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Neural insensitivity to upticks in value is associated with the disposition effect

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ABSTRACT

The disposition effect is a phenomenon in which investors hold onto losing assets longer than they hold onto gaining assets. In this study, we used functional magnetic resonance imaging (fMRI) to measure the response of valuation regions in the brain during the decision to keep or to sell an asset that followed a random walk in price. The most common explanation for the disposition effect is preference-based: namely, that people are risk-averse over gains and risk-seeking over losses. This explanation would predict correlations between individuals' risk-preferences, the magnitude of their disposition effect, and activation in valuation structures of the brain. We did not observe these correlations. Nor did we find evidence for a realization utility explanation, which would predict differential responses in valuation regions during the decision to sell versus keep an asset that correlated with the magnitude of the disposition effect. Instead, we found an attenuated ventral striatum response to upticks in value below the purchase price in some individuals with a large disposition effect. Given the role of the striatum in signaling prediction error, the blunted striatal response is consistent with the expectation that an asset will rise when it is below the purchase price, thus spurring loss-holding behavior. This suggests that for some individuals, the disposition effect is likely driven by a belief that the asset will eventually return to the purchase price, also known as mean reversion.

Introduction

The disposition effect is a behavioral phenomenon in which investors "sell winners too early and ride losers too long" (Shefrin and Statman, 1985). There is robust field evidence that investors sell shares of stock significantly more often after an increase in the value of the shares, than they do after a decrease in value (Choe and Eom, 2009; Ferris et al., 1988; Grinblatt and Keloharju, 2001; Odean, 1998). This occurs despite the behavior being suboptimal in terms of profit earning (Choe and Eom, 2009; Odean, 1998). In experimental settings, where complex market forces are not present and participants are not experienced investors, the disposition effect still exist (Da Costa et al., 2008; Vlcek and Wang, 2008; Weber and Camerer, 1998). Even when decision-makers are aware that losing assets are more likely to continue falling, they hold onto these assets more than they hold onto rising assets (Weber and Camerer, 1998). These observations suggest that the disposition effect is a common property of decision-making and not simply a product of the stock market or limited to investors.

Several explanations for the disposition effect have been suggested. The most common is preference-based: namely, that people are risk-averse over gains and risk-seeking over losses (Kahneman and Tversky, 1979; Lakshminarayanan et al., 2010; Shefrin and Statman, 1985). Assuming that the purchase price of an asset is the reference point upon which investors judge gains or losses, then risk-aversion over gains would lead to the selling of assets when the value of the shares rise (the less risky option), while risk-seeking over losses would lead to holding assets when the value of the shares fall (the more risky option). This explanation is based on prospect theory, which assumes a value function that is concave over gains, but convex over losses (Kahneman and Tversky, 1979). Although risk-preference is often suggested as the driving force behind the disposition effect, several theoretical papers and experimental studies have questioned whether a preference-based explanation can fully explain the disposition effect (Barberis and Xiong, 2009; Kaustia, 2010; Vlcek and Wang, 2008). Alternatively, the realization utility hypothesis suggests that investors receive utility from the act of realizing a gain or loss, driving investors to sell gains to receive positive utility and hold losses to avoid negative utility (Barberis and Xiong, 2008). Another explanation suggests that investors have an irrational belief in mean reversion (Barberis and Thaler, 2002). This explanation predicts that an investor would hold onto a losing asset with the expectation that it would rise and sell a gaining asset with the expectation that it would fall. Despite it being an important phenomenon in finance, there is no consensus in the behavioral economics literature that mean reversion drives the disposition effect, although some experimental studies have found evidence for such a relationship (Andreassen, 1988; Hung and Yu, 2006). Hence, the question remains as to whether the disposition effect is driven by asymmetric risk-preferences over gains and losses, realization utility, or by belief-related mechanisms such as mean reversion.

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In this paper, we utilize functional magnetic resonance imaging (fMRI) during an asset-trading task to test these alternative theories of the disposition effect. We measured the blood oxygenation level dependent (BOLD) response in valuation regions of the brain during decisions to keep or to sell an asset that followed a random walk in price. A preference-based explanation for the disposition effect would predict correlations between individuals' risk-preferences, the magnitude of their disposition effect, and activation in valuation structures of the brain. A realization utility explanation would predict differential responses in valuation regions during the decision to sell versus keep an asset that correlate with the magnitude of the disposition effect. Finally, if participants believe that the asset price will eventually revert to the mean, we would predict an attenuated ventral striatum response to upticks in value below the purchase price and a greater response to upticks in value above the purchase price for individuals with a disposition effect. The ventral striatum has been shown to signal prediction error, and thus an expectation of a rise in asset price followed by an uptick should result in lessened striatal activity. Conversely, if an expectation of a fall in asset price is met by an uptick, striatal activity should increase. Of these three theories, the fMRI data were most consistent with an irrational belief in mean reversion.

