Emotion

The Influence of Contextual Factors on the Subjective Value of Control

Kainan S. Wang, Madhuri Kashyap, and Mauricio R. Delgado

Online First Publication, May 11, 2020. http://dx.doi.org/10.1037/emo0000760

AMERICAN PSYCHOLOGICAL ASSOCIATION

Emotion

ISSN: 1528-3542

http://dx.doi.org/10.1037/emo0000760

The Influence of Contextual Factors on the Subjective Value of Control

Kainan S. Wang
Harvard Medical School and McLean Imaging Center, McLean Hospital, Belmont, Massachusetts

Madhuri Kashyap and Mauricio R. Delgado
Rutgers University–Newark

The propensity to perceive and exert control in our environment contributes to both our adaptive behavior and general well-being. Prior studies have shown that humans have an inherent behavioral bias toward control-conferring environments and that this bias translates into greater subjective affect and is protective of our well-being. As such, it is vital to understand contextual factors that can alter our preference for control. In our previous work, we demonstrated that the behavioral bias toward control can be captured experimentally as the subjective value of control using a novel Value of Control task. We adapted this task in two experiments to study whether one's subjective value of control is (a) tied to overestimation of success probability or outcome magnitude (Experiment 1) and (b) affected by the contextual valence of a decision (e.g., gain, loss; Experiment 2). Using a within-subjects design (Experiment 1), we found that participants showed similar behavioral bias toward control regardless of whether probability or magnitude was manipulated, suggesting that the perception of control can increase both how much a reward is subjectively worth and the probability estimation for obtaining the given reward. Using a between-subjects design (Experiment 2), we showed that when the outcome was framed as a potential loss, participants significantly lowered their subjective value of control, suggesting that outcome valence plays a role in shaping how much perceived control influences our behavior. Collectively, these findings offer further insight into the malleability of an individual's perception of control and drive to perform control-seeking behaviors.

Keywords: perceived control, subjective value, outcome valence, decision making, reward

Our sense of control over our environment represents a basic need that is rooted in our deepest psychological makeup and exerts strong influences on decision-making and behaviors in our daily lives. This need for control often drives us to perform control-seeking actions and gravitate us toward control-conferring situations that fulfill our desire for control. The desire to have control is sometimes so powerful that we can be compelled to choose, even at a cost, situations endowing us with a sense of control over those that present a lack of control. This is because feeling in control itself elicits positive emotions and hence carries a subjective value that can generate approach behavior and bias our actions accordingly. Having an increased sense of control has been argued to serve an important role, both physiologically and psychologically, in helping to maintain general well-being (Leotti, Iyengar, & Ochsner, 2010; Wallston, Wallston, Smith, & Dobbins, 1987). When people feel in control, they tend to report greater happiness and satisfaction in their lives (Calvo, Haverstick, & Sass, 2009; Grob, 2000; Verme, 2009). On the other hand, a diminished or absent sense of control is a hallmark of depression, posttraumatic stress disorder, and addictive states (Bechara, 2005; Frazier, Steward, & Mortensen, 2004; Glass & McKnight, 1996). Thus, it is imperative to understand what factors can influence one's sense of control and subsequently bias control-seeking behaviors.

Animals and humans alike willingly perform control-seeking behaviors to try to influence their environment (Burger & Cooper, 1979; Leotti et al., 2010; Skinner, 1995; Solomon & Rodin, 1976). These behaviors are encapsulated in the preference that organisms across species demonstrate for having choices over no choices (Bown, Read, & Summers, 2003; Catania & Sagvolden, 1980; Lieberman, Ochsner, Gilbert, & Schacter, 2001; Suzuki, 1997, 1999). Indeed, organisms show an affinity toward exercising control, regardless of whether control is objectively present or has tangible effects on the outcome (Langer, 1975), and will voluntarily work harder when an outcome control is perceived (Schunk, 1991). Taken together, these studies support the notion that perceived control leads to a positive affective signal that encourages approach behavior toward seeking and exercising control (Ly, Wang, Bhanji, & Delgado, 2019).

We have previously shown that perceived control carries a subjective value that drives control-seeking behaviors (K. S. Wang & Delgado, 2019). Specifically, we used a *Value of Control* (VoC) task in which participants were presented with a series of binary

Kainan S. Wang, Department of Psychiatry, Harvard Medical School, and McLean Imaging Center, McLean Hospital, Belmont, Massachusetts; Madhuri Kashyap and Mauricio R. Delgado, Department of Psychology, Rutgers University–Newark.

This work was supported by funding from the National Institutes of Health (DA027764) and the McKnight Foundation. The authors declare no competing financial interests.

Correspondence concerning this article should be addressed to Mauricio R. Delgado, Department of Psychology, Rutgers University–Newark, 101 Warren Street, Room 340 Smith Hall, Newark, NJ 07102. E-mail: delgado@psychology.rutgers.edu

choices between a control-conferring or a control-relinquishing option. Each choice pair differed in the reward expected value (EV), and by examining participants' choice patterns, we could derive their subjective value of control. Participants attributed a positive subjective value to having control, choosing the option that allowed them to exert control despite accepting a smaller objective reward value. In the current article, we explore two potential factors that could influence this subjective value conferred by control: success probability (Experiment 1) and valence associated with the choice context (Experiment 2).

First, canonical value computations are subserved by both magnitude and success probability (Rangel, Camerer, & Montague, 2008). Prior work exploring how our magnitude and probability estimations are malleable based on our perception of control has found that in situations where the participant believed that the outcome was of the participant's own actions, the outcome success probability (Krueger & Dickson, 1994; Miller & Ross, 1975) and outcome magnitude (Inzlicht, Shenhav, & Olivola, 2018; L. Wang, Zheng, & Meng, 2017) were both inflated. These findings allude to the possibility that our sense of control bears on the subjective interpretation of success probability and outcome magnitude by encouraging us to overestimate them when we find ourselves in control-conferring situations. As such, do individuals willingly translate their probability and magnitude overestimation (from believing that they have control) into behaviors that require them to take on a cost and choose the control-conferring option even when the alternative control-relinquishing option is objectively better? Answering this question would expand our understanding of potential factors subserving our subjective value of control.

In Experiment 1, we independently manipulated reward magnitude and success probability in an adapted version of the VoC task to probe their respective impact on the subjective value of control. Using a within-subjects design, we hypothesized that independently manipulating both magnitude and probability components would yield subjective biases toward the control-conferring option because the subjective preference for control is likely to inflate both how much a reward is subjectively worth and how likely the individual believes it can be obtained (Kahneman & Tversky, 2013).

Second, an important factor in any decision-making is whether the potential choice leads to positive (e.g., gain) or negative (e.g., loss) consequences. The context of the choice can be influenced by framing the valence of the outcomes associated with the decision. Insofar as it pertains to our sense of control, it has previously been shown that in *loss* compared with *gain* contexts, participants not only have a weaker perception of control (Alloy & Abramson, 1979), but perhaps driven by the riskier circumstances of losses—because losses loom larger than gains (i.e., loss aversion; Kahneman, Knetsch, & Thaler, 1991)—they are also less likely to perceive having control to begin with (Dunn & Wilson, 1990). Another related line of work on self-serving bias (Miller & Ross, 1975) has reported that individuals' inherent sense of control is strongly related to whether they attribute failures (as in losses) to others instead of themselves (Campbell & Sedikides, 1999; Silvester, Anderson-Gough, Anderson, & Mohamed, 2002). As such, it is plausible that in the loss frame compared with the gain frame, participants would have a dampened desire to take on a cost to exercise control and accordingly show a lower subjective value of control. To test whether the valence associated with the choice context affects how much control is subjectively valued, we adapted the VoC task in Experiment 2 to present it either in a gain or loss frame to investigate potential changes in participants' subjective value of control. Using a between-subjects design, we hypothesized that participants who were asked to evaluate their preference for control in a loss context would show a weaker preference toward exercising control (i.e., lower subjective value of control) compared with those assessing control in a gain context.

