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What you give is what you get: Payment of one randomly selected trial induces risk-aversion and decreases brain responses to monetary feedback

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Abstract
In economic studies, it is standard practice to pay out the reward of only one randomly selected trial (pay-one) instead of the total reward accumulated across trials (pay-all), assuming that both methods are equivalent. We tested this assumption by recording electrophysiological activity to reward feedback from participants engaged in a decision-making task under both a pay-one and a pay-all condition. We show that participants are approximately 12% more risk averse in the pay-one condition than in the pay-all condition. Furthermore, we observed that the electrophysiological response to monetary rewards, the reward positivity, is significantly reduced in the pay-one condition relative to the pay-all condition. The difference of brain responses is associated with the difference in risky behavior across conditions. We concluded that the two payment methods lead to significantly different results and are therefore not equivalent.

Keywords Economic research · Risk behavior · Payment method · Reward positivity

Introduction

Research on economic decision-making has gained a lot of attention recently. Two pioneers in this field, Kahneman and Tversky, were awarded the Nobel prize in 2002, because they identified heuristics contradicting the view that humans are rational decision makers (Kahneman & Tversky, 1979). Later, neuroscientists identified the anterior cingulate cortex as a key brain area involved in decision making (Gehring & Willoughby, 2002; Holroyd & Coles, 2008). Activation of the anterior cingulate cortex can be assessed with an electroencephalogram (EEG) signal that is sensitive to monetary rewards and losses (Holroyd & Coles, 2002). Because neuroeconomic studies need many trials to obtain reliable estimates of the brain responses that they measure, participants make many economic decisions in such studies. Each of these decisions is associated with a certain monetary reward.

Because it can be expensive to pay participants the total reward accumulated across trials (pay-all), many behavioral experimenters instead pay only the reward associated with one randomly selected trial (pay-one) to reduce the costs of the study (De Martino et al., 2010). The use of the pay-one method was justified by findings concluding that paying out only one trial is equivalent to paying out all of the trials, as summarized in a recent overview by Charness, Gneezy & Halladay (2016). Many of these findings suffer from methodological problems, for example, by comparing payment conditions with unequal expected values. Interestingly, one of the most influential economists of the 20th century, Paul Samuelson, famously stated decades ago that it is less attractive to play a gamble once compared with playing a gamble 100 times (Samuelson, 1963, cited after Thaler, Tversky, Kahneman & Schwartz, 1997), which suggests that the pay-one and the pay-all method may be different from each other. In particular, a risky decision on one trial of a pay-one paradigm could—in the event of a loss—result in the participant leaving the experiment with no winnings at all. Pay-one paradigms therefore are riskier than pay-all paradigms, and participants accordingly make fewer risky decisions in them (Schmidt & Hewig, 2015). Still, the pay-one method is typically adopted as a convenient and equivalent substitute for the pay-all method (Charness et al., 2016).

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In the economic paradigm used in our study, we equalized the expected values of both payment methods by multiplying the outcome of the randomly selected trial with the number of trials. Although economic studies using the pay-one method do not typically do this, which would result in spending the same amount of money on participants' winnings as they would have received in the pay-all condition anyway, we did so to compare the two payment methods directly. Although other studies have adopted different pay-out procedures, such as paying out a certain percentage of trials or incorporating monetary losses in addition to monetary gains, our goal was to highlight the difference between pay-one and pay-all payment methods. For this reason, we chose the extreme version of paying out only one randomly selected trial. In addition, we only included monetary gains because of the nonsymmetric value function in the gain and loss domain (Kahneman & Tversky, 1979), which would make a comparison between payment methods complicated.

In the current study, we investigated the neural mechanisms that underlie the behavioral differences associated with the two payment methods. We recorded electrophysiological activity from the scalp of human participants engaged in a decision-making task that was played once under a pay-one instruction and once under a pay-all instruction. We analyzed the reward positivity, a reward-related brain response occurring in the event-related potential (ERP) approximately 280 ms after feedback stimuli in decision tasks. The reward positivity is more positive-going after gain or correct feedback than after loss or error feedback (Miltner et al., 1997) and is sensitive to violations in outcome expectation, being more negative when an outcome is worse than expected and more positive when an outcome is better than expected (Holroyd & Coles, 2002; Walsh & Anderson, 2012; Sambrook & Goslin, 2015). Importantly for our purpose, the reward positivity is related to individual differences in reward processing and cognitive control. For example, reward positivity amplitude is larger in populations associated with decreased control, such as problem gamblers (Hewig et al., 2010), high temporal discounters (Cherniawsky & Holroyd, 2013), adolescents (Huang et al., 2017), and impulsive individuals (Schmidt et al., 2017; for review see Holroyd & Umemoto, 2016). In addition, high reward positivity amplitudes predict irrational choices in the Ultimatum Game (Hewig et al., 2011). These findings suggest that a lower amount of cognitive control is associated with higher reward positivity amplitudes. Consequently, a higher amount of cognitive control is associated with smaller reward positivity amplitudes (Schmidt et al., 2017). With regard to our study, we predicted a higher amount of cognitive control in the pay-one condition as participants have to keep themselves from acting too risky. This higher amount of cognitive control should be associated with smaller reward positivity amplitudes in the pay-one condition. Furthermore, we predicted that the difference in reward positivity amplitudes between the two conditions would be positively correlated with the difference in risky behavior between the conditions across individuals.

