Differences in cognitive control between real and hypothetical payoffs

Working paper

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Abstract

This paper focuses on the question of neuronal differences in the evaluation of hypothetical and real payoffs. Previous research in experimental economics (e.g. Holt and Laury 2002) has shown that there are differences in subjects' behavior when evaluating hypothetical and real payoffs. We conducted a two sessions EEG-experiment with high-stake payoffs. We used the certainty equivalent method for payoff evaluation in which subjects were asked whether they preferred playing a lottery or receiving a sure payoff instead. Our behavioral results are in line with former studies indicating that subjects are more risk averse when being faced with real payoff. The EEG data provides evidence that these decision processes are different in brain activity. A greater N2 could be evoked for hypothetical payoffs, which shows that higher cognitive control is present in hypothetical decisions. These neuronal underpinnings provide an indication for additional evaluation processes for hypothetical decisions which could explain a shift of the certainty equivalent toward the expected value of a lottery.

Keywords: hypothetical bias, cognitive control, N2, decisions under risk

Introduction

In experimental economics an often discussed question has been how to verify observed behavior from an experiment in relation to behavior in the real world? Researchers always intend to reduce biasing effects of a lab-environment. Therefore, one common consensus in literature is to pay out decisions in experiments, since hypothetical decisions are supposed to be not reliable. However, there are special cases in which a realization of decision outcomes is not possible like for instance in experiments related to questions of moral conflicts or very high payoffs. In that case, hypothetical decisions can provide valuable information. The fact that hypothetical decisions failed to reflect real world decisions has been verified in several studies. For example, Holt and Laury (2002) confirmed this hypothetical bias for decisions under risk. In their investigation risk aversion of subjects increased sharply for lottery evaluations with high payoffs when decisions are paid for real.

In our study, we examine the hypothetical bias for lottery choices through an EEG paradigm in which subjects made hypothetical and real decisions. Beyond behavioral observations, the EEG technique can help to find more precise explanations of the hypothetical bias by revealing neuronal differences in evaluation processes of the human brain. For example, event-related brain potentials, recorded by EEG-technique, can show differences in cognitive control mechanisms.

Cognitive control enables human beings to adapt behavior to changing environmental demands in the most flexible manner. Several investigations have shown that in decision tasks, cognitive control increases when subjects have to choose between two or more competing alternatives. Here, we test the hypothesis that varying levels of cognitive control are one potential mechanism responsible for the hypothetical bias. In stimulus-locked EEG, the N2 – a negative deflection at fronto-central electrode sites appearing 200-300 ms after stimulus presentation – is assumed to reflect the neural underpinnings of cognitive control. We hypothesize that different levels of involvement of cognitive control in hypothetical and real payoffs should result in a different appearing of the N2 component.

Our study uses the certainty equivalent method to reveal preferences over monetary outcomes. The elicitation of different certainty equivalents for hypothetical and real choices should provide evidence for the hypothetical bias. As a consequence, we should expect differences in the N2 component if both evaluation processes differ, resulting in different behavior. A different evaluation of hypothetical and real choices could be caused by a broader range of alternative choice criteria for hypothetical choices. Hence, we assume that this extended set of alternatives should lead to an increase of cognitive control resulting in a higher N2 component for hypothetical choices. This assumption has also been stated, but not confirmed, in the study of Kang et al. (2011). They also investigated differences in hypothetical and real choices, although for consumer goods and in an fMRI study, and found evidence for higher cognitive control in real choices. Kang et al. argue that this could reflect a more careful comparison process for real choices. Thus, our alternative assumption is that a higher N2 for real decisions could also be expected in case of a conceivable higher importance of real decisions and should therefore allocate more resources which could lead to a higher cognitive control.

Hypotheses

Hypothesis 1

In our study, we expect to observe a hypothetical bias for the behavioral data. We hypothesize that for real decisions subjects are more risk averse compared to hypothetical decisions. Thus, our null hypothesis is that the elicited certainty equivalents of real choices are higher than the elicited certainty equivalents of hypothetical choices.

H_o: $CE_{real} > CE_{hypo}$

Hypothesis 2

When differences in the behavior occur, we also expect to discover differences in stimulus locked event-related potentials. Relating to our assumption that an extended set of choice criteria for hypothetical choices leads to higher cognitive control, we hypothesize that the N2 component is higher for hypothetical decisions than for real decisions. Thus, our null hypothesis is that the average voltage distribution for electrodes reflecting the N2 component is smaller for real decisions.