Experiment 1

The aim of this experiment was to investigate whether success probability and outcome magnitude would differentially influence participants' subjective value of control in a reward-based context.

Method

Participants. Fifty participants (13 males and 37 females) between the ages of 18 and 42 (mean [M] = 20.08, standard deviation [SD] = 3.82) were recruited from the Rutgers University Department of Psychology R-Points System. A power analysis for a paired t test was conducted according to the guidelines established by Lipsey (1990) using G*Power (Version 3.1; Faul, Erdfelder, Lang, & Buchner, 2007). To achieve an alpha of 0.05, a power of 0.80, and a medium effect size of 0.5, the desired sample size was 34. Extra participant recruitment was planned to offset potential experimental dropout and data loss. Participants were informed that their participation would earn them research credits for classwork as well as a chance for a monetary bonus (up to $5) based on task performance. Prior to the experiment, all participants read and signed consent forms detailing the experimental procedures approved by the Rutgers University Institutional Review Board. We excluded participants from data analysis if they met one of two related exclusion criteria determined prior to data collection: (a) Participants indicated verbally during the debriefing that they did not understand the task or were not engaged in the task. (b) Participants reported a random-choice pattern as indicated by an abnormally high or low point of equivalence (POE) measure. In total, seven participants were removed from data analysis (final participant count was 43).

Value of control task. The VoC task was designed to measure an individual's subjective value for exerting control during decision-making (K. S. Wang & Delgado, 2019). Each VoC trial was divided into two phases: choice and game phases. All computerized parts of the task were coded and presented using MATLAB and Psychtoolbox 3 (Brainard, 1997).

Choice phase. In the choice phase, participants were presented with a binary choice between a SELF option that gave them control over the subsequent game or a COMP option that represented relinquishing control of gameplay to the computer. Note that the placement of SELF/COMP options on the screen (i.e., left or right) was counterbalanced. We manipulated the reward EV of each option within the pairings so as to probe participants' choice pattern during the task. EV was manipulated by changing either the experimental points (i.e., magnitude, ranging from 0 to 20 in increments of 2) or success probability (ranging from 0% to 100% in increments of 10%) associated with each option. The choice phase terminated with a jittered 1.5- to 3.5-s interstimulus interval (ISI) after participants had made their selection.

Game phase. The game phase was adapted from Delgado, Nystrom, Fissell, Noll, and Fiez (2000) and consisted of a card-guessing game where participants were shown an unknown card that was concealing a number between 1 and 9. The objective of the game was to guess whether the concealed number was higher or lower than the number 5 (the number 5 itself was not an option). Depending on the option picked in the choice phase, participants could either make the guess themselves (i.e., SELF option) or have the computer play in their stead (i.e., COMP option). Regardless of what participants selected during the choice phase, they responded with a single button press during the game phase to ensure that motor effort was not relevant in biasing participants' choices. Each choice phase concluded with a jittered 2- to 4-s intertrial interval (ITI) that featured a fixation cross to signal the end of each trial. There was no feedback phase so as to minimize any opportunity to learn and prevent potential feedback bias on successive trials.

Any correct response either by the participant or the computer, resulted in the rewarding of the associated experimental points into participants' point bank, whereas incorrect guesses yielded no net gain or loss. Participants' performance in the experiment was resolved during the debriefing, when their point bank was revealed and converted into a monetary reward.

Training version of the value of control task. Prior to undergoing the actual task, participants first performed a shorter training version (20 trials) of the VoC task in order to learn the game. In the training version, participants were presented with an equal number of forced choices directed at either the SELF or the COMP option. Both options carried matching experimental points (verbalized but not displayed on the screen), and the placement of the options on the screen was counterbalanced across participants. The key distinction in the training version of the task was the inclusion of the feedback phase after the game phase, in which participants received feedback on the outcome of the card-guessing game after each trial. A correct guess by either the participant or the computer was shown as a green numbered card, whereas an incorrect guess was shown as a red numbered card. This was included to allow participants to experience the outcomes of both the SELF and COMP options, where they received 50% successful and 50% unsuccessful trials for both options.

Each feedback phase lasted 1 s and was followed by a jittered ITI lasting 2 to 4 s. At the conclusion of the training phase, participants were asked about their understanding of the game, especially the difference between the two choices. Participants were never explicitly asked about the contingencies for the options to avoid potential instructional bias.

Experimental design. Participants completed both the training and testing versions of the VoC task in that order. In the testing version, there were two counterbalanced experimental conditions (i.e., magnitude and probability), each featured in a run of 44 randomized trials. Importantly, the EV for the COMP/SELF pairings across all trials was equated between the two conditions.

Upon completing the computerized tasks, participants were asked to complete three paper questionnaires. The three questionnaires were given in the same order to all participants: (a) Mini Mood and Anxiety Symptom Questionnaire (MASQ; Clark & Watson, 1995); (b) General Perceived Self-Efficacy (GPSE; Schwarzer & Jerusalem, 2010); (c) Internal-External Locus of Control (LOC; Rotter, 1966). We included these questionnaires to measure participants' level of anhedonic depression as related to their mood (Clark & Watson, 1995), perception of self-efficacy (Schwarzer & Jerusalem, 2010), and locus of control (Rotter, 1966) to assess whether these subjective measures were related to their choices in the VoC task, which would help to shed light on potential underpinnings driving participants' preference for control.

Magnitude condition. In the magnitude-condition trials (see Figure 1), participants were presented with COMP options carrying a fixed success probability (50%) but a varied point value (0–20 points in increments of 2). In contrast, the SELF options were fixed at 10 points with an objective success percentage of 50% (based on task description and training-version feedback). Note that the success percentages of the SELF options were not displayed on the screen to participants. The magnitude condition was identical to the mixed condition in our previous article (K. S. Wang & Delgado, 2019) and thus served as the reference condition to which we compared the probability condition.

Probability condition. Conversely, in the probability-condition trials (see Figure 1), participants were presented with COMP options that had a fixed point value (10 points) but a varied success percentage (0–100% in increments of 10%). The SELF options were identical to those presented to participants in the magnitude condition, that is, a fixed value of 10 points and an objective success percentage of 50%.

Data analyses. Because we were interested in participants' choice behavior during the choice phase, we used a two-part analysis to explore whether participants (a) showed any bias toward one specific choice in each of the conditions (i.e., magnitude or probability) and (b) whether their bias was significantly different across the two conditions.

Derivation of point of equivalence measure. First, we considered the trial-by-trial data of each participant and fitted their individual choice behavior onto a logistic regression. We coded each trial using the EV difference between the two options (i.e., $EV_{COMP} - EV_{SELF}$). The EV was computed by multiplying the success probability (50% based on feedback received in the training version of the task) by the associated point magnitude (range of −5 to 5 in increments of 1). Using EV difference as the independent variable and employing maximum likelihood estimation, we fitted the trial-by-trial choice data of each participant to a single logistic function (Berkson, 1944; Davidson & MacKinnon, 2004; Press & Wilson, 1978; Reed & Berkson, 1929).