As a control, we also examined the amplitude of the P300, an ERP component elicited by task-relevant stimuli over posterior areas of the scalp (Donchin & Coles, 1988). The P300 has been intensively studied in so-called oddball paradigms in which frequent and rare stimuli are presented to participants. Rarely presented stimuli elicit a larger P300 compared with frequently presented stimuli, which is called the oddball effect. The P300 amplitude is enhanced when participants are instructed to pay attention to the rare stimuli, for example by pressing a button each time they hear it. The P300 is therefore sensitive to task engagement or motivation (Polich, 2007, Carrillo-de-la-Pena & Cadaveira, 2000). Crucially, if our predictions are correct, then the effect of the payment method should be specific to the reward processing function indexed by the reward positivity, as opposed to more general differences in motivation and arousal that affect P300 amplitude. Past research showed that P300 amplitudes are sensitive to reward magnitude (Yeung & Sanfey, 2004; Sato et al., 2005; Wu & Zhou, 2009; Kreussel et al., 2012). Therefore, we expected larger P300 amplitudes after positive monetary feedback that indicates a bigger monetary reward. However, we did not predict a difference in P300 amplitude between the pay-one and pay-all conditions.

In sum, we predicted that participants would behave less riskily and produce smaller reward positivity amplitudes in the pay-one condition compared to the pay-all condition. Furthermore, we predicted that these two measures would be correlated across participants, in line with our assumption that the two payment methods engage different neurocognitive processes that result in different behavior.

Methods

Participants

As the effect size of different risk behavior in the two payment conditions was $d = 0.5$ in our previous study (Schmidt & Hewig, 2015), we computed the required sample size (36) to detect an effect of $d = 0.5$ with alpha level of 0.05 and power of 0.9 with G*power (Faul et al., 2007). For our study, we recruited 40 participants (20 females, 20 males) who were on average 23.3 years old (range: 18-38 years, standard deviation [SD] = 4.5 years) by advertisements and via e-mail lists at the University of Jena. Participants were students at the University of Jena. The ethics committee of the Faculty of Social and Behavioral Sciences of the Friedrich Schiller University of Jena approved the study, and the study is in line with the Declaration of Helsinki.

Payment

Payment depended on the outcomes in the two risk conditions. In the pay-all condition, the outcomes of all 120 trials of the risk game were summed up. In the pay-one condition, one of the 120 trials was randomly chosen after the condition was finished and the associated outcome was multiplied by 120. The expected value for both conditions was therefore 2 (conditions) * 120 (risk trials in each condition) * 5.5 cents (expected value in every trial of the risk game) = 13.20 Euros. In our study, participants won on average 14.18 Euros (SD = 4.87 Euros). In addition, participants received 6 Euros per hour for participation or course credit.

Procedure

In the beginning of the experiment, participants read written instructions and signed an informed consent statement. Then, an electrode cap for recording the electroencephalogram (EEG) was placed on their heads. Participants were seated in a dimly lit room on a comfortable chair in front of a computer monitor at a distance of approximately 100 cm. They completed both the pay-one and pay-all conditions in a single experimental session. The sequential order of conditions was counterbalanced across participants. The experiment was performed using Presentation® software (Version 18.0, Neurobehavioral Systems, Inc., Berkeley, CA, www.neurobs.com). Experimental sessions lasted approximately 2 hours. We prepared the electrode cap in approximately 45 minutes. Each payment condition with risk game lasted approximately 20 minutes, so both lasted approximately 40 minutes. Afterwards, participants washed the electrode gel from their hair.

Risk game Participants played a risk game as described in past studies from our laboratory (Schmidt, Mussel & Hewig, 2013; Schmidt & Hewig, 2015; Schmidt, Kanis, Holroyd, Miltner & Hewig, 2018). Each game included two blocks for each experimental condition (pay-one and pay-all). At the beginning of each condition, participants were told which payment method would be applied. To test their comprehension, they were requested to repeat this instruction in their own words. When the experimenter was not sure if the participant got it right, she asked the participants to describe the payment instruction in more detail. In our experiment, all participants were able to describe the payment instruction correctly in their own words.

