Published in final edited form as:
Cogn Emot. 2014 January ; 28(1): . doi:10.1080/02699931.2013.809330.

Reappraisal and expected value modulate risk-taking

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Abstract

Decision-making is informed by appraisals of appetitive cues and their associated opportunities for rewards. Such appraisals can be modulated by cognitive regulation strategies in order to promote goal-directed choices. Little is known about how cognitive regulation strategies, especially reappraisal, alter risk-taking during decision-making. To characterize the effect of reappraisal on risk-taking, we systematically varied both the goal of regulation and the value of the decision options. Participants engaged in two reappraisal strategies with opposite goals, to increase ("Emphasize") or decrease ("Deemphasize") the importance of an upcoming decision, during the presentation of cues signaling monetary decisions. The expected value of taking a risk was systematically varied across decisions such that a risky choice could be beneficial or disadvantageous. Reappraisal strategies increased or decreased risk-taking in accordance both with regulation goals and expected value information. These results suggest that reappraisal can be used to flexibly alter behavior associated with appetitive cues while maintaining value information.

Keywords

cognitive reappraisal; emotion regulation; reward; decision-making; risk-taking

Appetitive cues signal opportunities to attain rewards and can facilitate advantageous decision-making by fostering approach behaviors. Unfortunately, appetitive cues may also promote maladaptive behaviors, as exemplified by drug-seeking. It has been suggested that the intensity of appetitive cues can be attenuated using cognitive emotion regulation strategies to modify appraisals of cues and rewards (e.g., Delgado, Gillis, & Phelps, 2008). However, little is known about the effect of cognitive regulation strategies on subsequent behavior. Does changing your interpretation or appraisal of a reward cue actually change how you act? To explore this question we tested the effect of cognitive strategies on risk-taking during decision-making. We examined risk-taking because taking a risk can be beneficial or disadvantageous depending on current goals and the value of the options. In this study, we probe whether a cognitive regulation strategy: 1) alters risk-taking inflexibly or in accordance with regulation goals and 2) distorts or maintains expected value information.

Cognitive regulation strategies are typically studied as means of changing emotion experience. Emotion regulation research has shown that cognitive strategies decrease affective responses to a variety of rewarding stimuli including erotic (Beauregard, Levesque, & Bourgouin, 2001) and pleasant pictures (Giuliani, McRae, & Gross, 2008; Kim &

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Hamann, 2007), and appetitive cues associated with drugs (Kober et al., 2010; Volkow et al., 2010) and money (Delgado et al., 2008; Staudinger, Erk, Abler, & Walter, 2009). Cognitive reappraisal, the mental process of reinterpreting an emotional event into less emotional terms (Gross, 1998), is a particularly effective emotion regulation strategy that can increase or decrease emotion depending on the goal (Ochsner & Gross, 2008; Ochsner et al., 2004). Given the demonstrated efficacy of reappraisal at modulating emotion experience, we chose to probe the effects of reappraisal on actual behavior assessed via risk-taking in a decision-making task.

Cognitive regulation strategies borrowed from the emotion regulation literature have only recently been applied in the context of decision-making (Grecucci, Giorgetta, Van't Wout, Bonini, & Sanfey, 2012; Heilman, Crisan, Houser, Miclea, & Miu, 2010; Hutcherson, Plassmann, Gross, & Rangel, 2012; Martin & Delgado, 2011; Panno, Lauriola, & Figner, 2013; Sokol-Hessner, Camerer, & Phelps, 2012; Sokol-Hessner et al., 2009; van't Wout, Chang, & Sanfey, 2010), with a small subset of studies examining regulation efforts during decisions involving risk. Engaging in a perspective-taking reappraisal strategy, thinking like a stock trader, during financial decisions reduced a behavioral measure of loss aversion and lowered arousal related to monetary losses (Sokol-Hessner et al., 2012; Sokol-Hessner et al., 2009). In this task, reappraisal putatively altered decision-making by changing evaluations of the options and outcomes, which reduced negative affect. Decreases in risk-taking have also been observed with an imagery-focused cognitive regulation strategy. Mentally visualizing relaxing imagery during reward cues that preceded financial decisions was associated with reduced risk-taking (Martin & Delgado, 2011). The imagery-focused regulation strategy altered decision-making by directing thoughts away from the opportunity for reward and the upcoming decision signaled by the cue. Taken together, these studies highlight the critical role of thoughts and evaluations in fostering changes in decision-making involving risk. Although emotion and more broadly, affect, often play an important role in decision-making, we posit that changes in decision-making induced by cognitive strategies can occur without emotion changes.