Using the logistically-regressed data, we derived the POE measure (i.e., identifying the EV pairing where participants showed a behavioral indifference toward either option) by setting p_{SELF} (y-intercept) to 0.5 using the inverse of the logistic function

$$\frac{p_{SELF}}{1 - p_{SELF}} = e^{\beta_0 + \beta_1 x}$$

where p_{SELF} is the probability of a SELF choice, β_0 is the coefficient of the constant term, β_1 is the coefficient of the predictor or independent variable, and x is the predictor ($EV_{COMP} - EV_{SELF}$). We solved for x, which we termed the *POE measure* and interpreted it as the difference in value between the two options (i.e., x-intercept: $EV_{COMP} - EV_{SELF}$) for each participant where the participant was equally likely (i.e., $p_{SELF} = 0.5$) to choose either option.

$$POE = \frac{\ln(1) - \beta_0}{\beta_1}$$

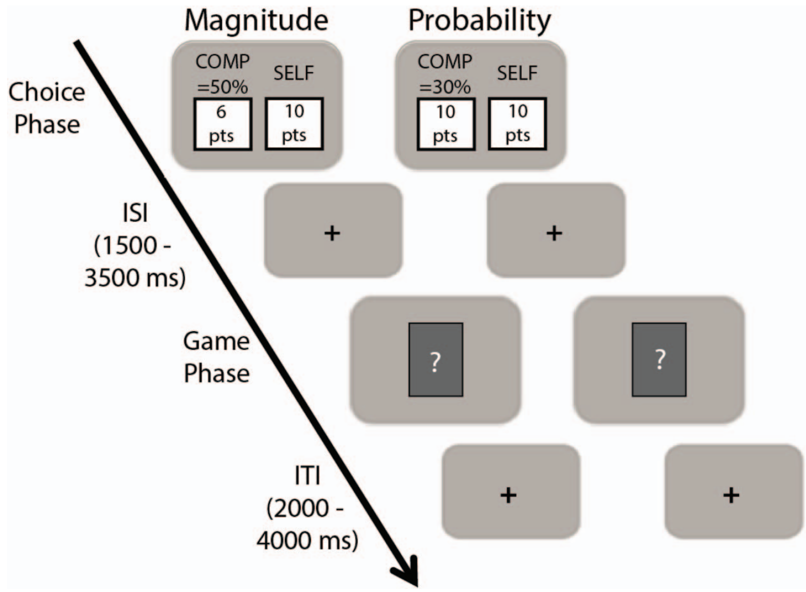

Figure 1. Magnitude and probability conditions of the Value of Control (VoC) task. The VoC task consisted of two phases, choice and game. In the choice phase, participants were asked to choose between the control-conferring SELF option or the control-relinquishing COMP option. This phase featured two trial types denoting either the magnitude or probability condition. Participants' decisions in the choice phase determined how they would play the game phase. See the online article for the color version of this figure.

The derivation of this POE provided a measure of the subjective value that participants ascribed to exerting control. In other words, participants' POE would yield (in units of experimental points) how much having control (i.e., SELF-option) was valued. We derived this POE for each participant and subsequently used *t* tests to compare participants' POEs for each condition against the hypothesized mean of 0. This hypothesized mean was rooted in our prior work demonstrating that when participants were asked to choose between two options that differed in EV but not along the dimension of control (e.g., two COMP or two SELF options), their mean POEs were not significantly different from 0 (K. S. Wang & Delgado, 2019).

Generalized mixed-effect model. To examine whether the two conditions (i.e., magnitude and probability) yielded differences in participants' choice behavior, we applied a generalized linear mixed-effects model (GLME) with a logistic link function (MATLAB *fitglme*) on participants' trial-by-trial data across both conditions. Again, each trial was coded with the EV difference between the two options (i.e., $EV_{COMP} - EV_{SELF}$). The GLME model formula is as follows:

$$\log\frac{SELF_{sc}}{(1 - SELF_{sc})} = \beta_0 + \beta_1 EVdiff_{SC} + \beta_2 Conditions_{SC} + \mu_{0S} + \mu_{0SC} + e_{SC}$$

where $\log\frac{SELF_{sc}}{(1 - SELF_{sc})}$ is the binomial response variable for SELF choices, β_0 is the fixed-effect intercept, $\beta_1 EVdiff_{SC}$ is the fixed-effect predictor coding for EV difference (for *s*th subject in *c* condition), $\beta_2 Conditions_{SC}$ is the fixed-effect predictor for condition (i.e., probability and magnitude), μ_{0S} is the random-effect intercept for the participant, μ_{0SC} is the random-effect intercept for the participant crossed with condition, and e_{SC} is the error term. Applying a logit function with Laplace distribution (Madsen & Thyregod, 2010), we tested whether condition was a significant predictor.

Reaction time. We examined participants' reaction time (RT) during the choice phase by running a 2 × 2 analysis of variance (ANOVA) looking at the interaction between the effect of condition (i.e., magnitude or probability) and choice type (i.e., SELF or COMP). The RT analysis would let us rule out differences in decisional uncertainty as a possible explanation for any variations in choice patterns because any significant increase in RT would suggest that participants were more indecisive in one of the two conditions, thereby potentially biasing their choices to the perceived easier option (Bonnet, Fauquet Ars, & Estaún Ferrer, 2008).

Results

We performed a logistic regression analysis on participants' trial-by-trial data to extract individual participants' POEs within each condition. A POE of 0 indicated that participants were equally likely to choose either option. We expected that participants' POEs would be significantly greater than 0, which would suggest that they showed a preference for the SELF option and inflated the subjective value for the said option.

For the magnitude condition, the regression analysis revealed a mean participant POE of 1.24 (Part A of Figure 2; SD = 1.95, range = −5.2 to 8.0). For the probability condition, participants carried a POE of 0.80 (Part A of Figure 2; SD = 2.58, range = −6.7 to 7.7). We found that participants' POEs in the magnitude condition were significantly different from the hypothesized POE of 0, $t(42) = 4.15$, 95% confidence interval (CI) [0.63, 1.84], $p = .0002$, Cohen's $d = 0.64$. For the probability condition, the POEs measures were found to not be normally distributed, so

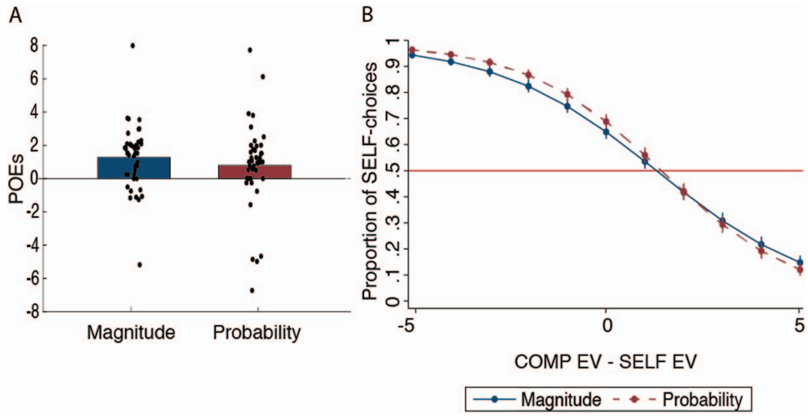

Figure 2. Behavioral findings in the choice phase. (A) Participants' average points of equivalence (POEs) for the two conditions. (B) Participants' choice behavior fitted to a mixed-effect logistic function. Participants showed overlapping choice patterns and attributed similar subjective value to control in both the probability (dashed line) and magnitude (solid line) conditions. The red (light gray) horizontal line indicates a SELF-choice proportion of 0.5. The intersection between the choice curves and this horizontal line marks the POE measure across participants. See the online article for the color version of this figure.

we applied the nonparametric one-sample Wilcoxon's signed ranked test instead of the originally-planned *t* test and found that participants' POEs were also significantly different from the expected POE of 0 ($z = 3.2$, $p = .001$, Rosenthal's *r* effect size = 0.49). Translating these findings in terms of experimental points, participants' POE measures in the magnitude condition suggested the SELF option carried an average of 25% point-value increase (percentage conversion based on 1.24-point inflation relative to a maximum of 5 points per choice pair), whereas their POEs in the probability condition suggested that the SELF option carried an average point-value increase of 16% (percentage conversion based on 0.8-point inflation relative to a maximum of 5 points per choice pair).