Each condition consisted of 120 trials. At the beginning of each trial, a fixation cross was shown for a random interval between 1,000 and 2,000 ms (Figure 1). Then, two options were presented that differed in their associated risk. Both of these options consisted of two monetary rewards. The expected value of both options was always 5.5 cents, and the degree of riskiness differed between the options: from 11 cents vs. 0 cents as the riskiest option and 6 cents vs. 5 cents as the safest option. The participants always chose between the riskiest option (11 cents vs. 0 cents) and one of the other less risky options, presented to the participants in random order and at random locations. Each of the five option combinations was presented 24 times per block. Participants were required to choose an option by pressing one of two corresponding buttons. After another random interval between 500 and 1,000 ms, two cards were shown face-down (Figure 1). Participants chose one of the cards by pressing one of two buttons with their right hand. After another random interval between 500 and 1,000 ms, the back of the selected card was shown, displaying either a diamond that indicated the higher monetary reward (positive feedback) or a square that indicated the lower monetary reward (negative feedback), together with the statement "You get XX cents!" for 1,500 ms. Unbeknownst to the participants, on 50% of the trials the monetary feedback was positive and on the other 50% the monetary feedback was negative, delivered at random independently of their choices. All stimuli in the risk game occupied approximately 10° of visual angle horizontally and 5° vertically. Each condition lasted approximately 20 minutes. Immediately following the pay-all condition, feedback indicating the total accumulated rewards was presented to the participants in one sum. Immediately following the pay-one condition, participants were presented with feedback indicating the outcome of one randomly selected trial multiplied by the number of trials (120). Please note that expected values were equal for the two payment conditions. Then, participants rated each option according to its valence, arousal, and riskiness on 9-point Likert scales, using the self-assessment manikin pictures (Bradley & Lang, 1994) for valence and arousal ratings. High ratings indicate high valence, high arousal, and high riskiness, respectively. At the end of the experiment, participants received feedback concerning their total earnings across both conditions and were paid the corresponding amount.

Risk questionnaire After finishing the risk game, participants completed a risk questionnaire (Schmidt & Hewig, 2015) that consisted of two questions corresponding to the two payment conditions, following recommendations of Kahneman and Tversky (1979). Corresponding to the pay-all condition, participants were asked to choose between the options “11 or 0 cents” and “6 or 5 cents” when allowed to play 120 trials. Corresponding to the pay-one condition, participants were asked to choose between the options “1,320 or 0 cents” and “720 or 600 cents.” The numbers are the product of the outcome in one trial and the number of trials: 11 cents * 120 trials = 1,320 cents, 6 cents * 120 trials = 720 cents, 5 cents * 120 trials = 600 cents.

EEG recording The electroencephalogram was recorded using BrainAmp amplifiers (Brain Products GmbH, Gilching,

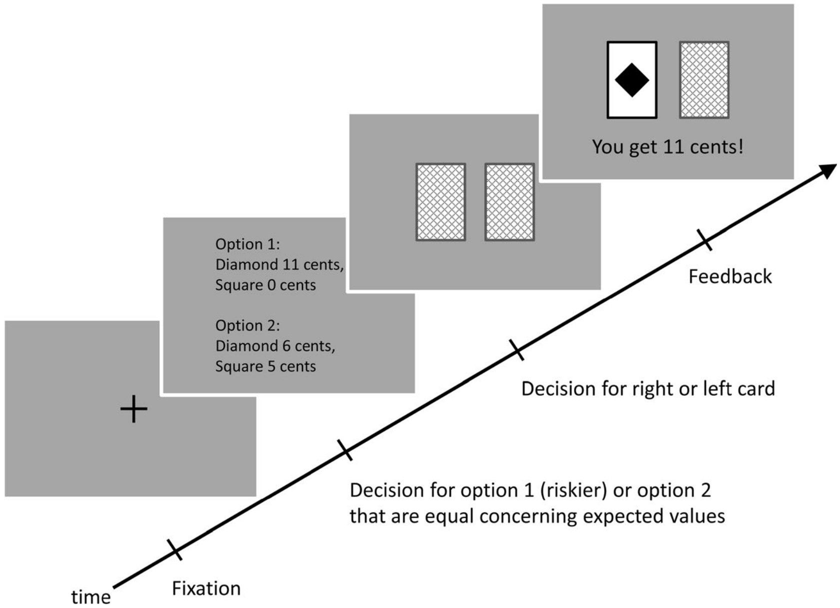

Figure 1 Time-course of one trial in both payment conditions.

Germany) from 64 Ag/AgCl electrodes mounted on participants' heads, including one electrode under the left eye. All electrodes were referenced to the electrode FCz. Additionally, one electrode served for heart rate recording. Impedances of all electrodes were kept below 10 kΩ. Data were band-pass filtered online from 0.016 Hz (10-sec time constant) to 250 Hz.

ERP quantification

For analysis of EEG data, the sampling rate was reduced from 500 Hz to 250 Hz. For eye artifact correction, independent component analysis (ICA) was used as proposed by Debener et al. (2010). Eye-related artifact components were removed by back-projection of all remaining components. The artifact-corrected data were then re-referenced to the mean of electrodes TP9 and TP10. For ERP analysis, the data were filtered with a low-pass filter of 20 Hz. For each participant and channel, the EEG data were then segmented into epochs around the event of interest, which is the outcome feedback in the risk game [−200 ms; 1,000 ms] and baseline-corrected [−200 ms; 0 ms]. Residual artifacts were identified by statistical criteria, namely joint probability and kurtosis. We used the EEGLAB function pop_jointprob for rejection of epochs based on joint probability with the local and global thresholds of 3 standard deviations. For rejection of epochs based on kurtosis, we used the EEGLAB function pop_rejkurt with local and global thresholds of 3 standard deviations. Epochs with artifacts were then removed. To quantify ERP responses in the risk game, we computed grand averages for each electrode, condition, and participant.