Whereas in classic emotion regulation experiments the benefit of applying reappraisal is to adaptively alter emotion experience/responses, the benefit of applying reappraisal in decision-making contexts is to promote decisions that are in line with goals, while maintaining an accurate representation of potential risks and rewards. Thus, an important question is whether reappraisal can flexibly alter (increase or decrease) risk-taking in accordance with regulation goals without disrupting processing of expected value information. To test this, we experimentally manipulated the goal of reappraisal and the relative benefit of taking a risk, specifically the expected value of the risky option (the product of the total value and the probability of attaining it). In the experiment, cues preceded two-choice financial decisions between risky and safe options. During the cue, participants were asked to respond naturally (no regulation, "Look") or engage in one of two reappraisal strategies with opposite goals: to increase ("Emphasize") or to decrease ("Deemphasize") the importance of the upcoming decision. We examined the effect of reappraisal on risk-taking during decisions in which the expected value (EV) of the risky option was varied such that it was equal to (equal condition), greater than (risky-advantageous condition), or less than (risky-disadvantageous condition) that of the safe option. To assess whether the reappraisal strategies induced changes in affect, we measured skin conductance responses (SCRs) during the reward cues.

We hypothesized that reappraisal and EV would independently affect risk-taking. We expected reappraisal strategies to alter risk-taking in line with their goals, with Emphasize decreasing and Deemphasize increasing risk-taking. We expected these reappraisals to foster new interpretations of the significance of the upcoming decisions. Because these

reappraisals occurred prior to the presentation of the specific options, we thought they would act like heuristics or frames for making the decision. Prior research has shown that framing a decision as a potential gain or loss affects loss aversion (Kahneman and Tversky, 1979; De Martino et al., 2006). We predicted Emphasize reappraisals would decrease risk-taking because thinking about the decision as really important would likely involve reinterpreting the decision as if it were being made in isolation. We expected Deemphasize reappraisals to increase risk-taking because thinking about the decision as one of many chances to win would decrease the need to receive guaranteed money on the current decision. Although we expected the reappraisal strategies to alter risk-taking, we predicted that reappraisal would not disrupt EV processing. That is, regardless of strategy, participants would be sensitive to the EVs of the options and their risk-taking would track EV such that participants would choose the risky option most on risky-advantageous trials and least on risky-disadvantageous trials. We predicted intact EV processing during reappraisal trials, because the reappraisals involved thoughts about the decisions and because participants were going to be paid based on their choices. With regard to the effect of the reappraisal strategies on affect, we were ambivalent. The strategies could induce arousal changes, but they might also exert their effects independently of shifts in affect, for instance by changing thoughts about taking a risk.

Method

Overview

Participants completed the experimental task, the Slot Machine Game (SMG, adapted from Martin & Delgado, 2011) on a PC computer in a testing room at Rutgers University. Prior to starting the task, participants received instructions about the financial decisions and were trained in applying the two kinds of reappraisal strategies. During the task, skin conductance measurements were collected to assess arousal responses to the reward cues. Afterwards, participants completed questionnaires, were debriefed, awarded research credits, and paid any earnings.

Participants

Thirty-six undergraduate volunteers participated in this study (18 females; age: $M = 22$, $SD = 6.1$). Participants received Psychology course credit and gave informed consent according to the Rutgers University Institutional Review Board.

The Slot Machine Game

Each trial in the SMG (Figure 1) consisted of the presentation of a strategy word (2 s), reward cue (slot machine, 4 or 6 s), decision (4 s), and inter-trial interval (4 or 6 s). Reward cue presentation was jittered to increase focus on the reward cues, because participants would not know exactly when the decision would appear. Decisions were between two monetary options: one risky, e.g., 50% chance of winning $8.41, and one safe, e.g., 100% chance of winning $4.20, that varied with respect their EV relationship (described below). The SMG was programmed in E-Prime (Psychology Software Tools, Pittsburgh, PA) and consisted of 108 total trials divided into four blocks.

