People toss coins with more vigor when the stakes are higher

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Abstract

We trust that the uncertainty regarding the outcome of a coin toss makes it a fair procedure for making a decision. Small differences in the force used to toss a coin should not affect this uncertainty. However, the voluntary movement involved in tossing a coin is subject to motivational influences arising from the anticipation of the value of the outcome of the toss. Presented here are measurements of hand velocities during coin tossing when the outcomes entail monetary gains and losses. Finger position measurements show that hand velocities are proportional to the amount of money at stake. Coin toss movements are faster and larger for higher stakes than for smaller monetary stakes.

Keywords: motor control, decision-making, affect, behavioral economics

Introduction

Animals move faster to acquire larger rewards than to acquire smaller rewards (Kawagoe, Takikawa and Hikosaka, 1998; Choi, Pavan and Shadmehr, 2014). Delays in acquiring a reward decrease the probability of being successful and, since future rewards are temporally discounted, they may also decrease the subjective value of the reward. It has been demonstrated that the vigor of a movement, which is overtly expressed as the reaction time and velocity of the movement, are influenced by motivation effects arising from the cost or value of the outcome (Turner and Desmurget, 2010). For example, people show faster eye saccades when they are in more rewarding environments (Haith, Reppert & Shadmehr, 2012) and monkeys make faster arm movement to higher reward targets (Opris, Lebedev & Nelson, 2011). It is hypothesized that the purpose of the larger vigor observed in movements for greater rewards is to increase the probability of success and decrease the time to acquire the reward (Choi, Pavan and Shadmehr, 2014; Turner and Desmurget, 2010; Guitart-Masip, Duzel, Dolan & Dayan, 2014). An open question is whether this vigor effect would be observed even when it is independent of the movement outcome. Such as in situations where changes in movement vigor do not influence the probability or timing of reward acquisition. For example, when tossing a coin for a monetary wager.

Coin tosses are used in sporting events such as cricket and American football to determine which team goes first. They are even used to settle the results of tied mayoral races in accordance with the law of many US states. When a game of chance is used to make a decision, the assumption is that there is sufficient uncertainty about the outcome to make the procedure fair. Even though coin tosses are the textbook example of uncertainty, coin tosses are entirely deterministic physical processes. The coin trajectory can be predicted from initial conditions with Newton's laws of motion and Euler's equation for rigid body dynamics. However, small differences in the initial velocity and spin of the coin result in different outcomes. Mahadevan and Yong (2011) performed a phase space analysis of the probability distributions of coin outcomes as function of initial spin and vertical speed. The analysis reveals a high sensitivity of the coin's outcome to its initial spin and vertical velocity. We can assume that most coin flippers have no knowledge of how initial toss conditions map onto outcomes. Stewart (2014) suggested that perhaps the precision of human hand control is not accurate enough to reliably affect the outcome given the thin alternating regions in the phase space between heads and tails. Perhaps the smallest possible motor error in voluntary movement to toss a coin is spread across two or more outcome distributions in the phase space. Considering this possibility, one might conclude that the coin toss procedure itself is deterministic, but the initial conditions are random. Therefore, coin tossing is a special case where the movement vigor is independent of the outcome.

The outcomes of bodily movements produce the substantive consequences of behavior. It is therefore not surprising that organisms have adapted to perform movements precisely and efficiently. The escape vectors of cockroaches (Domenici, Blagburn & Bacon, 2008), the foraging paths of bees (Reynolds et al., 2007) and the reaching arm movements of humans (Flash & Hogan, 1985) all demonstrate optimal or near optimal movement performance. Experimental measures of human movement performance are predicted well by mathematically optimal models of movement behavior (Körding and Wolpert, 2006; Todorov and Jordan, 2002; Dam and Körding, 2009).

