

# Persistence of Beliefs in an Investment Experiment

By

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## Abstract

A number of behavioral finance theories posit that investors adhere to prior beliefs in spite of new information. This paper reports the results of an investment experiment which shows that subjects' inferences are biased by their prior beliefs in a manner that depends on investment outcomes. Specifically, their perception of new information was more positively biased for their prior favored assets when incurring losses than gains. This asymmetric bias may help explain empirical patterns such as loser momentum and suggests modifications to models of belief persistence in markets.

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## Introduction

One of the main hypotheses of behavioral finance is that biased inferences can lead to suboptimal investment behavior and anomalous market pricing. Academic finance is currently faced with the challenge of distinguishing between several potential explanations, both behavioral and rational, for a number of documented anomalies.<sup>1</sup> Laboratory experiments can help distinguish between competing explanations in that they permit the observation of variables that are generally unobserved in market data. For example, a number of investment experiments have attempted to directly observe inferences to study how overconfidence (Glaser, Langer, and Weber, 2003), representativeness (Bloomfield and Hales, 2002), and other sampling biases (Nelson, et al., 2001) affect investment behavior and pricing.

Our experiment also observes inferences related to investments and, in particular, investigates the self-serving persistence of beliefs. One motivation for studying this issue comes from behavioral finance theories which conjecture that investors adhere to prior beliefs in spite of new information. For example, Daniel, Hirshleifer, and Subrahmanyam (1998) posit that the investors overreact to information that confirms prior beliefs and underreact to information that contradicts them, which leads to momentum in asset prices. In addition, behavioral models of overconfidence (Odean, 1998) and conservatism (Barberis, Shleifer, and Vishny, 1998) have the feature that investors adhere excessively to previously formed beliefs.

In our experiment, we test for the presence of several belief persistence biases in a simple investment game. Subjects in our game placed bets on which of two stocks (e.g.,

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<sup>1</sup> For example, there are numerous explanations for momentum in stock prices as documented by Jegadeesh and Titman (1993). Behavioral explanations include Daniel, Hirshleifer, and Subrahmanyam (1998), Barberis, Shleifer, and Vishny (1998), Hong and Stein (1999), and Grinblatt and Han (2005) while Hameed, Hong, and Warachka (2007), Ang, Chen, and Xing (2006), Chordia and Shivakumar (2002), Wu (2002), and Johnson (2002) offer rational interpretations.

Dell or Apple) would have a higher return in the subsequent week. Specifically, they allocated funds to a double-or-nothing bet that their favored stock would outperform the other, and this game was played repeatedly over six weeks. We also asked subjects to forecast their probability of winning this bet in addition to asking them to characterize new information regarding these stocks as good, bad, or neutral if they had observed any. This simplified investment setting allowed us to clearly observe relative disposition toward stocks and the processing of subsequent information.

In this setting, we test for the presence of three self-serving belief persistence biases documented in cognitive psychology whereby people accept favorable information and refute unfavorable information. The first is confirmatory bias which refers to the tendency to accept information that confirms prior beliefs and refute information that contradicts them as documented in studies such as Lord, Ross, and Lepper (1979). The second is that of self-attribution bias whereby people's belief in their own ability persists over time. Namely, people attribute success to ability and failure to bad luck as conjectured in the investment models of Daniel, et al. (1998) and Gervais and Odean (2001). Finally, we test whether either of these biases is impacted by the concept of motivated reasoning (e.g., Kunda, 1987) whereby people passively accept desirable information but actively scrutinize undesirable information in order to contradict it. This tendency applies to both confirmatory bias and self-attribution biases or inferences about external and internal attributes, respectively. Its predictions are more specific, however, implying that distortions will be greater for bad news (losses) than good news (gains).

We hypothesize that subjects should exhibit confirmatory bias such that their news reports for their prior favored stock (i.e., the stock they bet would outperform) should be positively biased while reports for their nonfavored stock (i.e., the stock they bet would underperform) should be negatively biased. We find that subjects' reports were positively biased for only their favored stock and more distorted for losses than gains. If subjects process information rationally, they should report news about their prior

avored stock as being better when winning than when losing the bet since this stock does better, on average, in the former case. In contrast, subjects in our experiment reported significantly better news about their favored stock, on average, when losing than when winning. In addition, they did not report their nonfavored stock as having significantly better news than their favored stock when losing the bet even though the nonfavored stock was outperforming the favored. Overall, our results indicate that subjects engaged in motivated reasoning to justify their prior choice of favored stock, i.e., they actively distorted new information about this stock more during undesirable than desirable outcomes. They did not seem to engage in this biased reasoning regarding the nonfavored stock, however, indicating that they framed their decision as choosing a good stock rather than avoiding a bad one.