To examine whether condition significantly predicted participants' choice behavior, we conducted the GLME on participants' trial-by-trial data. The fixed-effect predictor of EVdiff was significant, β: −0.57, 95% CI [−0.60, −0.53], standard error (*SE*): 0.018, $t(3,780) = -31.35$; $p < .0001$. More importantly, condition was not a significant predictor (Part B of Figure 2), β: −0.050, 95% CI [−0.26, 0.16], *SE*: 0.11, $t(3,780) = -0.46$; $p = .64$, suggesting that there was no significant difference in choice behavior between the two conditions. Taken together, these findings collectively suggest that across all participants, the SELF option carried a significant value increase compared with the COMP option, regardless of whether the probability or magnitude was manipulated.

Given that a variant of the VoC task was used in a prior published data set (K. S. Wang & Delgado, 2019), we conducted an exploratory analysis to compare that independent sample with a comparable experimental condition (i.e., magnitude condition) in our present study. We observed that the magnitude-condition POEs were not significantly different from the POEs reported in the prior work ($z = 0.38$, $p = .70$, Rosenthal's *r* effect size = 0.046), thus providing a replication of the value of control.

Reaction time. We also quantified participants' RTs during the choice phase between the two conditions (magnitude: $M = 1.98$, $SD = 0.70$; probability: $M = 1.68$, $SD = 0.57$). After removing two participants whose RTs were classified as extreme outliers (greater than 3 *SD*), we conducted a repeated-measure 2 × 2 ANOVA to investigate the effects of condition (i.e., magnitude and probability) and choice type (i.e., SELF and COMP). There were significant main effects of condition, $F(1, 120) = 10.37$, $p = .0017$, $\eta^2 = 0.080$, and a marginally significant main effect of choice type, $F(1, 120) = 3.51$, $p = .064$, $\eta^2 = 0.028$, but no interaction, $F(1, 120) = 0.35$, $p = .56$, $\eta^2 = 0.0029$. Post hoc analysis revealed that participants showed significantly slower choice RTs in the magnitude compared with the probability condition ($t = 2.79$, $p = 0.006$, Cohen's $d = 0.43$).

Questionnaires. Three questionnaires were collected during the experiment. We probed whether each of the questionnaires was correlated with our POE measure using Bonferroni-adjusted significance level. For the MASQ anhedonic depression score, participants scored an average of 21.0 ± 5.44. For the GPSE scale, participants scored an average of 32.43 ± 3.97. For the LOC scale, participants scored an average of 5.79 ± 1.99. There were no significant correlations between any of the questionnaire scores and the POE measure (MASQ: $r = .055$, $p = .73$; GPSE: $r = -0.0006$, $p = .99$; LOC: $r = -0.11$ $p = .57$).

Experiment 2

In Experiment 1, we found that perceived control carried a similar subjective value when probability and magnitude were independently manipulated, suggesting that our preference for control enhances both the subjective interpretation of how likely it is to obtain the outcome and how much that outcome is worth. This finding has implications in helping to delineate the factors that drive an inherent preference for control. When we are endowed with a sense of control over the environment, this perception of control bolsters both our belief that we can successfully obtain the outcome and our willingness to take on a cost to obtain it. Because our sense of control can inflate the value of an outcome, a related question is whether this perception of control can adapt to the valence of the outcome. In Experiment 2, we manipulated the contextual valence of the choice (gain or loss frame) in a between-subjects study design to investigate whether outcome valence could play a role in altering participants' subjective value of control.

Method

Participants. Seventy-eight individuals (27 males and 51 females) between the ages of 18 and 45 ($M = 20.4$, $SD = 3.8$) were recruited from the Rutgers University community. Participants received course credit for voluntary participation and were given the opportunity to receive a bonus (monetary compensation up to $5) based on their performance on the task. All participants provided written consent in accordance with the experimental protocol approved by the Rutgers University Institutional Review Board. Participants were randomly assigned to either the gain or loss groups. The sample size was determined based on published work (K. S. Wang & Delgado, 2019), where the desired final group size was at least 27 per group after accounting for experimental dropout and data loss. The predefined exclusion criteria (i.e., lack of task comprehension or random-choice pattern) were identical to those described for Experiment 1, and if either was met, the participant was removed from data analysis. In total, 12 individuals from the loss group and 4 from the gain group met exclusion criteria. Final data analysis was conducted on data collected from 31 participants in the loss group and 31 in the gain group (21 males and 41 females; $M = 20.4$, $SD = 4.1$).

Experimental design. Participants in both groups first completed the gambling game questionnaire (Benartzi & Thaler, 1999), which assessed their loss aversion based on their choices between different gamble pairs, before undergoing a four-trial training version of the VoC task (see Experiment 1 "Methods" section). They subsequently completed the testing version of the VoC task featuring two identical runs of 44 trials each. Note that the placement of the SELF and COMP options on the screen was counterbalanced across participants from both groups. Across all trials, each choice phase lasted until the participant selected an option. This selection was immediately followed by a 1.5- to 3.5-s fixation period (ISI). The game phase also lasted until a choice was made with the press of the button, followed by the conclusion of each trial with a 2- to 4-s ITI.

Between the first and second experimental run, participants from both groups completed one paper questionnaire: the LOC (Rotter, 1966). At the conclusion of the second experimental run, participants were asked to complete one more paper questionnaire: the Behavioral Inhibition System/Behavioral Activation System (BIS/BAS) Scale (Carver & White, 1994). These questionnaires were included to measure participants' loss aversion (Benartzi & Thaler, 1999), locus of control (Rotter, 1966), and reward approach behaviors (Carver & White, 1994) to assess for potential relationships between these subjective measures and participants' choices in the VoC task.

Gain group. At the conclusion of the training phase, participants were shown a white envelope holding $5 with the explicit instruction that it represented the monetary bonus they could *earn* by performing well in the VoC task. They were told the $5 translated into a maximum of 1,000 experimental points. Specifically, the experimental winnings were divided into five progressive point tiers, each worth $1. Prior to starting the first experimental run of the VoC task, participants were presented with a screen with the following question: "How many points do you have in your point bank?" to explicitly probe whether they understood that they started with 0 points and that their objective was to gain points during the task to maximize their monetary reward. Participants were also informed that they would never lose points during the task.

In the VoC task, participants were presented with the COMP and SELF choice pairs during each choice phase. Also shown on the screen were the point magnitudes associated with each option. The COMP options carried possible point magnitudes that ranged from 0 to 20 points in increments of 2. In contrast, the SELF options always carried 10 experimental points. To highlight that points could be gained, we added "+" signs in front of the point magnitudes displayed for both options (see Figure 3). The gain group had a comparable experimental design as our previously published article (K. S. Wang & Delgado, 2019) and hence served as the reference group to which we compared the loss group.

Loss group. At the conclusion of the training phase, participants were shown a white envelope holding $5 with the explicit instruction that it represented the monetary bonus and experimental points (1,000 points) they *possessed* at this juncture of the experiment. They were informed to minimize the monetary reward they would lose by performing well in the VoC task. Prior to starting the first experimental run of the VoC task, participants were presented with a screen with the following question: "How many points do you have in your point bank?" to explicitly probe whether they understood that they started with 1,000 points and that the objective was to avoid losing points during the task to retain the maximum monetary reward. Participants were instructed that the points were tiered into five progressive thresholds, each associated with $1.

Similar to the gain group, participants in the loss group were also presented with the COMP and SELF choice pairs during each choice phase of the VoC task. We showed the point magnitudes associated with each option on the screen, and to highlight that points could be lost, we added "–" signs in front of the point magnitudes (see Figure 3). In particular, the COMP options carried possible point magnitudes that ranged from 0 to 20 points in increments of 2. In contrast, the SELF options always carried 10 experimental points. Participants were informed that they would never gain points in the experiment and that any successful VoC trials would prevent the loss of points.

