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Affective response to a lottery prize moderates processing of payoffs and probabilities: An eye-tracking study[4]

Abstract

Expected utility theory posits that our preferences for gambles result from the weighting of utilities of monetary payoffs by their probabilities. However, recent studies have shown that combining payoffs and probabilities is often distorted by affective responses. In the current study, we hypothesized that affective response to a lottery prize moderates processing of payoffs and probabilities. Attentional engagement (measured by the number of fixations in the eye tracking experiment) was predicted by probability, value of an outcome, and their interaction, but only for affect-poor lottery tickets. A corresponding pattern of results was not observed in affect-rich lottery tickets, suggesting more simplified processing of such lotteries.

Keywords

affect, attention, decision-making, eye-tracking, probability

Streszczenie

Deskryptywne modele podejmowania decyzji (oparte na idei maksymalizacji oczekiwanej użyteczności) przewidują, że indywidualne preferencje wobec ryzyka wynikają z użyteczności potencjalnych wy-

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płat pieniężnych oraz prawdopodobieństwa ich otrzymania. Na przykład, zgodnie z przewidywaniami skumulowanej teorii perspektywy decydent wybiera zakład o wyższej wartości iloczynu użyteczności konsekwencji (subiektywnej reprezentacji wypłat pieniężnych) i wag decyzyjnych (subiektywnej reprezentacji prawdopodobieństwa). Ostatnie badania wykazały jednak, że poznawcza ocena oraz integracja wypłat i prawdopodobieństwa jest często zniekształcana przez reakcje afektywne. W obecnym eksperymencie prosiliśmy osoby badane o zapoznanie się z loteriami, w których można było wygrać nagrody budzące różne reakcje afektywne. Jednocześnie dokonywany był pomiar ruchu gałek ocznych. Postawiliśmy hipotezę, wedle której afektywna reakcja wobec nagrody będzie moderowała przetwarzanie wypłat oraz ich prawdopodobieństw. Otrzymane rezultaty wskazują, że poziom zaangażowania uwagowego (mierzonego liczbą fiksacji wzroku) był przewidywany przez prawdopodobieństwo wygrania danej nagrody, jej wartość oraz interakcję tych czynników. Związki te zachodziły jednak tylko dla loterii, które nie wywoływały reakcji afektywnych. Podobnego wzorca wyników nie zaobserwowano w przypadku loterii silnie afektywnych, co sugeruje bardziej uproszczony proces przetwarzania takich problemów decyzyjnych. Wyniki naszego badania są kolejnym dowodem na to, że procesy decyzyjne i ocena ryzyka w dużym stopniu zależą od intensywności reakcji afektywnych.

Słowa kluczowe

emocje, uwaga, podejmowanie decyzji, eye-tracking, prawdopodobieństwo

Introduction

Expected utility theory (von Neumann & Morgenstern, 1944) as well as its prominent descriptive alternatives (e.g., cumulative prospect theory, Tversky & Kahneman, 1992) posit that a decision-maker combines probabilities and consequences into a single "measure of value" (Starmer, 2000). That is, a rational choice is a result of the trade-off between alternatives made by weighting the utilities of consequences by their probabilities and by summing weighted outcomes across each alternative. For instance, an individual should prefer a gamble over a sure option when the expected utility of the former is higher. However, recent studies have demonstrated that accurate decisions can also be made using simple and fast heuristic processes that do not involve weighing and summing of utilities (e.g., priority heuristic, Brandstätter, Gigerenzer, & Hertwig, 2006). Moreover, it has been shown that efficient combining of the numerical characteristics of a lottery (i.e., probabilities and payoffs), as postulated by the expected utility theory, is often distorted by affective reactions to an outcome (Rottenstreich & Hsee, 2001). In this study, we address the question regarding differences in processing of probabilities and payoffs in cases of affect-rich and affect-poor outcomes. Specifically, we have employed eye-tracking methodology to investigate how information about payoff and probability is acquired in simple monetary lotteries and whether this process is moderated by the affective responses elicited by a lottery prize.