In addition, there is evidence that these biases affected not only stated perceptions but also subsequent investment behavior in our experiment. We finally study persistence in subjects' beliefs related to their stock-picking ability and find evidence of biased self-attribution and motivated reasoning in measures based on investment allocation.

These findings are important because they indicate that models of biased belief persistence in investments need to be modified for this asymmetry in biases between wins and losses. In the model of Daniel, Hirshleifer, and Subrahmanyam (1998), for example, investors have a symmetric distortion in response to both desirable and undesirable information. In other words, they overreact to confirming information as much as they underreact to contradictory information, creating equal momentum in positive and negative return directions. Our results indicate that investors' beliefs should be more persistent when losing money so that momentum ought to be stronger for loser than winner stocks. Several papers have documented the fact that momentum is driven primarily by persistence in losers (e.g., Chan, 2003; Kausar, Taffler, and Tan, 2006). Though some studies have argued that this "loser momentum" persists because of short-sales constraints on arbitrageurs (e.g., Ali and Trombley, 2006), others argue that the

profitability of momentum strategies remains economically significant even after accounting for these costs (e.g., Bushee and Raedy, 2005). Our results suggest that motivated reasoning in investments may also contribute to slow incorporation of information for loser stocks.

Our findings may help explain other empirical patterns as well. For example, some researchers have asserted that self-justification in the face of losses makes investors reluctant to sell loser stocks, causing the well-known disposition effect (e.g., Zuchel, 2001). Our finding of motivated reasoning in investment behavior and inferences provides further evidence in support of this hypothesis. Finally, this experiment suggests new predictions related to market patterns. For instance, short-sellers ought to be more reluctant to accept good news than bad about their shorted stocks since this positive news causes them to lose money. Hence, one testable implication of our experimental results is that stocks with higher short interest should exhibit stronger momentum in the positive return direction as a result of short sellers' motivated reasoning.

The remainder of this paper proceeds as follows. Section 1 reviews the related literature. Section 2 outlines the experimental method. Section 3 describes our experimental hypotheses and results while section 4 concludes.

## **1 Literature Review**

To date there are a number of experimental studies which attempt to observe biased inferences and perceptions in a financial investment setting. For example, Bloomfield and Hales (2002) test the Barberis, Shleifer, and Vishny (1998) model of representativeness and conservatism by asking subjects to forecast the next increment of a random walk. Inferences are extracted directly from market prices using the mechanism of Becker, DeGroot, and Marschak (1964) whereby subjects transact at all prices below

(above) their bid (ask). This study confirms that investors overreact to changes preceded by a lack of reversals and underreact to changes preceded by a long period of reversals. Nelson, Bloomfield, Hales, and Libby (2001) use the same mechanism to characterize how information strength and weight impact inferences and confidence in financial markets. Their experimental findings are consistent with Griffin and Tversky (1992) in that subjects are excessively influenced by information strength and insufficiently influenced by its weight. Finally, Glaser, Langer, and Weber (2003) study overconfidence in the prediction of trends by financial professionals and MBA students. They find that both sets of subjects are overconfident in estimating future confidence intervals but are underconfident in providing probability estimates of regimes.

No experiments have yet studied the persistence of inferences in an investment setting in spite of evidence from experimental psychology of excessive adherence to prior beliefs and financial market theories based on these biases. Behavioral models of overconfidence (Daniel, et al., 1998; Odean, 1998) and conservatism (Barberis, Shleifer, Vishny, 1998), for example, have the feature that investors adhere excessively to previously formed beliefs. This adherence generates underreaction to new information and return drift in asset prices. The principal behavioral theory of belief persistence in markets is that of Daniel, Hirshleifer, and Subrahmanyam (1998). Their model posits that the bias of overreacting to information that confirms prior beliefs while underreacting to information that refutes them can lead to momentum in asset prices. The bias in their model specifically takes the form of biased self-attribution whereby people attribute past success to ability and failure to bad luck. This tendency has been documented in numerous psychological studies including Fischhoff (1982), Langer and Roth (1975), and Taylor and Brown (1988).<sup>2</sup> This bias could also equivalently take the form of