The strategy word presented at the start of a trial directed participants either to respond naturally to the slot machine, that is, to think about the decision coming up and the chance to win money (“Look”, control condition) or to engage in reappraisal. Two reappraisal strategies adapted from previous work (Ochsner et al., 2004; Sokol-Hessner et al., 2009) with opposite regulation goals were used. The word “Emphasize” prompted participants to reinterpret the upcoming decision as very important and one in which they needed to make the right choice. The word “Deemphasize” prompted participants to reinterpret the

upcoming decision as one of many opportunities to win money and that the outcome was not very important. Reappraisal training involved providing participants with example statements for each reappraisal strategy, asking them to generate reappraisals in their own words, and having them complete practice trials. For the Emphasize strategy participants were given examples such as, “The decision coming up is really important; I need to make sure I make the right choice, as it matters a lot what I pick.” For Deemphasize they were given examples such as, “The decision coming up is not a big deal; I will have other chances.”

The SMG contained three different types of financial decisions that varied with respect to which option, risky or safe, had the higher EV. Decisions consisted of choices for which the EV was equal (equal condition), greater for the risky option (risky-advantageous condition), or greater for the safe option (risky-disadvantageous condition). Importantly, participants were not explicitly made aware of these EV differences. Further, we intentionally did not use whole dollar amounts (e.g. $4.00), in order to make it more difficult to calculate EV. There were nine unique financial decisions in the task, one for each combination of decision type (risky-advantageous, equal, risky-disadvantageous) and probability of winning (35%, 50%, 65%). The following are representative pairs for each decision type: risky-advantageous 50% $8.30 or 100% $2.91, equal 35% $11.85 or 100% $4.15, and risky-disadvantageous 65% $6.30 or 100% $5.32.

Prior to beginning the SMG task, all participants were extensively trained on the application of the reappraisal techniques. They were informed that a slot machine picture would signal an upcoming decision and opportunity to win money and that the word presented before the slot machine would serve as the strategy for that trial. Importantly, efforts were taken to minimize experimental demand. Participants were directed to engage in the reappraisal strategy during the cue phase; once the decision options appeared, participants were to focus on the decision and make a choice. Participants were explicitly told that no matter which word they saw at the beginning of the trial, they were free to choose however they liked.

To ensure the perception that each decision was independent and important, participants were informed that two decisions would be randomly chosen and realized at the end of the experimental session. At the end of the experiment, participants drew two decisions from a cup that contained one slip of paper for each trial, and they were paid based on their recorded choices and their associated probabilities. Participants received an average of $8.11 (*SD* = $3.11).

Skin conductance data collection and analysis

To assess changes in arousal due to reappraisal, skin conductance responses (SCRs) were measured during the cue phase. SCRs were collected and scored using the BIOPAC systems skin conductance module (AcqKnowledge, BIOPAC Systems, Goleta, CA). Electrodes were attached to participants’ middle phalanges of the second and third fingers in their non-dominant hand. The sampling rate was set at 200 samples per second (200 Hz). SCR waveforms were low-pass filtered using a Blackman window (cutoff frequency = 31 Hz) and smoothed over three consecutive data points prior to scoring (LaBar, Gatenby, Gore, LeDoux, & Phelps, 1998). The level of SCR was assessed as the base to peak difference for increases in the 0.5 to 4.5 second window following the onset of the cue (LaBar, LeDoux, Spencer, & Phelps, 1995). A minimum response criterion of 0.02 microSiemens was used, and all responses below this criterion were scored as 0. The total number of non-zero SCRs was calculated for each participant. Participants with a SCR count that was less than one standard deviation from the mean (two standard deviations from the mean was less than zero) were considered non-responders and were excluded from further analysis (Delgado et al., 2008; LaBar et al., 1998; Phelps et al., 2001). Five participants out of 35 were excluded

based on this criterion. Skin conductance data was not collected for one participant, because it was not physically possible due to a disability. Responses were square-root transformed prior to statistical analysis to reduce skewness (LaBar et al., 1998). For each participant, an average SCR was calculated for each strategy condition (Emphasize, Deemphasize, Look). Repeated measures analysis of variance (ANOVA) was used to test for effects of strategy on physiological responding.

Manipulation checks (questionnaires)

All participants completed a post-experimental questionnaire to assess their excitement about the decisions and potential rewards, whether they believed that they would actually be paid based on the selected decisions, and whether they engaged in the reappraisal strategies during the task. Excitement and belief about payment were assessed using a rating scale from 1 to 7, where 1 indicated not at all and 7 indicated very much. Engagement in reappraisal/natural responding was assessed by asking participants to report what they thought about in general for each strategy word (Emphasize, Deemphasize, Look).