Despite a long tradition in decision sciences according to which the decision-making process is purely cognitive, a growing body of evidence has been accumulated in the last few decades to show the crucial role of feelings and emotions in judgment and decision-making. Slovic, Finucane, Peters, and MacGregor (2007) argue that positive or negative affective responses to a stimulus serve as crucial information influencing the decision-making process. In this paper, we refer to *affect* defined by Slovic et al (2007) as "the specific quality of 'goodness' or 'badness' (i) experienced as a feeling state (with or without consciousness) and (ii) demarcating a positive or negative quality of a stimulus" (p. 1333). In this definition, affect is a part of the stimulus and its mental representation. That is, mental images of some objects or stimuli (e.g., a lottery prize) are tagged with affect, to which one could refer when making a judgment or decision. For example, in case of lottery prizes eliciting intense affective responses (i.e., affect-rich lotteries), a decision maker can rely on affect that serves as a cue simplifying a judgment and decision-making process. On the other hand, when no affective cue is provided (i.e., in affect-poor lotteries), a decision maker is more likely to use different information (e.g., calculating expected value using payoff and probability information).

One of the most important theoretical models linking emotions and decision-making – the risk-as-feelings hypothesis (Loewenstein, Weber, Hsee, & Welch, 2001) – assumes that cognitive integration of numerical characteristics of the decision problem (payoffs and probabilities) through expected utility calculus can be moderated by affective responses to a stimulus. Rottenstreich and Hsee (2001) documented a larger insensitivity to changes in the probability scale for affect-rich outcomes (a $500 coupon that could be redeemed toward expenses associated with holidays in Europe) than for affect-poor outcomes (a $500 coupon that could be used toward tuition payments at the university). A similar effect (i.e., a larger insensitivity to changes in numerical features of risky prospects) emerges when the magnitude of a stimulus (e.g., monetary value) is evaluated by feelings rather than by calculation (Hsee & Rottenstreich, 2004). In the same vein, it has recently been shown that people pay less attention to probability information in affect-rich than affect-poor decision problems what results in suboptimal choices (Pachur & Galesic, 2013). Importantly, in cases of affect-poor decision problems, people base their choices on compensatory strategies – they use weighting and summing processes to make the trade-off between payoffs and probabilities within each alternative (Pachur, Hertwig, & Wolkewitz, 2014). On the other hand, affect-rich decision problems lead to the incorporation of less effortful non-compensatory heuristic strategies: People pay less attention to probabilities and make more dimension-wise comparisons between alternatives. Following this line of results, affect-poor lotteries should lead to processing of payoffs and probabilities in a more expected utility-based calculation (interaction of payoffs and probabilities) whereas affect-rich lotteries should be related to processing based on simple heuristics (e.g., separate processing of payoffs and probabilities).

Recent research has shown that eye-tracking measures, such as the number and time of fixations, are related to the level of information processing (Horstmann, Ahlgrimm, & Glöckner, 2009) and the amount of attentional resources engaged in this processing (Fiedler & Glöckner, 2012). Furthermore, numerical characteristics of a lottery (i.e., probability, value of an outcome, and interaction between them) were predictive of the number of fixations on the favored gamble (Fiedler & Glöckner, 2012). Nevertheless, conclusions drawn from these studies are based only on emotionally neutral lotteries.

In this paper, we were interested in investigating the eye-movement pattern of payoff and probability acquisition at the initial stage of a decision-making process. That is, we expected differences in spontaneous payoff and probability information acquisition during the passive inspection of affect-rich and affect-poor lottery tickets. Our main hypothesis is that the process of integrating information about probabilities and values would be moderated by the strength of subjective ratings of affective responses to a lottery prize: Participants would pay more attention to integrate values and probabilities, but only in the case of affect-poor lotteries, whereas affect-rich lotteries would alter the integration process.

Materials and Methods

Participants

Twenty-seven undergraduate psychology students (71% females, age range from 19 to 28 years) took part in this study in exchange for course credits. All participants had normal or corrected-to-normal vision and gave informed consent before the experiment. Data from two participants were not submitted to further analysis because of an excessive gaze deviation in the eye-tracking calibration procedure (> 1.0º).

Materials and apparatus

Lottery tickets. Based on a pilot study in which 30 judges rated the intensity of affective responses evoked by 28 lottery prizes, eight lottery tickets were selected (Table 1). Each ticket was crossed with six probability levels (1%, 2%, 5%, 95%, 98%, 99%) and assigned to one of four monetary values (30 PLN, 60 PLN, 150 PLN, 250 PLN). We used these probability levels due to the shape of the probability weighting function (Tversky & Kahneman, 1992) which assumes the highest deviations from linear probability weighting at the endpoints of the probability scale. To avoid the possibility that some lottery tickets would be subjectively priced as more expensive due to their affective meaning or attractiveness, the assignment of monetary values was counterbalanced between affect-rich and affect-poor lottery prizes. In total, 48 different tickets: 6 (probabilities) x 4 (monetary values) x 2 (affect-rich/poor prizes) were used in this study.