The reward positivity was evaluated within a time window between 272 ms and 300 ms after the presentation of monetary feedback, following the recommendation of Sambrook & Goslin (2015). Originally termed the feedback error-related negativity (FRN; Miltner et al., 1997), this ERP component was renamed because of its apparently greater sensitivity to positive rather than negative feedback (Holroyd et al., 2008; Baker & Holroyd, 2011; Proudfit, 2015). We assessed the average amplitude of the raw waveforms in the window of interest. In the following, we will call this component FRN. Furthermore, to minimize overlap with other ERP components (Holroyd & Krigolson, 2007; Sambrook & Goslin, 2015), we also assessed the average value of the difference wave within this window, which was calculated by subtracting the ERP to negative feedback from the ERP to positive feedback (i.e., positive - negative). Hence, more positive values correspond to larger reward positivities. These amplitudes were computed for all scalp electrode locations, but the reward positivity was evaluated at channel FCz, where it is maximal (Miltner et al., 1997; Holroyd & Krigolson, 2007). The P300 amplitude was assessed as the average value of the voltages recorded at channel Pz, where it is normally maximal (Polich, 2007), between 328 ms and 380 ms after feedback onset.

Software and Statistics

For offline data processing, EEGLAB (Delorme, & Makeig, 2004) running under the MATLAB environment (The MathWorks, Inc.) was used. Statistical analyses were performed with R (R Development Core Team, 2016). For between-group *t* tests, we used the Welch unequal variances *t* test implemented in R that corrects the degrees of freedom in case of unequal variances. We used Cohen's d to quantify effect sizes for *t* tests. For within-group tests, we used the formula Cohen's $d = t$-value/root (sample size) as recommended by Lakens (2013) in equation 7. For between-group tests, we used the standard formula for Cohen's *d*. For ANOVA effects, we report generalized eta-squared values as effect size. We tested one-tailed in the analysis of risk choices in the risk game, as we had the specific hypothesis of less risky behavior in the pay-one condition compared with the pay-all condition based on previous results (Schmidt & Hewig, 2015).

Results

Risk choices in risk game

Participants chose the riskier option significantly less often in the pay-one condition (36%) than in the pay-all condition (48%): $t(39) = 2.5$, $p = 0.008$ (one-tailed), $d = 0.4$ (Figure 2, left panel).

Only first condition analyzed To rule out the possibility that this finding resulted from the order of the conditions, we also analyzed only the first condition for every participant, that is, we analyzed the data as a between-subjects design rather than as a within-subjects design. Despite omitting half of the data, the effect remained statistically significant: $t(35.41) = 2.6$, $p = 0.007$ (one-tailed), $d = 0.8$. In this analysis, participants were 23% less risky in the pay-one condition compared with the pay-all condition. The percentage of risky decisions in the pay-one condition was 39%, in the pay-all condition 62%.

Response time in risk game

There were no significant differences in response time between the payment conditions, neither for response times for the risk choice ($p = 0.8$), nor concerning response times for the card choice ($p = 0.7$). The mean response time for the risk choice was 1.41 seconds (SE: 0.07 seconds) and for the card choice 0.62 seconds (SE: 0.04 seconds).

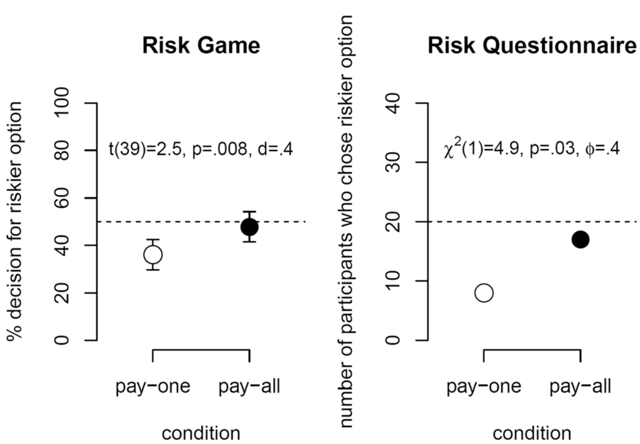

Figure 2. Less risky decisions in the pay-one condition than in the pay-all condition in the risk game (left) and the risk questionnaire (right). Error bars indicate within-subject 95% confidence intervals as prescribed by Loftus & Masson (1994)

Risk questionnaire

Fewer participants chose the riskier option on the risk questionnaire in the pay-one condition (8/40) compared with the pay-all condition (17/40). Application of the McNemar test indicated that this difference was significant: X^2 (1) = 4.9, $p = 0.03$, $\varphi = 0.4$ (Figure 2, right panel). Risk behavior and risk questionnaire answers were significantly correlated across participants: for the pay-one condition $r = 0.51$, $p < 0.001$ and for the pay-all condition $r = 0.46$, $p = 0.003$.