Data analyses. Data analyses were similar to those described for Experiment 1, except that participants' POEs were computed by coding each trial using the magnitude difference (-10 to 10 points in increments of 2) between the two options based on their presentation during the task (i.e., the magnitude difference was used as the independent variable in each participant's logistic function). We first fitted each participant's trial-by-trial data onto a logistic function with magnitude difference as the independent variable (i.e., $\text{Mag}_{\text{COMP}} - \text{Mag}_{\text{SELF}}$). From the logistically regressed data, we derived the POE measure for all participants using the inverse of the logistic function and compared this measure for each condition using a t test against the hypothesized mean of 0. We next considered whether group (i.e., gain

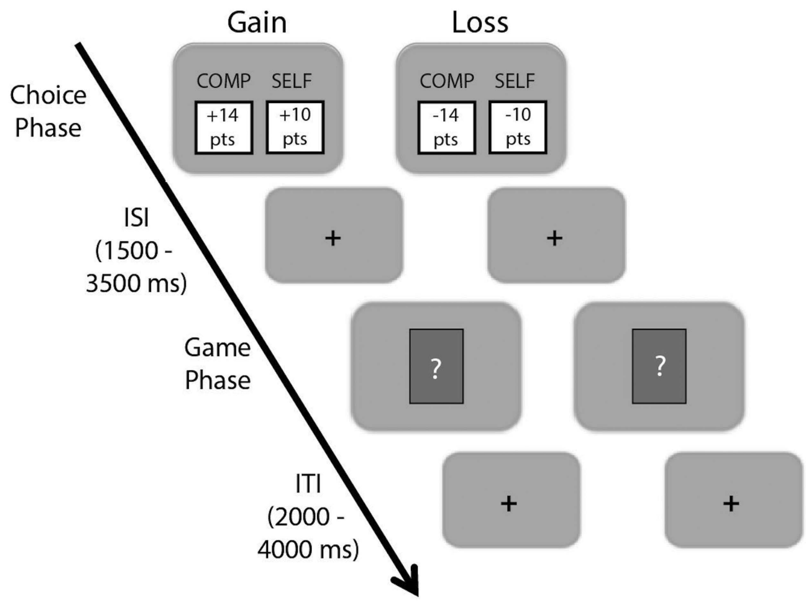

Figure 3. Gain and loss versions of the Value of Control (VoC) task. Participants in the gain group were presented with a choice phase where they were asked to choose between two options (SELF or COMP) that both presented the opportunity to obtain experimental points. The participants in the loss group were instead shown a choice phase where they had to choose between the SELF and COMP options that each carried experimental points that they could potentially lose. Participants' decisions in the choice phase determined how they would play the game phase. The goal of both groups was to be successful in the game phase in order to either earn points (i.e., gain group) or prevent the loss of points already possessed (i.e., loss group).

and loss) was a significant predictor of participants' choices by applying a GLME with a logistic link function on participants' trial-by-trial data across both conditions. Each trial was coded using the magnitude difference (range of −10 to 10 in increments of 2) between the two options (i.e., $\text{Mag}_{\text{COMP}} - \text{Mag}_{\text{SELF}}$). The GLME model formula is as follows:

$$\log\frac{\text{SELF}_{sg}}{(1-\text{SELF}_{sg})} = \beta_0 + \beta_1\text{MAGdiff}_{Sg} + \beta_2\text{Group}_{Sg} + \mu_{0S} + \mu_{0Sg} + e_{sg}$$

where $\log\frac{\text{SELF}_{sg}}{(1-\text{SELF}_{sg})}$ is the binomial response variable for SELF choices, β_0 is the fixed-effect intercept, $\beta_1\text{MAGdiff}_{Sg}$ is the fixed-effect predictor coding for magnitude difference (for *s*th subject in *g* group), $\beta_2\text{Group}_{Sg}$ is the fixed-effect predictor for group (i.e., gain and loss), μ_{0S} is the random-effect intercept for participants, μ_{0Sg} is the random-effect intercept for participants nested within group, and e_{sg} is the error term. Applying a logit function with Laplace distribution (Madsen & Thyregod, 2010), we investigated whether group was a significant predictor.

Finally, we also examined whether there were group differences in participants' choice RTs using a 2 (gain vs. loss) × 2 (SELF vs. COMP) ANOVA.

Results

To examine how much greater subjective value was attributed to the SELF option in each of the two groups (i.e., gain and loss), we performed a logistic regression analysis on participants' trial-by-trial data to extract individual participants' POEs within each group. Again, if controllability did not contribute at all to decision making, participants' POEs were expected to be 0 to indicate that participants were equally likely to choose either the SELF or COMP option when both options carried equal point magnitude. Based on participants' choice bias from the aforementioned analysis, we predicted that the POEs extracted from both groups would be greater than 0 but that the gain group would have a significantly higher POEs compared with the loss group. We tested this hypothesis within each group before using a GLME to test for the effect of group on participants' choice behavior.

For the gain group, the regression model revealed a mean participant POE of 3.00 (Part A of Figure 4, $SD = 4.7$, range = −2.0 to 21.5), whereas for the loss group, the regression analysis yielded an average participant POE of 0.81 (Part A of Figure 4, $SD = 2.2$, range = −7.7 to 5.5). The POEs measures for both the gain and loss groups were found to not be normally distributed; therefore, to compare each group to the hypothesized POE of 0, we applied the nonparametric one-sample Wilcoxon's signed ranked test instead of the originally-planned *t* test. The gain group had significantly different POEs from the expected POE of 0 ($z = 4.21$, $p < .001$, Rosenthal's *r* effect size = 0.76), suggesting that the SELF option carried a 30% point-value inflation compared with the COMP option. The loss group also showed significantly different POEs from the expected POE of 0 ($z = -2.92$, $p = .0027$, Rosenthal's *r* effect size = 0.52), suggesting that the SELF option carried an 8% point-value inflation compared with the COMP option.

To determine whether group significantly predicted participants' choice behavior, we implemented a GLME. The fixed-

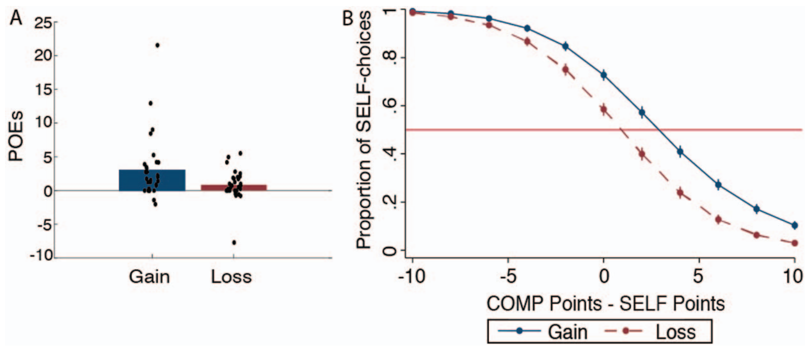

Figure 4. Choice behavior between gain and loss groups. (A) Participants' average points of equivalence (POEs) for the two groups. (B) Participants' choice behavior fitted to a mixed-effect logistic function. Participants in the gain group (blue [dark gray] solid line) attributed a significantly larger subjective value (i.e., POE measure) toward control (i.e., SELF choices) compared with those in the loss group (red [light gray] dashed line). The red [light gray] horizontal line indicates a SELF-choice proportion of 0.5. The intersection between the choice curves and this horizontal line marks the POE measure across participants. See the online article for the color version of this figure.

effect predictor of magnitude difference was significant, β: 0.009, 95% CI [0.0004, 0.018], *SE*: 0.0044, $t(5{,}453) = 2.06$; $p = .039$. More importantly, group was a significant predictor (Part B of Figure 4), β: −0.26, 95% CI [−0.47, −0.050], *SE*: 0.11, $t(5{,}453) = -2.43$; $p = .015$, suggesting that there was a significant difference in choice behavior between the two groups. Taken together, participants from the gain group attributed a significantly greater value inflation for the SELF option compared with those in loss group.