Table 1. Lottery tickets with mean ratings of the intensity of affective reactions.

	Mean subjective ratings of affective response intensity (SD)	Monetary value in the eye-tracking study
1. Ticket to a concert by your favorite band	6.7 (3.0)	30 PLN
2. Newest album of your favorite band/artist	5.7 (2.5)	60 PLN
3. Romantic dinner with your partner in a restaurant	7.0 (2.4)	150 PLN
4. Shopping in your favorite store/boutique	8.0 (1.8)	250 PLN
5. Warm socks	3.1 (2.6)	30 PLN
6. Two coffee mugs with logo	1.7 (1.4)	60 PLN
7. Entrance to a construction industry exhibition	1.6 (1.4)	150 PLN
8. Participation in a labor law course	2.7 (1.9)	250 PLN

Eye movements recording. We presented stimuli using Experiment Center software (Version 3.4; SensoMotoric Instruments, Teltow, Germany) on a 475 × 300 mm monitor (resolution = 1024 × 768 pixels). Eye movements were registered using an iView RED250 eye tracker (SensoMotoric Instruments) that recorded binocularly at 120 Hz. Data were recorded using iView X 2.7 software, following five-point calibration plus validation (average measurement accuracy = 0.62°; *SD*= 0.49°).

Procedure

Participants were seated individually in a laboratory room approximately 60 cm from the monitor screen. We informed participants that they will be presented with several lottery tickets which they could win or buy for themselves in a hypothetical lottery (e.g., a ticket for a concert, two coffee mugs or a voucher for a romantic dinner). In each trial, participants were instructed to pay attention to a short description of the lottery ticket displayed on the top of the screen for 4000 ms. Next, a black fixation cross appeared in the center of the screen for 500 ms and was immediately followed by information about the probability of winning and the value of the lottery outcome presented in two separate white rectangles (subtending 5.7º and 3.8º of visual angle) located at a distance of 8.6º on the left- and right-hand side of the fixation point. In order to balance the effect of a side, each ticket was presented twice: (1) with the probability level on the left side and value on the right side, (2) inversely, with value on the left side and the probability level on the right side. After 4000 ms, a blank screen appeared, and an inter-trial interval of 1000 ms preceded the next trial that started automatically (for details see Figure 1). The study consisted of 96 trials (48 different lottery tickets varying in probability and value x 2 sides of the probability-value presentation). Three technical breaks for the recalibration of the eye tracker were included. After completing the eye-tracking measurement, participants were asked to rate the intensity of affective reactions evoked by lottery tickets and prizes presented in the study using a 10-point scale (from 1 – *no affective reactions* to 10 – *very strong emotions*). The whole procedure lasted approximately 20 minutes.

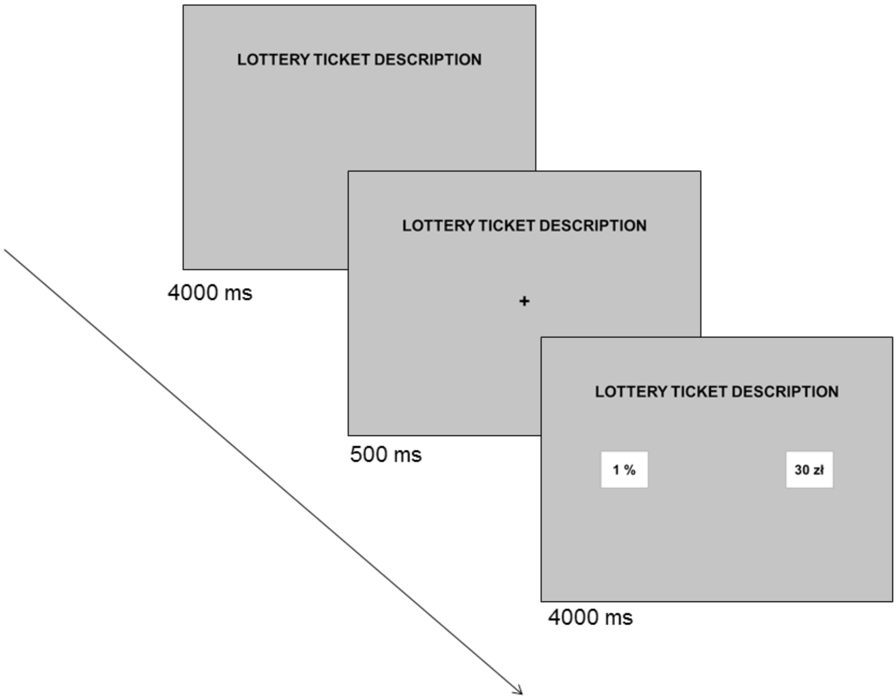

Figure 1. Schematic illustration of the sequence of events in each trial.