The success of optimal models for understanding movement stands in contrast to the descriptive models used to understand human judgment and decision-making. People demonstrate a variety of persistent and systematic biases in many domains of decision-making. A large body of research has shown that people are particularly prone to error during economic decisions. For example, in many situations people are *loss averse*, where they are about twice as unhappy with a monetary loss than they are happy with an equal magnitude monetary gain (Kahneman and Tversky, 1979). This leads to errors in decision making, such as a greater willingness to take a risk when potential losses are looming than when there is an equal potential gain to be had. Deviations from normative models have been traditionally attributed to distortions of judgments of value and probability made by the decision maker. Interestingly, the irrational distortions observed in economic decision tasks are only partially present in mathematically equivalent motor tasks and demonstrate qualitatively different judgements of probability (Wu, Delgado and Maloney, 2009). This suggests that decision makers use information about the outcome value and probability differently when making economic decisions than when making motor decisions.

Tossing a coin for a monetary stake combines a voluntary movement with a cognitive evaluation of the outcome. For a person that has learned the motor skill of coin tossing, the movement is simple and involves little effort or deliberate planning. The hypothesis here is that the vigor of coin tosses will be affected by both the amount and valence (loss or gain) of the outcome. Specifically, the prediction is that the velocity and size of the coin tossing movements would be larger when the monetary stakes where higher. Additionally, considering loss aversion, movement velocities should be roughly twice a high when tossing a coin for a potential loss than for a potential gain of equal value.

Figure 1: An illustration of the coin toss movement made by participants during the experiment. Tosses were made with the coin placed on the back of the hand in a palm down position. This procedure for coin tossing increased the accuracy of measurements of hand velocities by allowing the tracking of individual finger tips.

Method

Participants

The experimental protocol was approved in accordance with Indiana University's policy statement on the use of human participants. Informed consent was obtained from fifty right-handed participants (21 male, 29 female). Participants were compensated a $5 stipend prior to beginning the experiment. In addition to this stipend, participants were compensated according to the outcomes of the coins tosses as described below.

Design

Each participant tossed a standard US quarter dollar coin with their dominant hand. The hand movements of the toss were performed above an instrument designed to measured finger and hand position. There were six conditions resulting from a 2 (valence of outcome: loss or gain) X 3 (amount: 10¢ or 25¢ or $1) factorial within-subjects design. The dependent variable was the vertical velocity of the right hand during the coin tossing movement.

Materials

A Leap Motion Controller was used to measure hand movements during the experiment. The controller uses three infrared LED emitters and two cameras to track finger and hand position, directions of movement and velocities. The device's resolution is below 0.78 mm of movement (Oliveira & Andrade, 2015). The cameras capture more than 290 frames a second from which position, velocity and direction of movement are computed to provide a sampling rate of 145Hz.

Procedure

The experiment was designed to measure whether the stakes of a coin toss would influence how the coin is tossed. At the beginning of each trial participants placed a quarter on the back of their dominant hand near the fingernails while standing. Participants were instructed to position their dominant arm with their elbow bent at 90 degrees and with their hand extended in the pronated position (palm down). The device was attached to a tripod that was adjustable vertically in height and placed 5 cm below the hand so that the tossing movement would take place within its effective workspace. This was done to assure accurate measures of hand position.

Figure 1 illustrates how the coin tosses were performed. Participants tossed the coin by accelerating it vertically into the air and then allowing the coin to bounce on the floor. The result was read from the coin as it lay on the floor. Each participant performed 30 coin tosses. Altogether 1378 coin tosses were measured from 1500 trials. The missing trials are due to participants performing the movement outside the device's effective workspace. Although some participants had a higher tendency to perform the toss outside of the devices' effective range, the missing trials are randomly distributed across conditions with 23, 24, 31, 16, 24 and 34 trials missing data from conditions +10¢, -10¢, +25¢, -25¢, +$1, and -$1 respectively

During each trial the outcome of a single coin flip determined a monetary gain or loss to the participant. Half of the trials were gain conditions, where the participant stood to make money contingent on the outcome of the coin toss. During the other 15 trials, participants faced a potential monetary loss. The outcomes of all coin tosses were added to determine the total stipend for participation with a mean stipend of $5.67 ranging from $5 to $9.20. The presentation of trial condition was randomized and fully balanced with