H_0: $V_{real}<V_{hypo}$

Material and Methods

Participants

In our study the participants were 21 neurologically healthy, right-handed subjects (12 women, age range 20 to 31). Most of the subjects were students from the Otto-von-Guericke University of Magdeburg who were recruited from the ORSEE (Greiner 2004) subject pool of the university. Subjects received 14 Euro for participation in the hypothetical treatment and were paid according to one randomly selected decision in the real paid treatment.

General procedure

During the experiment all subjects were seated in a comfortable armchair in front of a 19'' screen at a distance of 80 to 100 cm. Subjects made their selections by pressing a button with their left or right index finger. The experiment comprised two sessions within two weeks. Both sessions were conducted in the same way, except for the condition of either hypothetical or real payoffs, and were assigned randomly to the subjects. Every session consisted of 20 practice trials to familiarize subjects with the task. The experiment itself comprised 9 blocks with 64 decision trials each. The experiment duration was about 35 minutes.

Task

The experimental procedure followed the method for eliciting certainty equivalents for binary lotteries. The subjects' task was to decide either to play a lottery or to receive a sure payoff. We used a fifty-fifty lottery, in which one payoff was zero and the other payoff indicated a high-stake outcome of about 100 Euros. All sure payoffs were assigned between the two outcomes of the binary lottery.

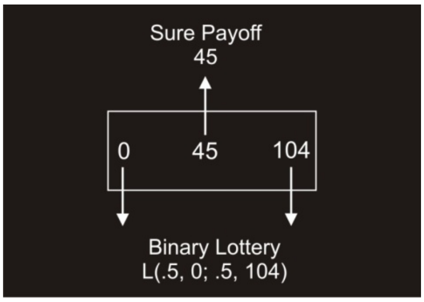

Figure 1: Display of the certainty equivalent method as used in the experiment

In each trial, lasting between 2700 to 3400 ms, a string of three numbers surrounded by a white box was presented (see Figure 1). The two outer numbers were shown first. After 1000 ms, the inner number was added and the completed array stayed on the screen for another 1000 ms. The sequence of screens is shown in Figure 2.

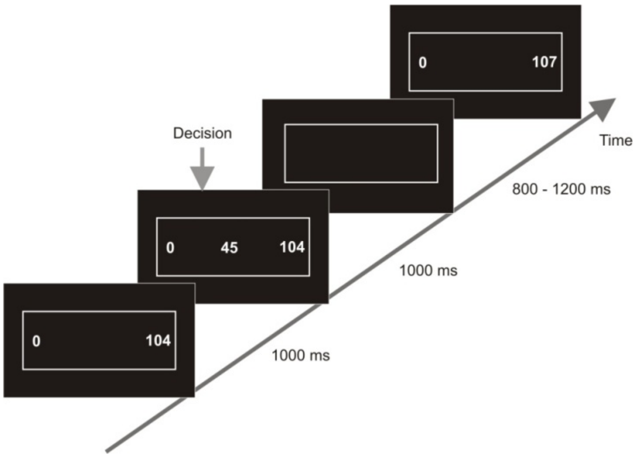

Figure 2: Sequence of Screens presented to the subjects

The array's left number was always zero, the values of the array's right number differed between 100 and 107. Sure payoff values, as indicated by the inner number, were assigned to decimal values from 10 to 90 with eight different values (0-7) for each decimal. Thus, the inner number varied between values of 10 and 97. The variation of each sure payoff value was assigned to every lottery payoff value and the combination of all values resulted in 576 decision trials for each subject.

Behavioral analysis

Behavioral data were categorized by the distance of the sure payoff compared to the expected value of the lottery. A comparison of the expected value of a lottery L(.5, 0; .5, 100) equal to 50 and a sure payoff of 30 resulted in a distance of -20. A sure payoff of 60 therefore resulted in a distance of +10. Thus, all 576 decision trials are arranged according to values between -43 to +47. Relative choice frequencies of all distances to the expected value were calculated for every subject. A relative frequency of 0.5 for lottery choices indicated the indifference point of a subject.