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<sup>2</sup> Gervais and Odean (2001) have a dynamic investment model, which studies how self-attribution bias affects investor self-confidence over time.

confirmatory bias, which refers to the process whereby an individual interprets ambiguous evidence as confirmation of his or her hypothesis. Confirmatory biases were first documented by Wason (1960) and have since been studied extensively in the context of processing new information for forming political opinions on the death penalty (Lord, Ross, and Lepper, 1979), the safety of nuclear technology (Plous, 1991), and social stereotypes (Darley and Gross, 1983). Motivated reasoning provides another framework for how both prior beliefs and preferences can distort subsequent inferences, which predicts that people are less critical of information which supports desired or existing beliefs than information which is inconsistent with such beliefs. This framework implies that people exert more effort to distort undesirable than desirable information. While motivated reasoning as a cognitive bias has become an integral part of the psychology literature in studies such as Kunda (1987, 1990), Ditto and Lopez (1992), Ditto, et al. (1998, 2003), it has been largely ignored in the field of behavioral finance.

Our paper is closely related to that of Hales (2006), which studies motivated reasoning in an accounting environment. In his experiment, subjects forecast the earnings of an unknown NYSE firm in which they were exogenously given either a long or short position. Hales' analysis finds that subject forecasts were affected in a manner consistent with motivated reasoning. Namely, their forecasts were more biased, either upward for long positions and downward for short positions, when they faced a loss on their investment position than when they faced a gain. Our experiment differs in several important ways. First, Hales' experiment examines a single-period setting with exogenous positions whereas our experiment simulates actual investment in that subjects have endogenous positions in a multi-period setting. Our experiment also allows us to study whether stated perceptions affect actual investment behavior. Specifically, we can observe in our dynamic investment game how investment decisions and outcomes in one week influence both perceptions and investment behavior in the following week.

Finally, our paper is related to the literature on entrapment, escalating commitment, and sunk cost whereby people maintain or increase their commitment to losing courses of action.<sup>3</sup> Psychologists attribute this tendency to cognitive dissonance, i.e., a reluctance to admit that past decisions were incorrect. Several researchers have proposed that this self-justification makes investors persist in holding losing positions, causing the disposition effect (e.g., Zuchel, 2001, and Weber and Camerer, 1998). Our finding of motivated reasoning in investment behavior and inferences lends further support to this hypothesis. One noteworthy experimental study of the disposition effect by Weber and Welfens (2007) finds results, however, that seem to contradict ours. Namely, prices in their experiment underreact more to good news than to bad news in contrast to our results. We conjecture that these results are obtained because of the experiment's simplistic and symmetric information structure where subjects are not required to interpret any subjective information. Market outcomes are consequently the result of non-standard preferences rather than distorted information processing. For this reason, the authors come to the counterfactual conclusion that momentum ought to be stronger for positive than negative return news in contradiction with known empirics.

## **2 Experimental Design**

Our experiment consisted of an investment game and related questions administered on a website and repeated each week over six weeks. We performed the experiment twice, once in the fall semester from November 3 until December 14 of 2003 and once in the spring semester from March 1 until April 18 of 2004. We skipped one week in each period for Thanksgiving during the fall semester and spring break during the spring

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<sup>3</sup> See Staw (1997) for a discussion of this literature.



semester. There were 33 subjects in the fall and 63 subjects in the spring who played the game. All subjects were either MBA or undergraduate students in finance classes at Penn State University.

The investment game consisted of a portfolio allocation decision where each week subjects were endowed with 1000 points (\$10 USD), which they could allocate between two double-or-nothing bets and cash. The first bet was called the “stock bet” where subjects were given a pair of stocks and could bet on which of the two stocks would have a higher return in the subsequent week. If they picked the correct stock, they would double the money allocated to this bet. The “chance bet” served as a benchmark bet and was an i.i.d. double-or-nothing bet with a 50% chance of winning or losing, based upon the powerball lottery drawing of the subsequent week. Subjects could allocate their money in any way between these two bets and cash except that shortsales were restricted. They were reallocated 1000 points each week, and profits from one week were not rolled over into the next.