Ratings of options in risk game

Separate analyses of variance on the valence, arousal, and riskiness ratings of the risk options, with task condition (pay-one, pay-all) and risk option (6:5 cents, 7:4 cents, 8:3 cents, 9:2 cents, 10:1 cents, 11:0 cents) as within-subject factors, revealed main effects of risk option for all ratings (valence $F(5,195) = 7.8$, $p < 0.001$, $\eta^2 = 0.10$, arousal $F(5,195) = 45.2$, $p < 0.001$, $\eta^2 = 0.27$, and riskiness $F(5,195) = 234.4$, $p < 0.001$, $\eta^2 = 0.74$). Visual inspection of the data indicates lower valence, higher arousal, and higher perceived riskiness with increasing riskiness of the options (Figure 3).

Moreover, there was a significant interaction of condition and option for the valence ratings, $F(5,195) = 6.1$, $p < 0.001$, $\eta^2 = 0.03$; all other interactions for the three analyses of variance did not reach significance. Post-hoc tests indicated that participants rated the riskiest option (11:0 cents), $t(39) = 4.3$, $p < 0.001$, $d = 0.7$, and the second-riskiest option (10:1 cents), $t(39) = 2.1$, $p = 0.04$, $d = 0.3$, as less positive in the pay-one condition compared to the pay-all condition. Furthermore, the difference between the valence ratings for the riskiest option (11:0 cents) between the two conditions (pay-all minus pay-one) was positively correlated with the difference between the proportion of risky decisions between the conditions (pay-all minus pay-one), $r = 0.35$, $p = 0.03$. In other words, the less positively the participants rated the riskiest option in the pay-one condition, the less risky were their decisions in that condition.

Electrophysiology: FRN and reward positivity amplitudes

A within-subject ANOVA on FRN amplitudes with task condition (pay-one, pay-all) and monetary feedback (positive, negative) as factors revealed a significant main effect of feedback ($F(1,39) = 41.0$, $p < 0.001$, $\eta^2 = 0.03$), indicating more negative amplitudes for negative feedback than for positive feedback, and a statistically significant interaction of condition and feedback ($F(1,39) = 4.1$, $p = 0.05$, $\eta^2 = 0.003$). As

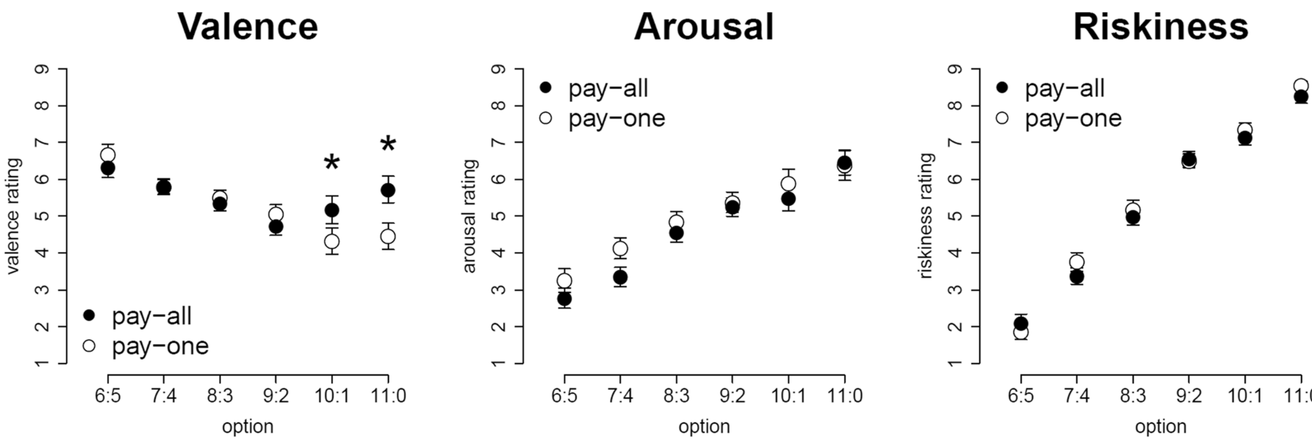

Figure 3. Valence, arousal and riskiness ratings for all risk options and both conditions. Risky options were rated more positively in the pay-all condition. Error bars indicate standard errors

indicated in Figure 4, FRN amplitudes were less affected by the valence of the feedback in the pay-one condition compared to the pay-all condition. Figure 5 illustrates the interaction effect on FRN mean amplitudes. We conducted post-hoc *t* tests on the effect of payment conditions on positive and negative feedback separately. The difference between payment conditions was $t(39) = 1.8$, $p = 0.08$ for positive feedback and $t(39) = 0.3$, $p = 0.8$ for negative feedback. The post-hoc tests revealed that the interaction effect was not driven by the effect of payment conditions on either positive or negative feedback alone. In order to isolate the interaction effect using a standard difference wave approach (Holroyd & Krigolson, 2007; Sambrook & Goslin, 2015), we computed the reward positivity as the difference between the ERPs to positive minus negative feedback stimuli. The reward positivity was smaller in the pay-one condition than in the pay-all condition, $t(39) = 2.0$, $p = 0.05$, $d = 0.3$ (mean reward positivity amplitude in the pay-one condition = 1.7 µV, SE = 0.5 µV; mean reward positivity amplitude in the pay-all condition = 3.1 µV, SE = 0.6 µV). The scalp distribution of the reward positivity was frontal-central (Figure 6), confirming the identification of this component as the reward positivity.