EEG-recording and analysis

The electroencephalogram was recorded from 61 thin electrodes mounted in an elastic cap and placed according to the international 10-10 system. The EEG was re-referenced offline to the mean activity at the left and right mastoid. In order to enable offline rejection of eye movement artifacts, horizontal and vertical electrooculograms (EOG) were recorded using bipolar montages. All channels were amplified (bandpass 0.05-70 Hz, notch-filter at 50Hz) and digitized with 4 ms resolution, all electrode impedances were kept below 10 kΩ. After epoching the data time locked to stimulus onset (baseline -100 to 0, epoch length 1000 ms) epochs confounded with eye blink or other artifacts (muscle activity, step-like artifacts etc.) were excluded from the calculation of the subject average. Finally, subject averages were filtered with a 12 Hz low pass filter.

Epochs were sorted into three different bins: (1) choices made around the individual indifference point, (2) sure lottery choices and (3) sure payoff choices. Choices were classified as belonging to the indifference area (1) was arranged according to the individual indifference point of a subject based on the behavioral data. Furthermore, the indifference point also determined both areas of sure choices. According to the indifference point and to both lottery payoffs, the point at half distance between the indifference point and the lottery payoff of zero indicated the area for sure lottery choices (2). Therefore, the point at half distance between the indifference point and the lottery payoff of 100 indicated the area for sure payoff choices (3). Thus, an indifference point at 40 determined the area of sure lottery choices by (40-0)/2=20 and the area of sure payoff choices by (100-40)/2+40=70.

Results

Behavior

Figure 3 depicts the relative frequency of lottery choices summarized across subjects. As can be seen relative frequency of lottery choices in the real paid treatment is constantly smaller compared to the hypothetical treatment. Accordingly, certainty equivalents in the real paid treatment have a median of -12 (mean= 11.38, SE=2.42) as a distance to the expected value. In contrast, the median of certainty equivalents for hypothetical choices is -7 (mean=8.48, SE=2.51). A one-sided pair-wised Wilcoxon signed-rank test confirmed on a 5% significance level (N=21, V = 138, p=0.43) that the certainty equivalents are smaller in the real paid treatment. Thus, we can reject our first null hypothesis that certainty equivalents of real choices are higher than certainty equivalents of hypothetical choices.

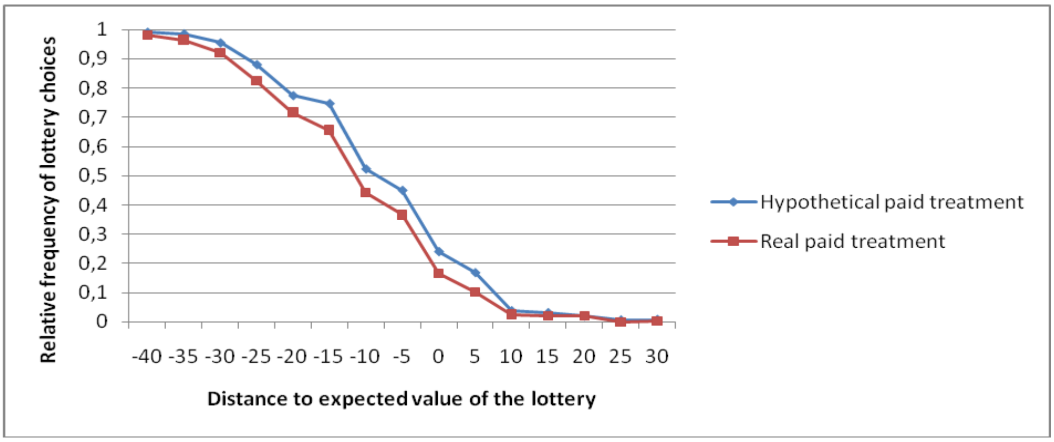

Figure 3: Relative frequency of lottery choices

In both treatments, subjects show risk averse behavior due to medians of certainty equivalents which are smaller than zero in their distance to the expected value of the lottery. Furthermore, certainty equivalents also differ between both treatments. Hence, subjects are more risk averse in the real paid treatment, as confirmed by the Wilcoxon test.

Event-related potentials

Event-related potentials were elicited in four bins for each treatment: (1) a sure choice area for lottery choices, (2) a sure choice area for fix payoff choices and two bins in the area around the indifference point separated by (3) lottery choices and (4) fix payoff choices. An N2 component was identified for both treatments, peaking at about 320 ms after stimulus presentation. An overview of stimulus-locked event-related potentials at Fz, Cz and Pz electrodes as well as bipolar montage electrodes are provided in Figure 4 and 5.