Given that a similar but not identical version of the VoC task was implemented in our prior work (K. S. Wang & Delgado, 2019), we explored whether the POEs obtained in that independent sample were different from a comparable condition (i.e., gain group) in our present study. We observed a replication of the prior effects in that the gain group POEs did not differ significantly from the POEs obtained in the published sample ($z = -0.96$, $p = .34$, Rosenthal's *r* effect size = 0.13).

Reaction time. We also quantified participants' RTs during the choice phase between the two groups (gain: $M = 1.75$, $SD = 0.78$; loss: $M = 1.83$; $SD = 0.72$). One participant's RT from the gain group was removed as an extreme outlier, defined by a RT greater than 3 *SD*. We conducted a mixed-effect 2 (gain and loss groups) × 2 (SELF and COMP choices) ANOVA and did not find a significant interaction between groups and choice type, $F(1, 59) = 1.29$, $p = .26$, $\eta^2 = 0.021$. In addition, we also did not find significant main effects of groups, $F(1, 59) = 1.34$, $p = .25$, $\eta^2 = 0.022$, and choice type, $F(1, 59) = 0.05$, $p = .83$, $\eta^2 = 0.00077$. Similarly, participants did not differ significantly in their SELF and COMP choice RTs in the gain group, $t(29) = -0.74$, $p = .46$, Cohen's $d = 0.14$, and loss group, $t(30) = 1.10$, $p = .28$, Cohen's $d = 0.20$, respectively.

Questionnaires. Three questionnaires were collected during the experiment (see Table 1). Both groups did not differ on the following questionnaires: gambling game questionnaire, $t(58) = -1.46$, $p = .15$, Cohen's $d = 0.38$; LOC scale, $t(58) = 0.24$, $p = .82$, Cohen's $d = 0.036$; BAS drive, $t(60) = -1.74$, $p = .087$, Cohen's $d = 0.44$; BAS fun-seeking, $t(60) = 0.32$, $p = .75$, Cohen's $d = 0.080$; BAS reward responsiveness, $t(59) = -0.20$, $p = .84$, Cohen's $d = 0.047$. In particular, we were interested in whether participants' loss-aversion score (obtained from the gambling game questionnaire) could have an effect on group differences. Therefore, we added the loss-aversion scores as a covariate and found that even after controlling for participants' loss-aversion scores, there was a significant group difference between the gain and loss groups in their preference for the SELF option, $F(1, 57) = 5.59$, $p = .021$, $\eta^2 = 0.089$, and their POE measures, $F(1, 57) = 5.33$, $p = .025$, $\eta^2 = 0.086$.

We also examined if these questionnaires correlated with our POE measure for each group. In the gain group, we found no significant correlations between any of the questionnaire scores and the POE measure using Bonferroni-adjusted significance level, loss aversion: $r(27) = 0.084$, $p = .69$; LOC: $r(27) = 0.094$, $p = .66$; BAS drive: $r(27) = -0.17$, $p = .41$; BAS fun-seeking: $r(27) = 0.25$, $p = .22$; BAS reward responsiveness: $r(27) = 0.21$, $p = .32$. Interestingly, for the loss group, we found a significant negative correlation between BAS fun-seeking and the POE measure using Bonferroni-adjusted significance level, $r(28) = -0.52$, $p = .0071$. We compared the relationships that the *gain and loss* groups each demonstrated between POE and BAS fun-seeking and found that the two groups differed significantly in how their respective POE measures related to their BAS fun-seeking scores ($z = -3.03$, $p = .0024$). The other questionnaire scores were not significantly correlated with the POE measure, loss aversion:

Table 1
Mean Questionnaire Results for Participants in the Two Groups

Questionnaire	Gain group ($M \pm SD$)	Loss group ($M \pm SD$)
Gambling game (loss-aversion score)	1.11 ± 1.94	1.81 ± 1.77
Locus of Control	5.70 ± 2.14	5.57 ± 2.31
BIS/BAS—BAS drive	11.55 ± 2.59	12.58 ± 2.05
BIS/BAS—fun-seeking	12.35 ± 2.39	12.16 ± 2.35
BIS/BAS—reward responsiveness	18.27 ± 1.66	18.35 ± 1.72

Note. BIS/BAS = Behavioral Inhibition System/Behavioral Activation System Scales.

$r(28) = -0.13$, $p = .53$; LOC: $r(28) = -0.17$, $p = .41$; BAS drive: $r(28) = -0.21$, $p = .32$; BAS reward responsiveness: $r(28) = 0.28$, $p = .17$.

Interim Discussion

We observed that participants, when placed in a loss frame, significantly dampened their preference toward control and decreased their subjective value accordingly. This decrease in the preference for control was possibly driven by the undesirability of the outcome in the loss frame (i.e., potentially losing points). When the outcome became undesirable, participants, perhaps driven by a loss-aversion or self-serving bias, decreased their subjective value of control and lowered the cost they were willing to take on to have control.

General Discussion

We set out to investigate factors that could exert influence on participants' subjective value of control. In Experiment 1, we found that participants showed comparable behavioral preference toward exercising control when reward probability and magnitude were independently manipulated. In Experiment 2, we observed that when participants were asked to assess their preference for control in a loss frame, their subjective value of control was significantly diminished compared with when they were presented the decision in a gain frame. Together, these findings collectively suggest that probability and magnitude both contribute to biasing our behavior toward exercising control and that this subjective value of control is responsive to outcome valence.

Given our previous finding showing that perceived control influences the subjective assessment of the reward value (K. S. Wang & Delgado, 2019), we replicated the results and further demonstrated that the desire for control encouraged behavioral bias toward the control-conferring option irrespective of whether probability or magnitude was individually manipulated. We can draw two viable conclusions from the findings in Experiment 1. First, participants' subjective valuation of control was fairly consistent even when they were making choices against options that emphasized different subcomponents of value computation (i.e., probability and magnitude). In both conditions, participants showed a behavioral bias *toward* the control-conferring option, and this observation bolstered the notion that seeking and exercising control is behaviorally reinforcing or, simply, rewarding.

Second and related to the first point, participants' desire to choose the control-conferring option (i.e., SELF option) and their associated subjective value of control likely involved the inflation of both their probability and magnitude estimations. It is plausible that participants subscribed to the belief that they had a greater chance than the computer to succeed (i.e., self-efficacy; Bandura, 1977) or that they ascribed a greater magnitude to rewards they obtained via their own behaviors (i.e., choosing the SELF option and playing the game themselves). However, it is important to note that our current experimental design did not permit us to fully dissociate how much of a role probability and magnitude each played in governing the value of control but, rather, that they were both likely involved. Thus, our findings from Experiment 1 supported the notion that we attribute a positive subjective value to having that sense of control by means of inflating our probability and magnitude estimations and actively seek out opportunities to exert control.

In Experiment 2, we found that participants in the loss group showed a significantly lowered subjective value of control compared with their counterparts in the gain group. Notably, the gain group showed a subjective value of control comparable to that of an independent cohort in a previously published data set (K. S. Wang & Delgado, 2019), suggesting consistency of the POE measure across samples. These findings collectively suggest that how much we subjectively value control is adaptable to contextual factors, such as how choices are framed in their outcome valence. Our belief in control has been shown to be an unstable measure and is susceptible to changes due to external forces (Hovenkamp-Hermelink et al., 2019; Twenge, Zhang, & Im, 2004). It is therefore likely that our preference for control is also vulnerable to perturbations from factors such as the valence of choices.