After subjects made their portfolio decisions, they answered a series of questions on the website. First, subjects were asked to provide their subjective probability that their favored stock would outperform the other, to which they could also answer “no opinion,” as a measure of confidence in stock selection. Second, they were asked to characterize any new information they had observed in each stock with the following choices: good new information, bad new information, neutral new information, and no new information observed.<sup>4</sup> Screenshots of the website are provided in figures 1 and 2.

We asked the subjects to play the game and answer these questions on our website each week (beginning on Monday at 12 am EST) for six consecutive weeks. They bet on

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<sup>4</sup> Subjects were also asked to rate their mood and characterize it with the objective of examining the impact of mood on trading. We reserve this analysis for a future study and focus here on information processing and trading.

returns for the following market week from Monday at 9:30 am until Friday at 4 pm. Subjects could play and change their decisions anytime during the week with their final decisions being registered the next Monday at 12 am. Subjects could, therefore, make their decisions for the current bet either during the week while the prior bet was underway or on the weekend after it had been determined. Our results only rely on the fact that subjects could observe some (not necessarily complete) information about the performance of their stocks and their prior bet during the week when they made their decisions and answered the survey. The website provided information on outcomes and earnings from prior weeks as well as links to the Yahoo! finance pages for the two stocks of the stock bet although there were no restrictions on information subjects could use. We paid subjects the sum of their earnings (bet earnings plus cash) over the six weeks in one lump sum after the end of the experiment.

The two stocks in each stock pair were matched to have similar risk characteristics in order to remove any differences in expected return or predictability in their relative returns. Specifically, we included all stocks listed on CRSP which were in the same industry according to their 3-digit SIC code as well as the same quintile among CRSP stocks for their three-factor loadings and their three-factor squared residual based on regressions of monthly returns from the prior sixty months of available data.<sup>5</sup> There were 9 pairs in the fall study and 8 pairs in the spring with one overlapping pair between the semesters, which are listed in table I. Each subject in the sample was given the same pair of stocks to bet on every week.

### **3 Experimental Results**

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<sup>5</sup> Lo and Mackinlay (1988) find that the idiosyncratic component of risk is unpredictable (based on prior returns) for weekly returns.

We employ “repeated measures” analysis to analyze our data involving panels of repeated observations over time for each subject. Specifically, we first obtain one observation per subject by computing time-series averages of a dependent variable. We then test hypotheses on cross-sectional averages across subjects. This procedure is used to simplify the analysis and employ standard t-tests without having to account for correlations within subject observations across different weeks.

Table II presents summary statistics for subjects’ portfolio allocation decisions and their changes between weeks. Subjects allocated the largest portion of their wealth in the stock bet, on average, of 450 units (\$4.50) or 45% of each week’s funds. Smaller average allocations were made in cash and the chance bet of 35% and 20%, respectively. There was significant participation in the stock bet, therefore, as 90 of 96 total subjects allocated a non-zero amount to this bet for at least one week. In addition, the average change in stock, chance, and cash allocations from the prior week are all statistically insignificant. Hence, subjects did not substantially change their allocations over time unconditionally in our sample.

### 3.1 News Reporting

#### 3.1.1 *Hypotheses*

We conjecture that subjects should exhibit confirmatory biases and perceive new information as justifying their prior choice of stock. If subjects were to choose Dell (their favored stock) over Apple (their nonfavored stock) in their stock bet, for example, their subsequent news reports should be positively biased for Dell and negatively biased for Apple. We first consider the benchmark case when subjects process information rationally. In this case, we should observe the following patterns:

*R1:* If subjects are rational, they should report news about their prior favored stock as being better than news about their prior nonfavored stock when winning the stock bet.

They should also report news about their favored stock as being worse than about their nonfavored stock when losing.

*R2*: If subjects are rational, they should report news about their prior favored stock to be better when winning than when losing the stock bet. They should also report news about their nonfavored stock to be better when losing than when winning.

A pictorial depiction is shown in figure 3. *R1* is obtained because the prior favored stock outperforms the nonfavored stock when the subject wins the bet while the favored stock underperforms the nonfavored stock when the subject loses. *R2* is obtained because the favored stock does better while the nonfavored stock does worse, on average, when subjects win than when they lose the bet.