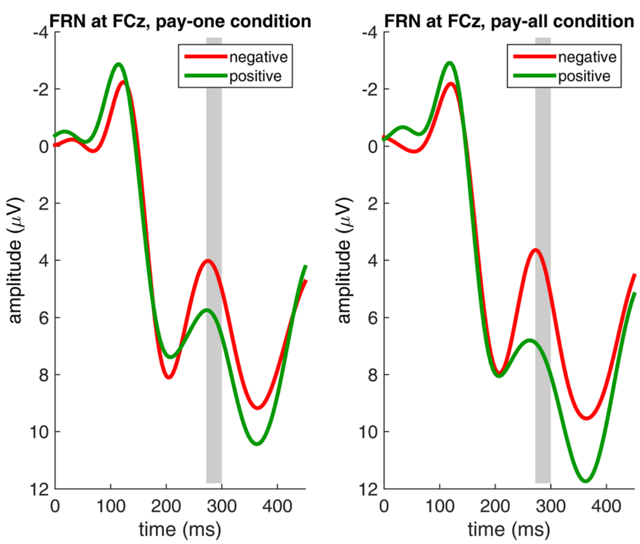

Figure 4. ERP amplitudes for negative monetary feedback (red) and positive monetary feedback (green) in the pay-one condition (left) and the pay-one condition (right). Grey areas indicate the time window for FRN/reward positivity analysis.

Only first condition analyzed The difference of reward positivity amplitudes was not statistically significant when only the data for the first block of every participant were analyzed, $t(36.84) = 1.9$, $p = 0.07$, $d = 0.6$ (mean reward positivity amplitude in the pay-one condition = 1.8 µV, SE: 0.5 µV; mean reward positivity amplitude in the pay-all condition = 3.9 µV, SE: 0.6 µV).

Correlation reward positivity and risk behavior

The difference in reward positivity amplitudes between conditions (pay-all minus pay-one) was associated with the difference in risky behavior between conditions (pay-all minus

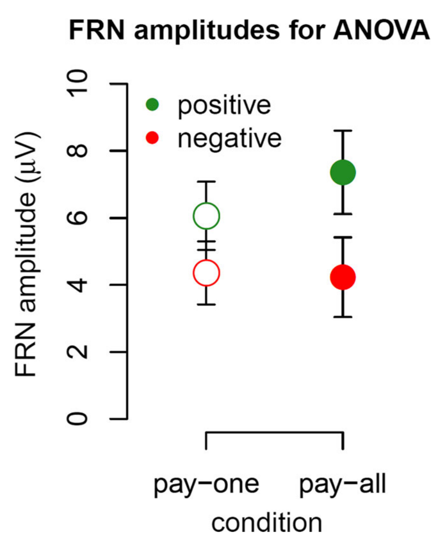

Figure 5 Mean FRN amplitudes with standard errors, illustrating the significant interaction of payment condition and monetary feedback

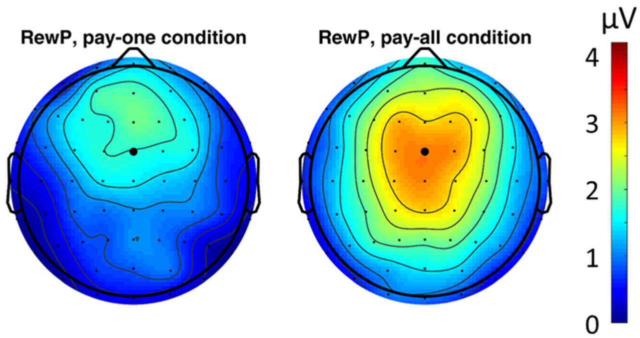

Figure 6 Scalp distribution of the reward positivity (RewP), computed as difference in FRN amplitudes (positive feedback minus negative feedback), in the pay-one and the pay-all conditions

pay-one), $r = 0.37$, $p = 0.02$ (Figure 7). In other words, participants with smaller reward positivity amplitudes in the pay-one condition also selected the risky choices less often in the pay-one condition compared with the pay-all condition.