Indeed, in Experiment 2, we found that when the same decision was framed as a potential loss, participants' preference for control weakened, and their subjective value of control decreased accordingly. This finding bolstered conclusions from previous work showing that perceived control in the loss frame was less affectively salient than in the gain frame (Leotti & Delgado, 2014) and that participants were more likely to make optimal choices (e.g., choose based on EV) in a loss frame (Chatterjee, Heath, Milberg, & France, 2000; Park & Cho, 2018). In addition, our observation that only in the loss frame did participants' subjective value of control show a significant relationship with a subjective trait measure (i.e., BAS fun-seeking scale) further supported the notion that individual differences may play a larger role in the context of negative outcomes. As a group, even though the participants in the loss group showed a weaker preference for control than their gain-group counterparts, they still demonstrated a behavioral preference for the control-conferring option that was in line with previous work (Leotti & Delgado, 2014). It could very well be that in the loss domain, there is more individual variability in how participants perceive and seek control. In addition, even though we did not observe a relationship between our measure of loss aversion and participants' subjective value of control, it is likely that loss aversion plays an important role in driving participants' preference for control. As such, further research using a larger sample size and with a more sophisticated assessment of loss aversion (e.g., Sokol-Hessner et al., 2009) is warranted to probe deeper into the individual variability in how we value control, particularly in the context of losses.

In short, perceived control carries a context-dependent subjective value that influences our decision-making in both appetitive and aversive domains. Across the two experiments, we noted that perceiving control can inflate both the success probability and the magnitude of the associated outcome but significantly more so in the context of gains than losses. These findings add to our understanding of factors that can influence how much we subjectively value control in different environments and, in turn, how we adapt our behaviors accordingly. This work has particular implications in clinical populations where the loss of control is often described as a main trigger for symptoms in psychopathologies such as addiction (Belin, Belin-Rauscent, Murray, & Everitt, 2013) and depression (Rubenstein, Alloy, & Abramson, 2016). Although we used a more abstract form of reward in the study (i.e., experimental points), future studies may consider alternative rewards that are more tangible, such as actual monetary values (e.g., K. S. Wang et al., 2020) or context-specific stimuli (e.g., cigarette puffs; Manglani, Lewis, Wilson, & Delgado, 2017). Moreover, it could be worthwhile to also study the effects of other potential factors on control, such as varying the absolute reward at stake or manipulating success probability in a loss frame. Together, in trying to characterize ways that our subjective value of control can be manipulated, we can improve on our therapeutic interventions for such psychopathologies where our perception of control is often negatively perturbed.

References

Alloy, L. B., & Abramson, L. Y. (1979). Judgment of contingency in depressed and nondepressed students: Sadder but wiser? *Journal of Experimental Psychology: General, 108,* 441–485. http://dx.doi.org/10.1037/0096-3445.108.4.441

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84,* 191–215. http://dx.doi.org/10.1037/0033-295X.84.2.191

Bechara, A. (2005). Decision making, impulse control and loss of willpower to resist drugs: A neurocognitive perspective. *Nature Neuroscience, 8,* 1458–1463. http://dx.doi.org/10.1038/nn1584

Belin, D., Belin-Rauscent, A., Murray, J. E., & Everitt, B. J. (2013). Addiction: Failure of control over maladaptive incentive habits. *Current Opinion in Neurobiology, 23,* 564–572. http://dx.doi.org/10.1016/j.conb.2013.01.025

Benartzi, S., & Thaler, R. H. (1999). Risk aversion or myopia? Choices in repeated gambles and retirement investments. *Management Science, 45,* 364–381. http://dx.doi.org/10.1287/mnsc.45.3.364

Berkson, J. (1944). Application of the logistic function to bio-assay. *Journal of the American Statistical Association, 39,* 357–365.

Bonnet, C., Fauquet Ars, J., & Estaún Ferrer, S. (2008). Reaction times as a measure of uncertainty. *Psicothema, 20,* 43–48.

Bown, N. J., Read, D., & Summers, B. (2003). The lure of choice. *Journal of Behavioral Decision Making, 16,* 297–308. http://dx.doi.org/10.1002/bdm.447

Brainard, D. H. (1997). The Psychophysics toolbox. *Spatial Vision, 10,* 433–436. http://dx.doi.org/10.1163/156856897X00357

Burger, J. M., & Cooper, H. M. (1979). The desirability of control. *Motivation and Emotion, 3,* 381–393. http://dx.doi.org/10.1007/BF00994052

Calvo, E., Haverstick, K., & Sass, S. A. (2009). Gradual retirement, sense of control, and retirees' happiness. *Research on Aging, 31,* 112–135. http://dx.doi.org/10.1177/0164027508324704

Campbell, W. K., & Sedikides, C. (1999). Self-threat magnifies the self-serving bias: A meta-analytic integration. *Review of General Psychology, 3,* 23–43. http://dx.doi.org/10.1037/1089-2680.3.1.23

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of Personality and Social Psychology, 67,* 319–333. http://dx.doi.org/10.1037/0022-3514.67.2.319

Catania, A. C., & Sagvolden, T. (1980). Preference for free choice over forced choice in pigeons. *Journal of the Experimental Analysis of Behavior, 34,* 77–86. http://dx.doi.org/10.1901/jeab.1980.34-77

Chatterjee, S., Heath, T. B., Milberg, S. J., & France, K. R. (2000). The differential processing of price in gains and losses: The effects of frame and need for cognition. *Journal of Behavioral Decision Making, 13,* 61–75. http://dx.doi.org/10.1002/(SICI)1099-0771(200001/03)13:1<61::AID-BDM343>3.0.CO;2-J

Clark, L., & Watson, D. (1995). *The Mini Mood and Anxiety Symptom Questionnaire (Mini-MASQ).* Unpublished manuscript, University of Iowa, Iowa City, IA.

Davidson, R., & MacKinnon, J. G. (2004). *Econometric theory and methods* (Vol. 5). New York, NY: Oxford University Press.

Delgado, M. R., Nystrom, L. E., Fissell, C., Noll, D. C., & Fiez, J. A. (2000). Tracking the hemodynamic responses to reward and punishment in the striatum. *Journal of Neurophysiology, 84,* 3072–3077. http://dx.doi.org/10.1152/jn.2000.84.6.3072

Dunn, D. S., & Wilson, T. D. (1990). When the stakes are high: A limit to the illusion-of-control effect. *Social Cognition, 8,* 305–323. http://dx.doi.org/10.1521/soco.1990.8.3.305

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39,* 175–191. http://dx.doi.org/10.3758/BF03193146

Frazier, P., Steward, J., & Mortensen, H. (2004). Perceived control and adjustment to trauma: A comparison across events. *Journal of Social and Clinical Psychology, 23,* 303–324. http://dx.doi.org/10.1521/jscp.23.3.303.35452

Glass, D., & McKnight, J. (1996). Perceived control, depressive symptomatology, and professional burnout: A review of the evidence. *Psychology & Health, 11,* 23–48. http://dx.doi.org/10.1080/08870449608401975

Grob, A. (2000). Perceived control and subjective well-being across nations and across the life span. In E. Diener & E. M. Suh (Eds.), *Culture and subjective well-being* (pp. 319–339). Cambridge, MA: MIT Press.