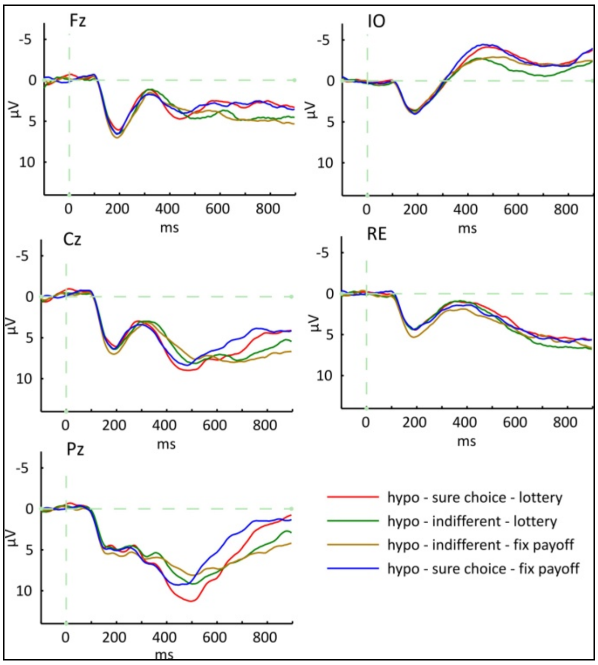

Figure 4: Stimulus-locked event-related potentials for hypothetical choices

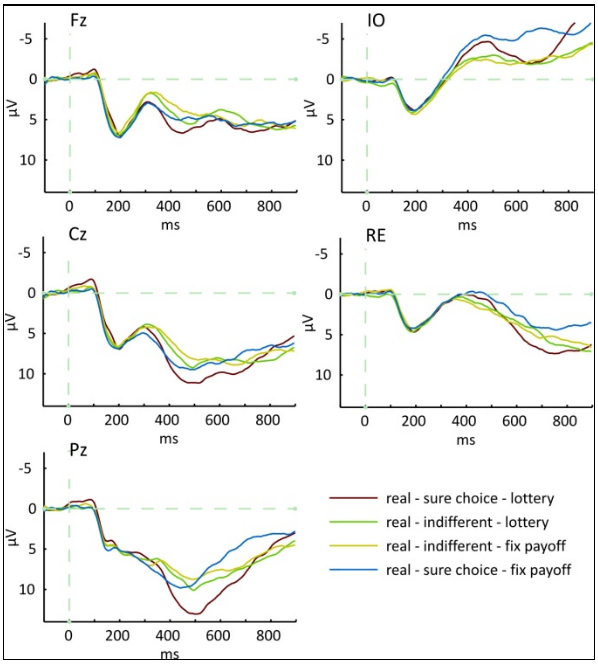

Figure 5: Stimulus-locked event-related potentials for real choices

Furthermore, an ERP comparison between the hypothetical and the real treatment at the Fz electrode is presented in the following figures. N2 amplitudes for choices outside of the indifference area (see Figure 7) differ between both treatments, which is not the case for choices inside of the indifference area (see Figure 6).

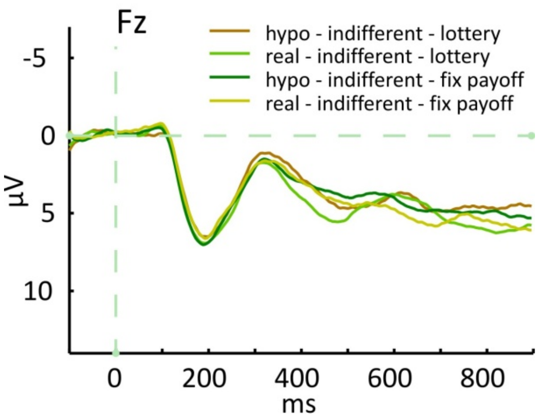

Figure 6: Stimulus-locked ERPs at Fz electrode for real and hypothetical choices inside of the indifference area