Data analysis

The SMG task consisted of a 3 X 3 design: strategy type (Look, Emphasize, Deemphasize) and decision type (equal, risky-advantageous, risky-disadvantageous). For each unique condition, participants' choices were quantified as the average proportion that the risky option was selected. For ease of communication, we refer to the option that involved risk (winning was not guaranteed and dependent on a certain probability) as the risky option and selection of that option as risk-taking. Choice data were analyzed for effects of strategy and decision type using repeated measures ANOVA.

Results

Manipulation checks

Participants reported moderate excitement about the money they could win in the game (M = 5.03, SD = 1.68) and believing they would be paid based on their choices (M = 5.14, SD = 1.93). All participants reported using the reappraisal strategies as instructed, and on average they felt moderately successful at using reappraisal (Emphasize: M = 5.17, SD = 1.34, Deemphasize: M =4.86, SD = 1.84. There was no significant difference in reported success for Emphasize and Deemphasize, $t(35) = 1.01$, $p = 0.32$.

Decision-making

We observed main effects of strategy, $F(1.37, 47.96) = 7.42$, $p = 0.005$, $\chi_p^2 = 0.18$, and decision type, $F(1.56, 54.54) = 82.99$, $p = 0.001$, $\chi_p^2 = 0.70$, (both Greenhouse-Geisser corrected) on risk-taking (Figure 2). Risk-taking was greatest for Deemphasize trials and lowest for Emphasize trials (Deemphasize: M = 0.52, SD = 0.22; Look: M = 0.44, SD = 0.17; Emphasize: M = 0.37, SD = 0.22). With regard to the decision types, risk-taking was greatest for risky-advantageous decisions and lowest for risky-disadvantageous decisions (risky-advantageous: M = 0.66, SD = 0.17; equal: M = 0.41, SD = 0.21; risky-disadvantageous: M = 0.26, SD = 0.19). The interaction of strategy and decision type was not significant, $F(4, 140) = 1.97$, $p = 0.10$, $\chi_p^2 = 0.05$.

Although the interaction was not significant at an alpha of 0.05, because we had an a priori prediction that strategy and EV would exert independent effects, and a p value of 0.10 is considered a trend, we conducted post-hoc t tests. For risky-disadvantageous decisions Emphasize risk-taking did not differ from Look, $t(35) = 0.98$, $p = 0.33$; Deemphasize risk-taking was significantly greater than Look, $t(35) = 2.90$, $p = 0.006$; and Deemphasize risk-

taking was significantly greater than Emphasize risk-taking, $t(35) = 2.63$, $p = 0.01$. For equal decisions Emphasize risk-taking was lower than Look at a trend level, $t(35) = 1.79$, $p = 0.08$; Deemphasize risk-taking was greater than Look at a trend level, $t(35) = 1.67$, $p = 0.10$; and Deemphasize risk-taking was significantly greater than Emphasize, $t(35) = 2.43$, $p = 0.02$. Finally, for risky-advantageous decisions Emphasize risk-taking was significantly lower than Look, $t(35) = 2.97$, $p = 0.005$; Deemphasize risk-taking did not differ from Look, $t(35) = 1.13$, $p = 0.27$; and Deemphasize risk-taking was significantly greater than Emphasize, $t(35) = 3.30$, $p = 0.002$.

Skin conductance

We tested for effects of regulation on physiological responding using SCRs for 30 eligible participants (see Method section above). No significant effect of strategy was observed, $F(1.58, 45.71) = 1.76$, $p = 0.19$.

Discussion

The current study examined shifts in risk-taking associated with using reappraisal strategies when faced with cues signaling opportunities to win money. Money could be earned by making financial decisions that varied in terms of which option, risky or safe, had the highest EV. As predicted, reappraisals that heightened the perceived importance of the next decision (Emphasize) decreased risk-taking, whereas reappraisals that reduced the perceived significance of the next decision (Deemphasize) increased risk-taking. This effect was independent from that of EV, which was characterized by increased risk-taking when the risky option had the higher EV. Taken together the results demonstrate the efficacy of reappraisal at influencing behavior in accordance with regulation goals without interfering with value processing.