If subjects exhibit confirmatory bias, they should accept news that confirms prior beliefs and refute news that contradicts them. Namely, subjects should accept the news that their favored stock is outperforming their nonfavored stock when winning the bet while not accepting the news that their favored stock is underperforming when losing. Hence, confirmatory bias should imply that:

*H1*: Subjects report news about their prior favored stock as being better than about their prior nonfavored stock when winning the stock bet. They do *not*, however, report news about their prior favored stock as being worse than about their prior nonfavored stock when losing.

Our second hypothesis is related to motivated reasoning, which should cause people to scrutinize and distort undesirable information more than desirable information. Hence, biases should be asymmetric such that they are greater for losses than gains. If confirmatory bias were symmetric, reported news for the favored stock (nonfavored) would be positively (negatively) biased for both losses and gains equally. Hence, *R2* above would remain true. Since these distortions should be more severe for losses than for gains we hypothesize that subjects should not perceive that their favored stock is

doing worse (or that their nonfavored stock is doing better) when losing than when winning. Hence, motivated reasoning implies the following:

*H2:* Subjects do *not* report news for their prior favored stock to be worse when losing than when winning the stock bet. Similarly, they do *not* report news for their nonfavored stock to be better when losing than when winning the stock bet.

We finally conjecture that subjects should observe, scrutinize, and consequently report more information when losing than when winning the bet as a result of motivated reasoning. For example, Redlawsk (2002) finds evidence that individuals expend both time and effort to counterargue information which is inconsistent with their personal beliefs. We hypothesize, therefore, that:

*H3:* Subjects report more information about both stocks when losing than when winning the stock bet.

### 3.1.2 Results

To address these hypotheses, we analyze the following measures of news reporting:

- *Observednews\_(non)favored:* 1 if news observed for the prior (non)favored stock for subject-week, 0 if news not observed
- *Qualitynews\_(non)favored:* 1 if good news reported for the prior (non)favored stock, 0 if neutral news, and -1 if bad news

The first variable measures whether or not news was observed for the favored (or nonfavored) stock of the prior week and is an indicator variable equal to 1 if the subject reported new information in a particular week and 0 otherwise. The second variable measures the quality of reported news using a scale of 1 for good news, 0 for neutral, and

-1 for bad news. Our results do not change materially if we add other measures of news quality such as the frequency of good or bad news reported separately.

Panel A of Table III presents summary statistics for these variables. The means of *observenews* variables indicate that subjects reported news for 69.8% and 71.0% of weeks after participating in the stock bet for the favored and nonfavored stocks, respectively. Experimental subjects, therefore, not only committed the largest portion of their wealth to the stock bet but also reported observing news in a majority of the weeks after betting on the stocks. Finally, the average of *qualitynews* for both the favored and nonfavored stocks were significantly greater than zero.<sup>6</sup> This outcome results from the fact that the majority of news reports were characterized as good news for both the favored (61.2%) and the nonfavored stocks (62.8%) whereas only a small fraction were characterized as bad news for the favored (7.6%) and nonfavored (8.5%).

We first study differences in news reporting between the favored and nonfavored stocks to address hypothesis 1. All differences in this paper are computed as the average across subjects of the difference between two time-series averages for each subject. The objective is again to eliminate correlations within subject observations across weeks and produce one observation per subject so we can employ standard t-tests.

Our results in panel B of table III provide some support for hypothesis 1 since subject's reported significantly better news for the favored than the nonfavored stock when winning the bet but do not report significantly worse news when losing. Specifically, the average difference of *qualitynews* for the favored minus the nonfavored

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<sup>6</sup> We should point out that the number of subject observations, *N*, varies across averages. For example, it is equal to 90 for the *observenews* averages in panel A of table III which is less than the total number of subjects in our sample of 96. The reason for the discrepancy is that this average includes only subjects who played the stock bet, six of whom did not. In addition, *N* for the *qualitynews* averages in panel A is equal to 78 and 73 for the favored and nonfavored stocks, respectively, since these averages include only subjects who played the stock bet and reported news for these stocks. Similar reductions in *N* occur with conditional averages in subsequent results since these averages include only subjects who whom these events occurred.

stock is positive and significant at  $p \approx 10\%$  conditional on winning while this difference is insignificant conditional on losing. We should point out that the unconditional average difference is also insignificant, meaning that subjects did not report significantly better news for their favored than their nonfavored stock across all weeks. These results likely stem from the fact that subjects appeared to have not paid much attention to information when winning, indicating a passive acceptance of good news in line with motivated reasoning. Hence, the average difference in reported news quality between the favored and nonfavored stocks when winning was not highly significant even though the favored stock was outperforming the nonfavored.