Methods

Thirty-eight participants (18 female; 18–51 years) were recruited from the Emory University campus and completed the asset-trading task. Of this group, thirty-three participants were scanned using fMRI (17 female; 18–51 years). Of the thirty-three scanned participants, we excluded one participant from our imaging model because of excessive motion and five participants because they lacked observations for the regressors of interest. This was due to a high variability in participant behavior that was tied to the number of observations in each of the regressors in our model. All participants were right-handed, reported no psychiatric or neurological disorders, or other characteristics that might preclude them from safely undergoing fMRI. All participants provided informed consent to experimental procedures approved by the Emory University Institutional Review Board. Prior to beginning the experiment, participants were told that they would be paid \$20 for showing up, and \$30 for completing three questionnaires, including the BIS/BAS, EPQR, and a risk-preference worksheet. The total amount of \$50 had to be used in the subsequent asset-trading task, where participants could earn an additional \$50, or lose \$50. Therefore the total possible compensation ranged from \$0 to \$100 (actual \$30–\$75).

Asset trading task

Participants completed 40 trials of an asset-trading task while undergoing fMRI. The main screen of the asset-trading task consisted of a graph with relative value (in dollars) of an asset on the y-axis, and time (in periods) on the x-axis. For each trial, participants were initially forced to purchase an asset worth \$50 using all of the money they earned prior to entering the scanner (\$50). A gray circle at relative value zero and period 10 indicated the purchase point. To make sure that the current decision period was always centered on the screen, each asset had a 10-period history prior to purchase that was different for all 40 assets. Each history was generated in the same manner as the forward asset price trajectory—by generating a random walk beginning at the purchase price, but in this case going backwards for ten periods. After a button press, the asset subsequently increased or decreased in value by \$5 with equal probability.

Participants were then given the choice of keeping the asset for another period, or selling the asset for its worth in that period. If participants chose to keep the asset, it again increased or decreased by \$5 with equal probability after a 3 second delay. A single decision period is shown in Fig. 1 (panel A). To avoid influencing participant decision-making by having a finite number of periods where participants potentially behave differently towards the end of the trial, we implemented an infinite horizon. This was accomplished by using a 'soft' ending, where the trial ended and asset force-sold with a 5% probability each time the participant chose to keep the asset (Camerer and Weigelt, 1993; Noussair and Matheny, 2000). Participants could therefore keep the asset as long as they wanted, keeping in mind that each trial had a 5% probability of ending each time they kept the asset. If participants chose to sell the asset, they earned what the asset was worth in that period. Each sell period was followed by five periods where they saw what trajectory the price would have followed had they of kept the asset. Each time the asset was sold or force-sold, participants saw an outcome screen stating the relative amount that their asset was sold for. The maximum relative value that the asset could reach was $+\$50$, and minimum of $-\$50$. Participants were given full information regarding the determination of asset price and the infinite horizon prior. Participants were verbally tested on the probabilities and independence of the asset pricing, and completed two practice trials prior to the actual asset-trading task.

Note that because the size and probability of an increase or decrease in asset value was always equal and independent across periods, the expected value of keeping the asset was the same as selling the asset at every decision point. Furthermore, because of the random-walk nature of the asset price, there is no optimal selling strategy that maximizes earnings in the task. Therefore, no matter what strategy is taken, participants on average earn a relative value of \$0 across trials (\$50).

Behavioral data analysis

To measure the disposition effect for each individual, we computed the integral of asset value (in dollars) relative to purchase price over time and averaged across all trials. If each asset was held regardless of value and never sold, the average integral would be close to zero because the price of the asset followed a random walk (Fig. 1; panel B). If assets below the purchase price were held longer than assets above the purchase price, then the average integral would be negative (Fig. 1; panel C).

We estimated risk-preference and loss aversion parameters using a method developed by Tanaka et al. (2010). Participants were given three series of paired lotteries. In each series, participants were asked to choose the point at which they would switch from lottery A to lottery B. The expected value of lottery B increased downward in each series. By solving a system of inequalities in which constant relative risk aversion is assumed ($U(x) = x^{\alpha}$), a unique set of risk-preference and loss aversion parameters were estimated for each participant.

To understand the factors that were most important in driving participants' decisions to keep or sell, and thus create an imaging model most relevant to participant behavior, we estimated a mixed-effects logistic regression with "keep" or "sell" for each period as the outcome variable (1 for sell, 0 for keep), five fixed-effects regressors which described local asset price characteristics, and a subject-wise regressor describing the magnitude of a participant's disposition effect. Subject was included as a random-effects factor. The regression took the following form:

$$\mathrm{logit}(\mathrm{Sell}_t) = \beta_0 + \beta_1 \mathrm{Value}_t + \beta_2 \mathrm{Value}'_t + \beta_3 \mathrm{Value}''_t + \beta_4 \mathrm{DE} + \mathrm{interactions}$$

Value_t was the value of the asset at time t (which ranged from -50 to 50 in multiples of 5). Value'_t was the difference in value from time t to $t-1$ (which could carry values -5 or 5). We subsequently refer to value'_t as "delta" throughout this paper. Value''_t was the change in price direction, calculated the following way: $(\mathrm{value}_t - \mathrm{value}_{t-1}) - (\mathrm{value}_{t-1} - \mathrm{value}_{t-2})$. Thus, value''_t can carry values of 10, 0, or -10.