P300 amplitudes

Finally, a within-subjects ANOVA on P300 amplitude with task condition (pay-one, pay-all) and monetary feedback (positive, negative) as factors revealed a significant main effect of feedback, $F(1,39) = 32.9$, $p < 0.001$, $\eta^2 = 0.04$, indicating higher P300 amplitudes for positive feedback (M: 12.6 µV, SE: 0.9 µV) than for negative feedback (M: 10.3 µV, SE: 0.8 µV) (Figure 8). The main effect of condition did not reach significance, $F(1,39) = 2.4$, $p = 0.1$, $\eta^2 = 0.01$, as well as the interaction

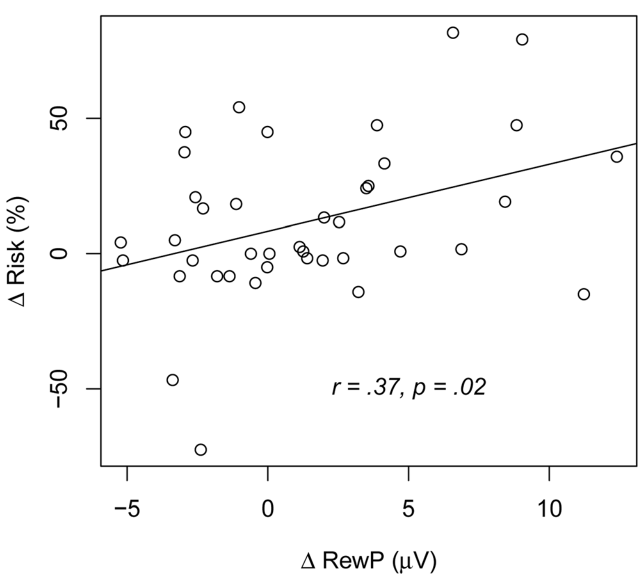

Figure 7 Reduced reward positivity amplitudes in the pay-one condition compared with the pay-all condition are significantly associated with fewer risky choices in the pay-one condition compared to the pay-all condition. ΔRewP indicates the difference in reward positivity amplitude between the two conditions (pay-all minus pay-one), and ΔRisk indicates the difference between the percentages of risky decisions between the two conditions (pay-all minus pay-one)

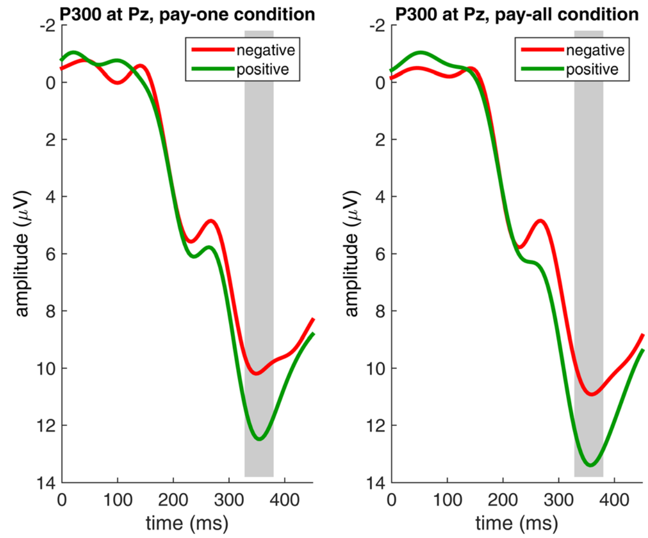

Figure 8 ERP amplitudes for negative monetary feedback (red) and positive monetary feedback (green) in the pay-one condition (left) and the pay-one condition (right). Grey areas indicate the time window for P300 analysis

effect between feedback and condition, $F(1,39) = 0.3$, $p = 0.6$, $\eta^2 = 0.00$. The scalp distribution of the component was parietal, consistent with its identification as the P300 (Figure 9). Critically, in contrast to the reward positivity, the main effect of condition was not statistically significant ($p = 0.1$).

The number of trials to quantify the reward positivity and P300 amplitudes in the different conditions were as follows: positive feedback/pay-one: M = 33.5, SD = 4.7 (range: 22-46); positive feedback/pay-all: M = 32.1, SD = 5.0 (range: 20-42); negative feedback/pay-one: M = 32.4, SD = 4.8 (range: 24-44); negative feedback/pay-all: M = 32.1, SD = 4.7 (range: 22-43). These numbers meet the recommendation by Marco-Pallares et al. (2011) for at least 20 trials to measure a stable FRN. Please note that the number of trials did not allow for further differentiating the ERP results according to the five presented option combinations.

Discussion

Risk behavior is the main dependent variable in economic paradigms on risky decision-making, where it is assumed that participants base each decision on the expected reward it will elicit. Typically, participants' behavior is assessed through a series of trials, with the winnings paid out at the end of the experiment. To avoid excessive costs, researchers developed the pay-one method, which entails paying out only one randomly selected trial at the end of the experiment. Although this pay-one method is usually treated as equivalent to the pay-all method, in which all of the trials are paid out (De Martino et al., 2010; Levy et al., 2010), the pay-one method is actually riskier, given that a single unfavorable outcome in