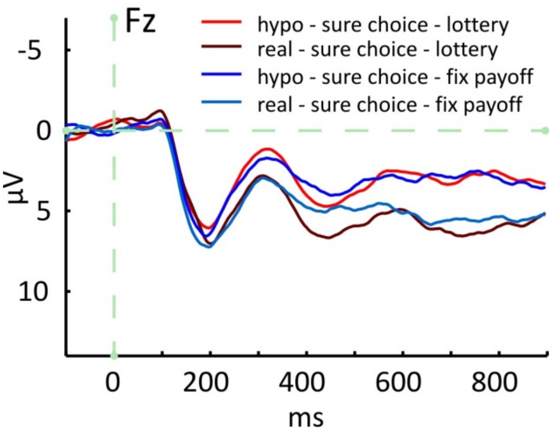

Figure 7: Stimulus-locked ERPs at Fz electrode for real and hypothetical choices outside of the indifference area

Therefore, mean amplitudes were analyzed within a time range of 270-370 ms after stimulus presentation. A repeated measures AnoVa was performed for Fz, Cz, and Pz electrode as anterior-posterior factor (3) and with treatment (2), choice (2) and indifferent position (2) as further factors. An interaction for anterior-posterior, treatment and indifferent position was revealed ($F(1.361)=5.911$, $p=0.014$). A further AnoVa for the Fz electrode confirmed an interaction *treatment x indifferent position* ($F(1)=4.990$, $p=0.037$). All p-values are reported as Greenhouse-Geisser corrected.

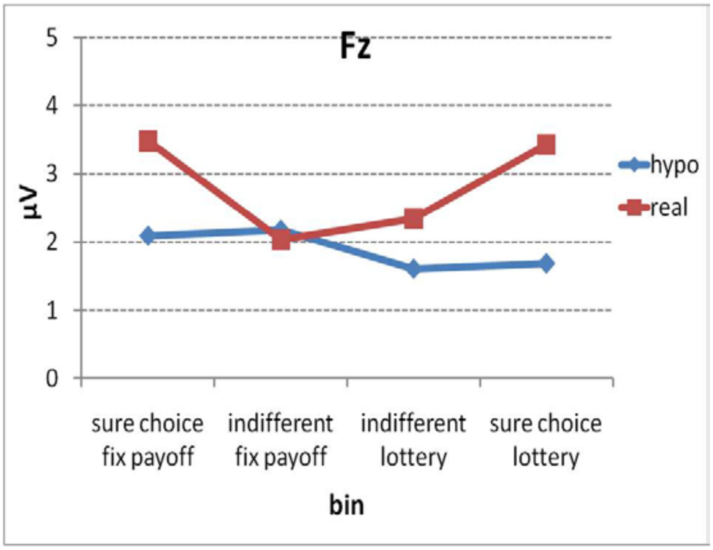

Figure 8: Mean amplitudes of stimulus-locked ERPs at FZ electrode between 270 and 370 ms

Pair	**Fz** electrode
hypo – sure choice – lottery hypo – indifferent – lottery	T(20)=0.253 p=0.802
real – sure choice – lottery real – indifferent – lottery	**T(20)=2.007 p=0.058**
hypo – sure choice – fix payoff hypo – indifferent – fix payoff	T(20)=-0.196 p=0.847
real – sure choice– fix payoff real – indifferent – fix payoff	**T(20)=2.435 p=0.024**
hypo – sure choice – lottery real – sure choice – lottery	**T(20)=-2.245 p=0.036**
hypo – indifferent – lottery real – indifferent – lottery	T(20)=-1.021 p=0.319
hypo – indifferent – fix payoff real – indifferent – fix payoff	T(20)=0.192 p=0.849
hypo – sure choice – fix payoff real – sure choice– fix payoff	**T(20)=-1.768 p=0.092**

Table 1: Paired t-test (two-sided) for mean amplitudes between 270 and 370 ms

Subsequently, a pair-wised t-test controlling for differences in mean amplitudes was performed in order to control for our second hypothesis that hypothetical choices elicit higher cognitive control. The t-test showed significant differences ($p<0.05$, one-sided) between both treatments for the choice areas outside of the indifference area (see also Table 1). Difference could also be confirmed within real choices between mean amplitudes inside and outside of the indifference area ($p<0.05$, one-sided). Differences within hypothetical choices could not be found. Thus, the N2 amplitudes of real choices outside of the indifference area are significantly smaller compared to all other N2 amplitudes of this study. In Figure 9 and 10, a topography of all bins is presented, showing that a distinct N2 pattern for real choices outside of the indifference area is not existent.