Results

Eye Movements Data Preprocessing

Eye-tracking data were analyzed using Begaze 3.4 software (SensoMotoric Instruments). Two identically sized (6.6º x 4.7º of visual angle) oval non-overlapping areas of interest (AOIs) covered the values and probabilities assigned to each lottery ticket. Analyses were conducted using two measures indicative of the amount of attentional resources engaged in information processing (the number of fixations and total dwell time, Holmqvist et al., 2011). Fixations were identified as eye-gaze events of a minimum duration of 80 ms and a maximum dispersion of 100 pixels. The dwell-time variable was defined as total time spent in the AOIs. Square root transformation was performed to normalize skewed distribution of a total dwell time in the AOIs. The overall number of 4,800 trials (96 lotteries x 25 subjects x 2 AOIs) was analyzed in this study.

Linear Mixed-effects Models Predicting Processing of Lottery Tickets

The statistical analyses and results reported below are based on linear mixed-effects models performed using the lme4 package (Bates, Maechler, Bolker, & Walker, 2014) version 1.1-7 run on R statistical computing software (2014) version 3.1.2. Fixed effect significance was tested with the lmerTest package version 2.0-20 (Kuznetsova, Brockhoff, & Christensen, 2014).

To investigate the fixed effects of the subjective intensity of affective responses to a lottery prize (i.e., affect), the numerical characteristics of lottery tickets (i.e., probability and value) and their interactions on information processing, two separate linear mixed-effects models were used with the number of fixations and dwell time in the AOIs as dependent variables and subjects, and AOI (value and probability) and AOI presentation side (left and right) as random effects (Table 2).

In both models, the number of fixations and dwell time in the AOIs increased with higher value and probability. Interestingly, we found a significant interaction of affect, probability and value in predicting the amount of fixations (b = -0.0003, t = -2.09, p = .037). Following Bauer and Curran's (2005) guidelines, we used a 'pick-a-point' approach to probe this three-way interaction. The continuous moderator variable (affect) was dichotomized to probe the conditional effects for relatively affect-poor (M - SD) and affect-rich (M + SD) lottery prizes. Two additional models with probability and monetary value as fixed effects were fitted separately for affect-rich and affect-poor lottery tickets. In cases of affect-rich lottery tickets, none of the main effects of predictors or their interactions were significant. Critically, we found a significant interaction of numerical characteristics of a lottery when affect-poor tickets were taken into account. Specifically, the number of fixations increased with higher levels of probability and monetary value of an outcome (b = 0.003, t= 2.67, p = .008).

Table 2. Linear mixed-effect model predicting the number of fixations and dwell time (square root transformation) in the area of interest from the subjective ratings of the intensity of affective responses (Affect), the monetary value of the lottery outcome (Value), probability (Prob.), and their interactions. Predictors were mean-centered before introducing them to the models

	Number of fixations			Dwell time		
Coefficient	Estimate	Std. error	t value	Estimate	Std. error	t value
Fixed						
Intercept	291.50	16.400	17.77**	34.310	1.8400	18.64**
Affect	0.1198	0.6939	0.17	−0.0295	0.0504	−0.59
Value	0.0494	0.0250	1.97*	0.0031	0.0018	1.73†
Prob.	0.1113	0.0450	2.47*	0.0058	0.0033	1.79†
Affect*Value	0.0010	0.0079	0.12	0.0003	0.0006	0.48
Affect*Prob.	0.0174	0.0138	1.26	0.0004	0.0010	0.36

	Number of fixations			Dwell time		
Coefficient	Estimate	Std. error	t value	Estimate	Std. error	t value
Value*Prob.	−0.0002	0.0005	−0.29	0.0001	0.0001	−0.23
Affect*Value*Prob.	−0.0003	0.0002	−2.09*	0.0001	0.0001	−1.23
Random effect	Variance			Variance		
Subject	4049.36			20.63		
Presentation side	76.55			0.67		
AOI type	128.51			4.42		
Residual	21621.64			113.94		

Note: † p < .1 * p < .05 ** p < .01

Discussion

Results of our study revealed that affect (here defined as the subjective ratings of the intensity of affective responses to a lottery prize) moderated the processing of the numerical characteristics of lotteries (i.e., payoffs and probabilities). Similarly to previous studies (Fiedler & Glöckner, 2012), the amount of attentional resources engaged in processing lotteries (measured by the number of fixations and dwell time in the present study) was positively associated with the probability and value of an outcome. Moreover, we found a significant interaction between probabilities and payoffs predicting the number of fixations, which suggests their integration, but only in processing of affect-poor lottery tickets. A corresponding pattern of results was not observed for affect-rich lottery tickets.

