limitations that should be considered. First, participants retroactively self-reported their emotional responses to feedback after completing the WTP task. While our findings did not suggest emotional influences on subjective valuation of feedback, future versions of the WTP task could incorporate trial-wise feedback emotion ratings during the task to more thoroughly capture feedback-elicited emotions. Other variations where feedback emphasizes information (without requiring an initial response) versus valence (feedback that a response was correct or incorrect) might better isolate contributions of emotion to feedback seeking. Such a design might model situations where a student might prefer to just review the answers to a practice test instead of taking the practice test. Second, learning during the task was incentivized with a monetary reward contingent on future performance. It is therefore possible that such an incentive structure is necessary for highlighting the learning utility of feedback over its associated emotional responses. However, neural evidence has indicated that non-monetary experimental manipulations can induce changes in reward-related brain activity in response to negative feedback (Lempert & Tricomi, 2015; Tricomi & Fiez, 2012). Regardless, future iterations of this task that include a non-monetary performance incentive (e.g., points) could further elucidate the importance of incentive structure on the effects reported here. Related to this point, a limitation of the study is that the stakes involved in getting an answer incorrect were minor compared to real-world situations where negative feedback-seeking is important, such as in standardized testing, job interviews, or performance reviews.

The current study provides evidence for the strong influence of confidence on value-based decision-making about whether or not to seek performance feedback. Additionally, we show that physiological and emotional responses to feedback may not be as prominent in shaping these decisions, although we advise caution with interpretation of the latter, given that emotional responses to feedback were assessed post-task in this study. Thus, during feedback valuation computations, the reward of gaining information to improve learning may outweigh the affective risks of negative feedback – at least when such learning is tied to a future monetary incentive. Our results also indicate that negative feedback improves associative memory performance. Taken together, these findings suggest it is possible to highlight the learning utility of negative feedback above and beyond the associated unpleasant risk of being wrong (a risk that is greatest when the learner is not confident in their performance). But, if the learner should receive negative feedback, their learning should improve most from it. Therefore, this work has direct translational applications to educational, occupational, rehabilitation, and other settings where learning is critical to success. Teaching people that being wrong is okay and that it leads to learning is often a significant challenge in these arenas (Dweck & Yeager, 2019). The current study's findings identify factors to consider for addressing this challenge and motivating people to engage with their own learning.

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CRediT authorship contribution statement

Christopher J. Cagna: Writing – review & editing, Writing – original draft, Formal analysis. **Jamil P. Bhanji:** Writing – review & editing, Writing – original draft, Visualization, Software, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Da'Quallon Smith:** Writing – review & editing, Investigation. **Mauricio R. Delgado:** Writing – review & editing, Supervision, Resources, Methodology, Funding acquisition, Conceptualization. **Elizabeth Tricomi:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

Declaration of Competing Interest

None

Data availability

The preregistration and data that support the findings of this study are openly available in the Open Science Framework at https://doi.org/10.17605/OSF.IO/NC2JV.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.lmot.2024.102051.

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