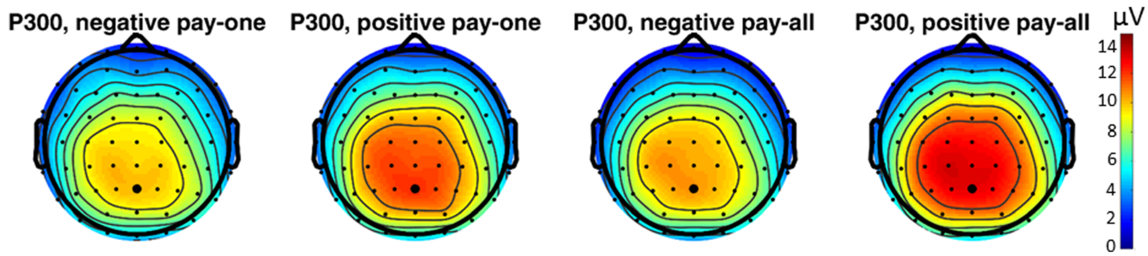

Figure 9 Scalp distributions of the P300 component for negative and positive feedback in the pay-one and the pay-all condition

the experiment can result in the participant leaving the experiment with no winnings at all. Therefore, in line with previous findings (Schmidt & Hewig, 2015), we predicted that participants would select riskier choices less often in the pay-one condition relative to the pay-all condition. Furthermore, we expected that participants would exert more cognitive control in the pay-one condition to keep themselves from choosing the risky option. Based on the literature (Holroyd & Umemoto, 2016; Schmidt et al., 2017), the reward positivity is smaller in situations and populations associated with increased levels of cognitive control. We therefore predicted that reward positivity amplitude would be smaller in the pay-one condition relative to the pay-all condition and that this amplitude reduction would be associated with the difference in risky behavior across participants. These predictions were confirmed, indicating that the two payment methods significantly differ in terms of behavior and neuronal responses.

Importantly, our study ruled out several alternative explanations for these findings. First, these findings cannot result from the fact that the two payment conditions were presented to the participants sequentially. When we analyzed only the payment condition that was presented first, the results remained statistically significant. In fact, the effect sizes were even twice as big in this between-subjects analysis as compared to the within-subjects analysis ($d = 0.8$ vs. $d = 0.4$ for risk decisions, $d = 0.6$ vs. $d = 0.3$ for reward positivity amplitudes), despite excluding half of the data. Therefore, presenting both payment conditions in succession appears to wash out rather than drive the effect.

Second, it might be argued that the reduction in reward positivity amplitude reflects a general diminution of motivation or arousal in the pay-one condition. Two observations argue against this possibility. First, motivation (Weiss, 1965) and arousal (Schmidt et al., 2013) are associated with faster responses. However, response times did not differ between payment conditions in this study, suggesting that the two payment conditions did not elicit different levels of arousal and motivation. Likewise, larger P300 amplitudes are associated with enhanced levels of motivation (Carrillo-de-la-Pena & Cadaveira, 2000), but we did not observe a difference in P300 amplitudes between the pay-one and pay-all conditions, again indicating that motivation levels did not differ between the conditions. Taken together, these considerations suggest that the reduced reward positivity amplitudes in the pay-one condition do not result from lower levels of arousal or motivation.

Third, it is possible that participants perceived the rewards as being less valuable in the pay-one condition relative to the pay-all condition, resulting in a smaller reward positivity in the former compared with the latter. For example, participants might have applied an inaccurate heuristic in the pay-one condition, such as by estimating their possible winning on each trial by multiplying the outcome by 100 instead of by 120. Yet, this interpretation would suggest that participants would rate all possible choices as less positive in the pay-one condition relative to the pay-all condition, which is not what we observed (Figure 3, left panel). Rather, participants rated only the riskiest choices as less positive in the pay-one condition relative to the pay-all condition. Therefore, the relatively smaller reward positivity amplitudes in the pay-one condition appear not to result from differences in reward valuation across the conditions.

We conclude that the choice of payment method has severe consequences on decision-making. Participants in the pay-all condition behave almost risk-neutral, choosing the riskier option in about 50% of trials, which accords with economic theories that predict risk-neutral behavior when stakes are relatively low (Rabin, 2000). Interestingly, prospect theory even predicts riskier behavior in the pay-one condition as low probabilities (1/120) are overestimated to a greater extent than high values (outcomes times 120) are underestimated, according to the formulas presented in Tversky & Kahneman, 1992. In contrast, participants in the pay-one condition are 12% more risk averse. Thus, contrary to the common assumption that paying out only one randomly selected trial is equivalent to paying out all of the trials, both behavior and neural activity in fact differ between the payment methods. Although paying out every trial may be prohibitively expensive when the stakes are high, lower stakes are often sufficient to achieve the intended scientific aim. For example, Cameron (1999) showed that raising the stakes to three times the monthly expenditure of an average participant in the Ultimatum Game did not significantly impact the proposer's behavior. This observation suggests that it is the relative difference between outcomes that mainly affects behavior, not the absolute value of the outcomes.

Our findings are important for both economists and neuroscientists who are interested in optimizing their experimental paradigms. To make absolute statements concerning risk behavior and to obtain strong neuronal responses to rewards, we recommend that participants are paid all of the winnings they receive across all trials in an experiment, given that paying out only one randomly selected trial leads to less risky behavior and reduces neuronal responses to rewards.

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