Our study is the first to demonstrate that the amount of attentional resources (measured by eye-tracking technology) engaged in cognitive processing of lotteries is moderated by their affective meaning. More fixations and longer dwell time in the payoff and probability AOIs suggest that participants paid more attention to this information during lottery inspection. We showed that attention to lotteries was sensitive to changes in the probabilities and monetary values assigned to lottery tickets, as is predicted by the multiplicative expected utility calculus. However, affect elicited by a lottery outcome moderated this interaction, suggesting that even if monetary values and probabilities are kept constant, affective reactions exert an influence on processing information about risky prospects (which is in line with the risk-as-feelings hypothesis, Loewenstein et al., 2001). Nevertheless, the psychological mechanism underpinning this process is less clear. There are at least two possible theoretical explanations for our findings. First, it is plausible that affect-laden imagery diminished sensitivity to variations in the probability scale (Rottenstreich & Hsee, 2001; Traczyk, Sobkow, & Zaleskiewicz, 2015) by changing the way in which a decision-maker translates objective probabilities to decision weights, i.e., the shape of the probability weighting function (Fulawka & Traczyk, 2014; Petrova, van der Pligt, & Garcia-Retamero, 2014; Traczyk & Fulawka, 2016). With regard to the present study, mental images of lottery outcomes which are tagged by affect may contribute to a higher curvature of the non-linear inverse S-shape probability weighting function. As a result, when making a decision under intense affect, a decision-maker is able to detect changes only at the endpoints of the probability scale, i.e., from impossibility (0%) and to certainty (100%), while being insensitive to probability variations in midrange values (Gonzalez & Wu, 1999; Tversky & Kahneman, 1992). Second, it has recently been shown that an enhanced arousal level impairs feature binding in working memory (Mather et al., 2006). Assuming that affect elicited by a lottery outcome could increase arousal, we should also expect arousal-induced impairment of working memory performance in this case. Since the multiplication mechanism underlying the efficient combining of probabilities and payoffs to calculate expected utility demands more cognitive resources than comparison-based processing of probabilities and payoffs separately (Dehaene et al., 1996), affect-driven impaired working memory performance should guide choices to less effortful decision rules. Future studies are still needed to directly compare and test these two possible psychological mechanisms underpinning the decision process.

It seems that an interesting direction for future studies would be to include measures of individual differences in ability to comprehend and transform numerical information (i.e., numeracy; Peters & Bjalkebring, 2014). Crucially, people high in numeracy more frequently and efficiently incorporate probability information in the decision-making process (Peters et al., 2006), which results in more rational choices (Pachur & Galesic, 2013) probably through drawing more precise affective meaning from numbers (Petrova et al., 2014). To date, little is known about the exact link between attentional engagement to numerical information and numeracy. For instance, we could put forward a hypothesis according to which people high in numeracy (in comparison to low-numerate individuals) are more likely to base their choices on compensatory strategies. In the light of our results, they ought to integrate probability and payoff information more frequently, irrespectively of affective response to the lottery prize. On the other hand, such people are likely to adaptively use choice strategies and switch to fast and frugal heuristic processing (Traczyk, Sobkow, Fulawka, Kus, Petrova, & Garcia-Retamero, under review). Further research testing such predictions would be useful in understanding our results and, more importantly, in helping less numerate individuals to make accurate decisions.

The results of this study can also be used to gain insight into mechanisms of the gambling phenomenon. Therefore, they can be applied practically in developing more effective therapies for people addicted to gambling. Moreover, in line with our results, it seems important to construct and promote new, simplified methods of risk communication in affect-rich situations (e.g., speeding, gambling or choosing medical treatment) to help people make better everyday decisions.

To summarize, the current study demonstrated that the amount of attentional resources (measured be the number of eye fixations) engaged in the initial integration of probabilities and payoffs is moderated by the intensity of affective responses to a lottery prize. These results extend previous findings and offer a novel perspective on studying the role of affect in the decision-making process.

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