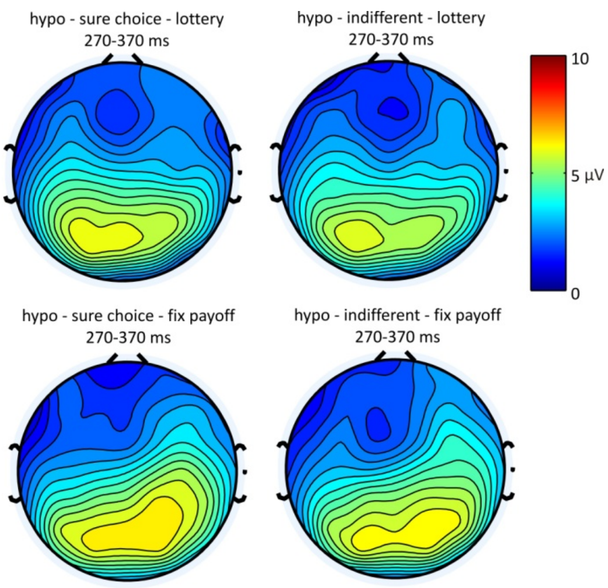

Figure 9: Topographies for hypothetical choices

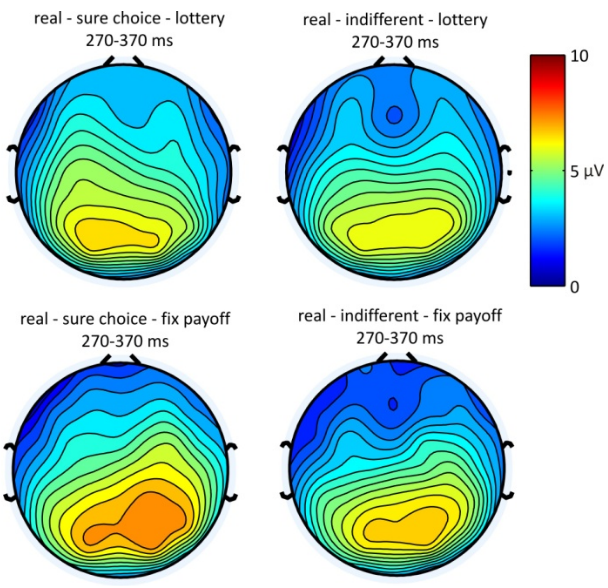

Figure 10: Topographies for real choices

Discussion

In our study, we analyzed hypothetical and real payoffs in an EEG paradigm. We used the certainty equivalent method to examine risk behavior for decision under risk. A hypothetical and real treatment with the same task was conducted. In both sessions, event-related brain potentials were measured through EEG.

The behavior results are in line with findings of former studies and illustrate that subjects are more risk averse in the real paid treatment. The event-related potentials show increased N2 amplitudes for hypothetical payoffs. In contrast, N2 amplitudes for real payoffs are only higher for choices around the indifference point. Differences in N2 amplitudes between choices around the indifference point and sure choices outside of the indifference area for real payoffs confirm that subjects are faced with an increased action conflict around the indifference point. Sure choices in real paid treatments seem to be for sure. This pattern cannot be found for hypothetical choices. Here we find an increased action conflict through all choices which could be attributed to an extended range of decision alternatives. We can conclude that hypothetical stimuli evoke an increase in cognitive control.

In contrast to Kang et al., we can confirm our first hypothesis that hypothetical decisions lead to an increase of cognitive control. As stated before, the increase of cognitive control can be reasoned by a broader range of alternative choice criteria for hypothetical choices. The difference in the behavioral data shows a shift of the hypothetical certainty equivalents toward the expected value of the lottery. This could indicate that if an extended range of choice criteria exists, the expected value of a lottery could be a more pronounced fix point in the choice set of the subjects for hypothetical decisions. Thus, the higher N2 could reflect an additional action control conflict between the true individual certainty equivalent of a real decision and the expected value of a more rational, risk neutral decision. These differences in cognitive control can lead to a different payoff evaluation resulting in a shift of the certainty equivalent toward the expected value for hypothetical decisions.

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