The reappraisal strategies involved maintaining focus on the upcoming decision and modulated thoughts associated with the decision and opportunity for reward. The increase in risk-taking for Deemphasize reappraisals is consistent with the reduced loss aversion observed by Sokol-Hessner and colleagues (2009, 2012). Additionally, this finding is in agreement with a study that found that habitual use of reappraisal was associated with increased risk-taking and reduced sensitivity to changes in probability and loss amounts in a cognitive risk-taking task (Panno et al., 2013). Emphasize reappraisals, on the other hand, seemed to increase risk aversion as participants made fewer risky choices in this condition. Subjective reports during post-experimental questioning suggested that participants effectively increased the importance of decisions for Emphasize trials, for instance, imagining they were making the decision for their whole family rather than just themselves.

We take these results as evidence that reappraisal is flexible because it increased and decreased risk-taking contingent on the regulation goal (Emphasize or Deemphasize). Flexible in this sense should not be conflated with rational. Rational decision-making is characterized by choosing the option with the greatest expected value. Neither reappraisal strategy increased rational decision-making across all decision types. However, our aim was not to test whether reappraisal would increase rational decision-making, but instead was to show that the goal of the reappraisal and the expected value of the options are both critical for shaping risk-taking. Thus, we did not expect either reappraisal strategy to increase rational decision-making overall because of the nature of the specific regulation goals and our expectation that they would act like frames. We demonstrated that the same kind of cognitive strategy (reappraisal) could be employed with opposite goals (Emphasize, Deemphasize) to produce opposite behavioral effects. It is possible that a different reappraisal goal, for instance, one that enhanced focus on expected value information, would promote more rational decision-making.

The reappraisal strategies affected risk-taking similarly across all EV contexts. We predicted these overall effects because reappraisal occurred prior to seeing the specific decision-options, and may have created a frame for the decisions. Previous research has shown that individuals exhibit increased loss-aversion for decisions framed as potential losses and increased risk-seeking for decisions framed as potential gains (De Martino, Kumaran, Seymour, & Dolan, 2006; Kahneman & Tversky, 1979).

In our study, we used SCRs as a proxy for emotional responses. Although both the reappraisal strategies altered risk-taking, neither strategy affected SCRs. It is difficult to draw conclusions from a null result, but we offer several possible explanations for the lack of a change in SCR. The first is that reappraisal may have altered risk-taking simply via changing thoughts about the decisions without also changing emotional responses. The caveat is that SCR is an indirect measure of emotion, and it primarily tracks arousal. Thus, it is possible that reappraisal changed non-arousal dependent emotional responses, but because we did not collect self-reports of emotion during the cues, we cannot empirically address this question. In this task, all of the risk and expected value information was presented after the cue, when the decision options appeared. It is possible that stronger emotional responses were evoked by the presentation of the decision options than by the cue, and reappraisal may have modulated responses during the decision options. We did not examine SCRs during the decision phase for two reasons: 1) the temporal proximity of the cue and decision presentations and 2) because active reappraisal occurred during the cue and we were interested in changes associated ongoing reappraisal. Future research is needed to assess valence shifts in affective responses in the context of reappraisal and decision-making.

We manipulated the EV relationships of the decision options to examine whether EV tracking would be maintained on reappraisal trials. We did not observe a significant interaction of strategy and decision type at the 0.05 alpha level, but since the interaction *p* value was equal to 0.10 and we had an a priori prediction of independent effects, we examined reappraisal effects on risk-taking separately for each decision type using *t* tests. Critically, for all three decision types Deemphasize reappraisals significantly increased risk-taking compared to Emphasize reappraisals (*p* values for each decision type = or < 0.02). The effects of the two reappraisal strategies relative to Look differed for the two non-ambiguous decision types, risky-advantageous and risky-disadvantageous. Specifically, we observed that when it was disadvantageous to take a risk, Emphasize reappraisals did not significantly reduce risk-taking relative to natural responding, whereas Deemphasize reappraisal did significantly increase risk-taking relative to natural responding. An opposite pattern was observed for the risky-advantageous decisions: Emphasize reappraisals decreased risk-taking relative to natural responding, whereas Deemphasize reappraisals did not increase risk-taking relative to natural responding. Natural risk-taking levels for the risky-disadvantageous decisions, characterized by low risk-taking, and risky-advantageous decisions, characterized by high risk-taking, may reflect true peaks and nadirs such that there is little room for reappraisal to enhance these natural tendencies. Importantly, reappraisals did shift risk-taking away from natural responding: both reappraisal strategies changed risk-taking during the equal decisions; Deemphasize increased risk-taking during risky-disadvantageous decisions; Emphasize decreased risk-taking during risky-advantageous decisions. Taken together, these results show that reappraisals affect risk-taking overall, but these effects are constrained by the range of natural risk-taking.