Hovenkamp-Hermelink, J. H. M., Jeronimus, B. F., van der Veen, D. C., Spinhoven, P., Penninx, B. W. J. H., Schoevers, R. A., & Riese, H. (2019). Differential associations of locus of control with anxiety, depression and life-events: A five-wave, nine-year study to test stability and change. *Journal of Affective Disorders, 253,* 26–34. http://dx.doi.org/10.1016/j.jad.2019.04.005

Inzlicht, M., Shenhav, A., & Olivola, C. Y. (2018). The effort paradox: Effort is both costly and valued. *Trends in Cognitive Sciences, 22,* 337–349. http://dx.doi.org/10.1016/j.tics.2018.01.007

Kahneman, D., Knetsch, J. L., & Thaler, R. H. (1991). Anomalies: The endowment effect, loss aversion, and status quo bias. *The Journal of Economic Perspectives, 5,* 193–206. http://dx.doi.org/10.1257/jep.5.1.193

Kahneman, D., & Tversky, A. (2013). Choices, values, and frames. In L. C. MacLean & W. T. Ziemba (Eds.), *Handbook of the fundamentals of financial decision making: Part I* (pp. 269–278). Toh Tuck Link, Singapore: World Scientific. http://dx.doi.org/10.1142/9789814417358_0016

Krueger, N., Jr., & Dickson, P. R. (1994). How believing in ourselves increases risk taking: Perceived self-efficacy and opportunity recognition. *Decision Sciences, 25,* 385–400. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1540-5915.1994.tb00810.x

Langer, E. J. (1975). The illusion of control. *Journal of Personality and Social Psychology, 32,* 311–328. http://dx.doi.org/10.1037/0022-3514.32.2.311

Leotti, L. A., & Delgado, M. R. (2014). The value of exercising control over monetary gains and losses. *Psychological Science, 25,* 596–604. http://dx.doi.org/10.1177/0956797613514589

Leotti, L. A., Iyengar, S. S., & Ochsner, K. N. (2010). Born to choose: The origins and value of the need for control. *Trends in Cognitive Sciences, 14,* 457–463. http://dx.doi.org/10.1016/j.tics.2010.08.001

Lieberman, M. D., Ochsner, K. N., Gilbert, D. T., & Schacter, D. L. (2001). Do amnesics exhibit cognitive dissonance reduction? The role of explicit memory and attention in attitude change. *Psychological Science, 12,* 135–140. http://dx.doi.org/10.1111/1467-9280.00323

Lipsey, M. W. (1990). *Design sensitivity: Statistical power for experimental research* (Vol. 19). Newbury Park, CA: Sage.

Ly, V., Wang, K. S., Bhanji, J., & Delgado, M. R. (2019). A reward-based framework of perceived control. *Frontiers in Neuroscience, 13,* 65–65. http://dx.doi.org/10.3389/fnins.2019.00065

Madsen, H., & Thyregod, P. (2010). *Introduction to general and generalized linear models*. Boca Raton, FL: CRC Press. http://dx.doi.org/10.1201/9781439891148

Manglani, H. R., Lewis, A. H., Wilson, S. J., & Delgado, M. R. (2017). Pavlovian-to-instrumental transfer of nicotine and food cues in deprived cigarette smokers. *Nicotine & Tobacco Research, 19,* 670–676. http://dx.doi.org/10.1093/ntr/ntx007

Miller, D. T., & Ross, M. (1975). Self-serving biases in the attribution of causality: Fact or fiction? *Psychological Bulletin, 82,* 213–225.

Park, I., & Cho, S. (2018). The influence of number line estimation precision and numeracy on risky financial decision making. *International Journal of Psychology, 54,* 530–538.

Press, S. J., & Wilson, S. (1978). Choosing between logistic regression and discriminant analysis. *Journal of the American Statistical Association, 73,* 699–705. http://dx.doi.org/10.1080/01621459.1978.10480080

Rangel, A., Camerer, C., & Montague, P. R. (2008). A framework for studying the neurobiology of value-based decision making. *Nature Reviews Neuroscience, 9,* 545–556. http://dx.doi.org/10.1038/nrn2357

Reed, L. J., & Berkson, J. (1929). The application of the logistic function to experimental data. *Journal of Physical Chemistry, 33,* 760–779. http://dx.doi.org/10.1021/j150299a014

Rotter, J. (1966). Generalized expectancies for internal versus external control of reinforcement. *Psychological Monographs: General and Applied, 80,* 1–28. http://dx.doi.org/10.1037/h0092976

Rubenstein, L. M., Alloy, L. B., & Abramson, L. (2016). Perceived control and depression. In J. W. Reich & F. J. Infurna (Eds.), *Perceived control: Theory, research, and practice in the first 50 years* (pp. 229–252). New York, NY: Oxford University Press.

Schunk, D. H. (1991). Self-efficacy and academic motivation. *Educational Psychologist, 26,* 207–231. http://dx.doi.org/10.1080/00461520.1991.9653133

Schwarzer, R., & Jerusalem, M. (2010). The General Self-Efficacy Scale (GSE). *Anxiety, Stress, and Coping, 12,* 329–345.

Silvester, J., Anderson-Gough, F. M., Anderson, N. R., & Mohamed, A. R. (2002). Locus of control, attributions and impression management in the selection interview. *Journal of Occupational and Organizational Psychology, 75,* 59–76. http://dx.doi.org/10.1348/096317902167649

Skinner, E. A. (1995). *Perceived control, motivation, & coping* (Vol. 8). Newbury Park, CA: Sage. http://dx.doi.org/10.4135/9781483327198

Sokol-Hessner, P., Hsu, M., Curley, N. G., Delgado, M. R., Camerer, C. F., & Phelps, E. A. (2009). Thinking like a trader selectively reduces individuals' loss aversion. *Proceedings of the National Academy of Sciences of the United States of America, 106,* 5035–5040. http://dx.doi.org/10.1073/pnas.0806761106

Solomon, S., & Rodin, J. (1976). *Control-seeking behavior: Are people motivated to attain control?* Unpublished manuscript, Yale University, New Haven, CT.

Suzuki, S. (1997). Effects of number of alternatives on choice in humans. *Behavioural Processes, 39,* 205–214. http://dx.doi.org/10.1016/S0376-6357(96)00049-6

Suzuki, S. (1999). Selection of forced-and free-choice by monkeys (*Macaca fascicularis*). *Perceptual and Motor Skills, 88,* 242–250. http://dx.doi.org/10.2466/pms.1999.88.1.242

Twenge, J. M., Zhang, L., & Im, C. (2004). It's beyond my control: A cross-temporal meta-analysis of increasing externality in locus of control, 1960–2002. *Personality and Social Psychology Review, 8,* 308–319. http://dx.doi.org/10.1207/s15327957pspr0803_5

Verme, P. (2009). Happiness, freedom and control. *Journal of Economic Behavior & Organization, 71,* 146–161. http://dx.doi.org/10.1016/j.jebo.2009.04.008

Wallston, K. A., Wallston, B. S., Smith, S., & Dobbins, C. J. (1987). Perceived control and health. *Current Psychological Research & Reviews, 6,* 5–25. http://dx.doi.org/10.1007/BF02686633

Wang, L., Zheng, J., & Meng, L. (2017). Effort provides its own reward: Endeavors reinforce subjective expectation and evaluation of task performance. *Experimental Brain Research, 235,* 1107–1118. http://dx.doi.org/10.1007/s00221-017-4873-z

Wang, K. S., & Delgado, M. R. (2019). Corticostriatal circuits encode the subjective value of perceived control. *Cerebral Cortex, 29,* 5049–5060. http://dx.doi.org/10.1093/cercor/bhz045

Wang, K. S., Zegel, M., Molokotos, E., Moran, L. V., Olson, D. P., Pizzagalli, D. A., & Janes, A. C. (2020). The acute effects of nicotine on corticostriatal responses to distinct phases of reward processing. *Neuropsychopharmacology*. Advance online publication. http://dx.doi.org/10.1038/s41386-020-0611-5

Received September 25, 2019
Revision received February 15, 2020
Accepted February 19, 2020 ■