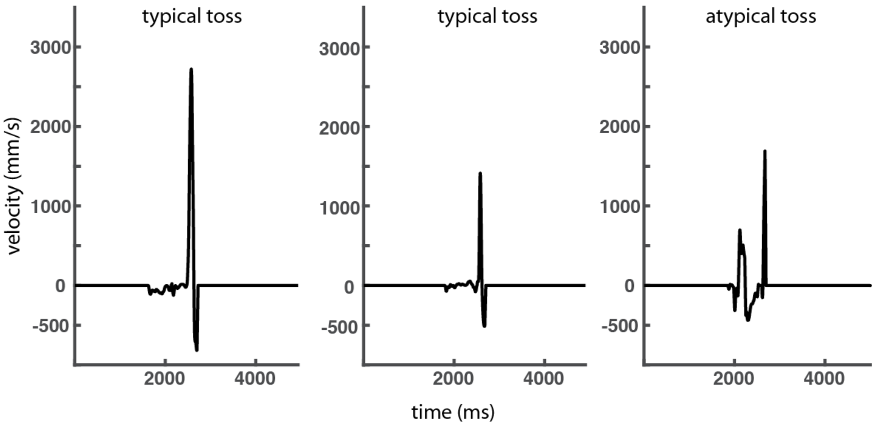

Figure 2: Hand velocities during three coin tosses. The two graph panels labeled 'typical toss' were chosen to represent the most common coin toss velocity profiles. The third panel labeled 'atypical toss' includes a pre-toss preparatory movement. Such pre-movement artifacts were excluded from the statistical analysis by using the maximum velocity as a measure of coin toss velocity.

each condition appearing exactly 5 times during the experiment.

At the beginning of each trial, the participant was informed of the trial condition by text that appeared on a 21' computer screen at a distance of 32 cm from their face. For example, the text: "If you lose this coin flip, you will lose $1" would appear during the -$1 trial conditions. Additionally, the text was read aloud by the experimenter prior to commencing the coin toss movement. Before each toss movement, the participant called the toss, choosing either 'heads' or 'tails' by pressing the corresponding key 'H' or 'T' on a computer keyboard. If the coin landed heads up and the participant called heads, then the toss was regarded as a win. If the coin result did not match the call, the coin toss was regarded a loss. During gain conditions (+10¢, +25¢ or +$1), if the coin toss was won, the monetary amount at stake was added to the total stipend. If the outcome didn't match the call, the stipend remained unchanged. During loss conditions (-10¢, -25¢ and -$1), participants stood to lose the monetary amount if the toss was lost, or leave the stipend unchanged in the case of a match in outcome and call.

The current total monetary stipend amount was displayed on the screen and updated after each coin toss. If the total stipend at the completion of 30 coin tosses was higher than $5, then participants were paid the difference in cash before completing the experiment. On the other hand, if participants finished with a total amount less than $5, they were allowed to keep the $5 show-up stipend. This was done to ensure that participants were not penalized for the outcomes of their tosses. On average, participants received $5.42 (SD = 1.51).

Economic decision making is often studied by measuring preferences between two or more lottery choices (Kahneman and Tversky, 1979). A lottery is a probability of obtaining an outcome that has an explicit value and can be expressed with the notation: [probability(outcome); value(outcome)]. For example, consider which lottery you would prefer: (a) five dollars for sure, or (b) a 50% chance of winning ten dollars and nothing otherwise. This choice between lottery can be expressed as a choice between (1, $5) or (0.5, $10; 0.5, 0), and most people prefer the sure outcome although according to rational choice theory we should be indifferent to the choice. Physically flipping a coin to decide an outcome is analogous to having selected a single lottery choice. If we assume that the procedure used for the coin toss is fair, then the probability will approach 0.5 as the number of tosses increases. For example, if a person cares about the outcome of a coin toss during the beginning of a sporting event, the coin toss lottery can be expressed as (0.5, my team gets the ball; 0.5, the other team gets the ball). How people value different prospects can be estimated by their preferences in lottery selections. The assumption in the current experiment is that the utility assigned to the potential outcome of the coin toss is reflected in the manner in which the movement is made.

Data collection and measures

Position and velocity measurements were collected for 10 seconds after the participant called the toss and indicated that they were going to make the movement. The average duration of the coin tossing movement for all participants across all conditions was 157.37 milliseconds (SD = 65.94), providing an average of 22.81 position measurements per movement. Since the instrument's measurements of fingertip positions are more accurate than for palm position, participants performed tosses with their palm down which allowed for the independent tracking of an average of 3.87 fingertips (SD = 1.23) on each toss. The vertical velocity of the hand was calculated as the mean vertical velocity of all fingertip positions captured by the cameras during the toss.