Reappraisal may have modulated decision-making by altering preferences for risk. This explanation is consistent with our finding that decisions reflected intact EV information. The effect of strategy on risk-taking during the equal EV decisions provides support for the idea that reappraisals altered preferences for risk. In equal EV decisions the EVs of the risky (option that involved a probability of attaining the total value) and safe options were

equivalent, thus the only difference between the two options was the risk information. Risk preference and EV are both components of subjective value. Two recent neuroimaging studies demonstrated that distancing reappraisals altered value encoding in the ventral striatum (Staudinger et al., 2009; Staudinger, Erk, & Walter, 2011). During reappraisal, ventral striatum activity no longer differentiated high and low reward cues, suggesting that reappraisal altered representations of the subjective value of the cues. These studies did not involve decision-making or explicit judgments of reward magnitude, making it unclear if explicit assessments of value were distorted by regulation. Future research is needed to understand the relationship between neural and behavioral indexes of value and whether these are differentially affected by reappraisal in certain contexts.

This research has potential implications for altering maladaptive appetitive behaviors such as overeating and substance abuse, because it demonstrates that using cognitive strategies to change how we experience an appetitive cue alters our behavior. Recent work with addicted populations suggests the promise of cognitive regulation techniques: cigarette smokers lowered self-reported craving (Kober, Kross, Mischel, Hart, & Ochsner, 2009; Kober et al., 2010) and smokers (Kober et al., 2010) and cocaine addicts (Volkow et al., 2010) reduced neural signatures of craving during cognitive regulation. An important goal for future research is to test whether changing thoughts about drug cues fosters shifts in actual drug-seeking behavior. The current study lays a foundation for future work by demonstrating that changing thoughts about typical appetitive cues using reappraisal alters reward-related behavior.

Acknowledgments

This work was supported by a National Institute on Drug Abuse grant to M.R.D. (DA027764) and a predoctoral National Research Service Award (NRSA) fellowship to L.M.B. (DA025426). The authors thank Mei-Fang Cheng, Kent Harber, Daniela Schiller, and Elizabeth Tricomi for comments and suggestions.

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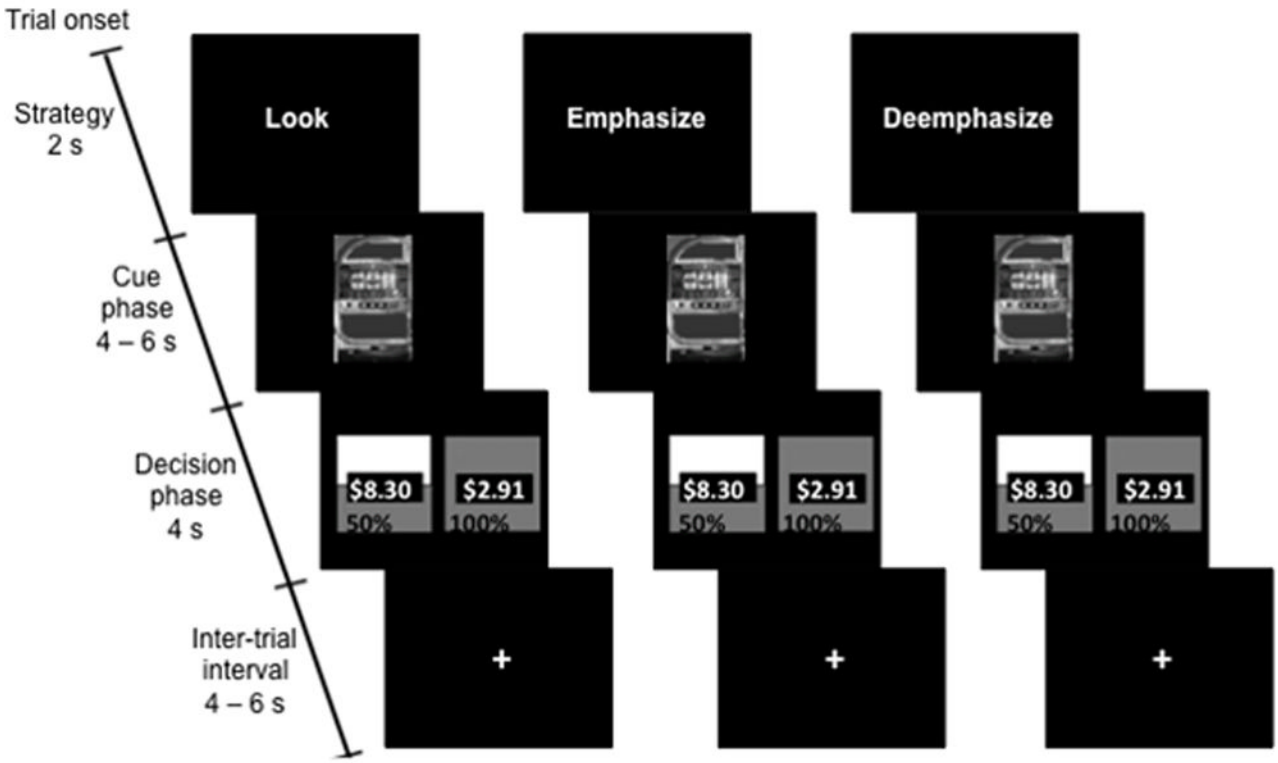

Figure 1.
Schematic of the Slot Machine Game. The number line on the left indicates the phases of the task and their durations. The location of the decision options was counterbalanced.

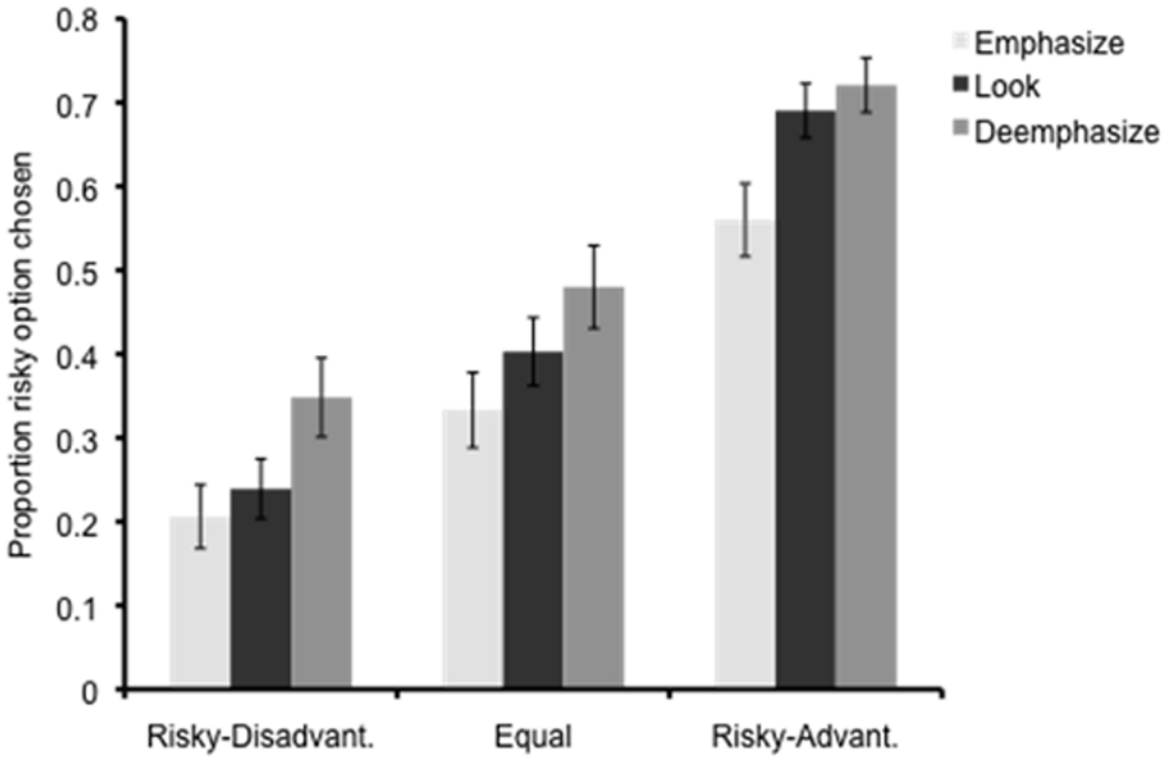

Figure 2.
Decision-making results. Risk-taking was significantly affected by reappraisal (Emphasize, Deemphasize) and by decision type (risky-disadvantageous, equal, risky- advantageous). Error bars indicate standard error of the mean.