Results

Figure 3 shows mean hand velocities as a function of time with 95% confidence intervals. The mean hand velocity profiles are similar in shape to typical toss movements. However, hand movements in preparation for the toss are

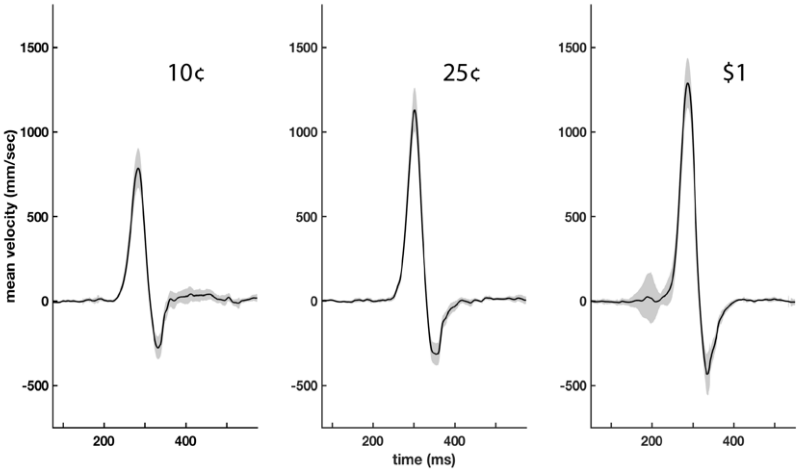

Figure 3: Mean hand velocities with 95%CIs across participants as a function of time. The six conditions are collapsed by amount into three groups: ±10¢, ±25¢ and ±$1.

included in the analysis. In order to quantify the velocity of individual coin tosses, the maximum vertical velocity of the hand was computed for each toss. Analyses using maximum acceleration and integrated velocity across the entire movement produced similar results to those described below.

Overall, the tossing movement is highly conserved across participants as is evident in the aligned and averaged coin tosses displayed in Figure 3. However, there is systematic variance in toss velocities evident in the tendency by some participants to consistently toss the coin with more or less vigor than the average participant.

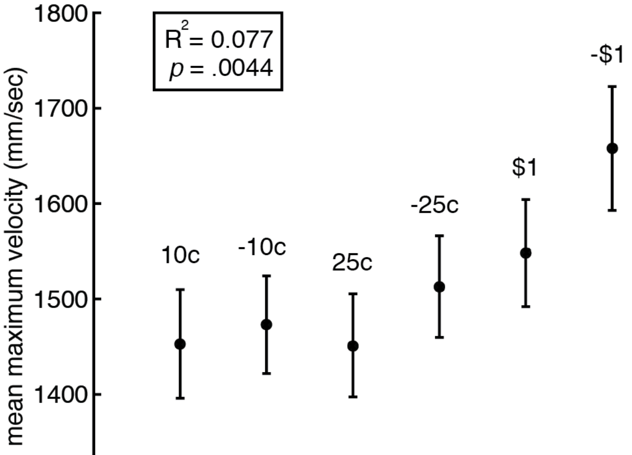

Figure 4: Mean maximum hand velocities with 1±SEM bars for all six toss conditions.

Maximum hand velocities were analyzed using linear mixed-effects regression (LMER) with the lme4 package in R (Bates, Maechler, Bolker & Walker, 2013). LMER allows for the controlling of random factors, such as the systematic variability in toss force between participants. The monetary amounts at stake for each toss were modeled as fixed effects. A main positive effect of monetary value on hand velocities was observed, *F*(1, 1297)=3.82, p = 0.022. Figure 4 shows the mean maximum velocity ± 1 SEM for all six conditions ordered so that an effect of loss aversion is visible. However, the effect of valence (gain or loss) on hand velocity was not significant, *F*(1, 1297)=2.15, p = 0.14. The interaction effect was non-significant, *F*(1, 1297) = 0.35, *p* > .55.

The mean maximum hand velocities for the ± 10¢, ± 25¢ and ± $1 conditions were 1463.17, 1482.23 and 1603.01 mm/sec with 95% CIs [1335.44, 1590.71], [1090.95, 1873.56] and [906.69, 2299.48] respectively. The Cohen's *d* effect sizes for monetary amount on maximum movement velocity were *d* = 0.022, for the difference between ± 10¢ and ± 25¢ conditions, *d* = 0.13, for the difference between 25¢ and ± $1 conditions, and *d* = 0.15 for the difference between the ± 10¢ and ± $1 conditions. Overall, the money at stake explains less than 8% of the variance in the maximum velocity of hand movements.

Discussion

This study was designed to investigate the effects of the anticipation of monetary outcomes on the movements for coin tossing a coin. As hypothesized, larger monetary stakes resulted in higher velocities of the hand during coin flipping. Prospect theory predicts that people are often twice as sensitive to monetary losses than to equal magnitude gains. In the context of coin tossing for a potential loss, prospect theory predicts twice as large an effect of outcome valence than outcome magnitude on movement velocity. This prediction was not observed. One possibility is that the current experiment may lack sufficient statistical power to demonstrate a loss aversion effect on coin tossing movements. However, the results suggest that the hypothesized effect is much smaller than predicted by the results from traditional behavioral economics experiments (Kahneman, Knetsch and Thaler, 1990). Previous studies have demonstrated that voluntary movements are not subject to distortions of value to the same degree as financial decisions as predicted by prospect theory, but are instead more subject to distortions of judgments of probability (Wu, Delgado and Maloney, 2009). Evidence from the current experiment provides further evidence that simple movements are not influenced by the same mechanisms that are involved in making explicit financial decisions.

An impressive analysis of over 2.5 million golf putts of professional golfers at PGA golfing championships demonstrated that golfers putt more accurately when they are behind than when they are leading (Pope and Schweitzer, 2011). The analysis of laser measured golf putts revealed that golfers are more likely to make a shot when they are in a loss frame (i.e. a par putt) than when they are in a gain frame (i.e. a birdie putt). Unlike coin flipping, golf putting is a complex skill that is made possible by a variety of cognitive functions such as attention to task, planning, and explicit decisions about the movement. Pope and Schweitzer (2011) suggested that golfers deliberately consider that hitting the ball too softly may decrease the probability of a success, but nearly guarantee good placement for the subsequent putt, a desired position if one is ahead putting for birdie, but not desired if one is behind putting for bogey. These explicit forecasts of potential outcomes are subject to influences from the current and predicted affective states of the golfer (Kermer, Driver-Linn, Wilson & Gilbert, 2006). However, it is reasonable to assume that no such deliberate movement planning occurs during coin tossing.

Russell (1980) proposed a two-dimensional circumplex model of emotion where emotions are classified according to arousal and valence. Applying this model to the current experiment, the monetary value of the outcome corresponds to the arousal associated with the outcome. Valence corresponds to whether the outcome is a loss or a gain. A large body of research on approach-avoidance motor behavior has shown an effect of emotional valence on the automatic activation of movements (Markman & Brendl, 2005; Lavender and Hommel, 2007 Maxwell & Davidson, 2007). Research has shown that reaction times are quickest for approach movements towards positive stimuli (i.e. high valence) and for avoidance movements away from negative stimuli (i.e. low valence). In these studies, images are most often used to elicit emotions rather than money.

Experimentally manipulating both valence and arousal with image stimuli is difficult, because images that are rated as low valence are typically, if not exclusively, also rated as high arousal. For example, there are no images or sounds rated as low valence and low arousal in the over 1200 stimuli available in International Affective Systems (IAPS and IADS). It remains a possibility that arousal ratings of emotional stimuli may have a larger effect on approach-avoidance movement response times and force than do valence ratings.

The experiment presented here was designed to independently measure the effects of monetary amount and valence on the velocity of coin tossing movements. The results show that the magnitude of the outcome has a small effect on movement vigor. However contrary to prospect theory's prediction, the valence of the outcome has little or no additional effect on the coin tossing movement. This provides further evidence that outcome value is assessed differently during movement planning than during financial decision-making.

Notes

The movement data, MATLAB analysis code and experimental protocol code are available at: `https://www.researchgate.net/project/People-toss-coins-with-more-vigor-when-the-stakes-are-higher`

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