We address hypotheses 2 and 3 by examining average differences in news reporting between winning and losing weeks for the stock bet. Our results in panel C of table III indicate that subjects engaged in a high degree of motivated reasoning regarding their favored but not their nonfavored stock. Namely, we obtain the surprising result that  $\text{qualitynews\_favored for winning minus losing weeks}$  is negative and significant at  $p < 5\%$ . Subjects in our experiment scrutinized undesirable information to such an extent that they actually perceived news for their favored stock to be better when losing than when winning the bet even though rational information processing dictates the opposite. We find no evidence of motivated reasoning for the nonfavored stock, however, since subjects reported news about this stock to be significantly better when losing than when winning. This finding is consistent with rationality (R2) since the nonfavored stock does better, on average, when losing than when winning the bet.

The absence of motivated reasoning for the nonfavored stock indicates that subjects may have framed their decision as choosing a good stock rather than avoiding a bad one. They may have consequently placed more importance on outcomes and information related to their favored than their nonfavored stock. We see further support for this conjecture from the fact that biases were greater for negative than positive returns. Namely, subjects exhibited significant confirmatory bias, reporting significantly better

news for their favored than their nonfavored stock for weeks when these stocks had negative but not positive returns. In other words, qualitynews for the favored minus the nonfavored stock was positive and significant conditional on negative returns while being insignificant conditional on positive returns in panel B of table III. Motivated reasoning predicts that biases ought to be greater for undesirable than for desirable information. Our results indicate, therefore, that subjects were unhappier when their favored (and nonfavored) stock did poorly than when their nonfavored (and favored) stock did well and consequently cared more about outcomes for their favored stock.<sup>7</sup>

Our results in panel C of table III also provide support for hypothesis 3 and further evidence of motivated reasoning regarding the favored stock. Namely, subjects reported more information about their favored stock when losing than when winning, i.e., the average of `observenews_favored` for wins minus losses is negative and significant at  $p=5.36\%$ . Hence, subjects scrutinized and observed information more when experiencing losses than gains consistent with motivated reasoning. Subjects did not report significantly more news about the nonfavored stock when losing than winning, however, again indicating a lack of motivated reasoning for this stock.

Further evidence of motivated reasoning for the favored but not the nonfavored stock can be seen by examining how reported news was affected by actual new information as proxied by the return on the stock for that week.<sup>8</sup> Subjects ought to report

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<sup>7</sup> A neuropsychological study by Westen, et al. (2006) examines neural patterns in experimental subjects engaged in political reasoning and finds that motivated reasoning only occurs when people have a “strong emotional stake in the conclusions reached.”

<sup>8</sup> There may, in fact, be a mismatch between the tenor of news reported by the financial media and returns. For example, currently publicized information may have been impounded into prices in the past as indicated by the oft-cited wisdom, “buy on the rumor, sell on the news.” We believe that returns are a reasonable proxy nonetheless for the tenor of new information to the extent that the financial press has strong incentives to produce timely information and also that subjects interpret “new information” as including information about returns. We thank Philip O’Connor for pointing out this fact.



better news about a stock when it has positive than when it has negative returns, on average, if their information processing is rational. Our subjects did indeed report significantly better news about their nonfavored stock for positive than for negative returns. In other words, the average difference of quality news for the nonfavored stock between positive and negative returns is positive and highly significant at  $p < 1\%$  in panel C of table III. This difference is insignificant for the favored stock, however. Subjects' news reports, therefore, were not sensitive to returns as a result of biases in the processing of information related to this stock.

To summarize, we found evidence of confirmatory biases for the favored stock in that the news reports were positively biased especially for losses. These biases appear to be the result of motivated reasoning for this stock in that subjects observed and distorted information more when losing than when winning the bet. No such biases were apparent for the nonfavored stock.

### *3.1.3 Betting Persistence*

We now attempt to address the issue of how the persistence of subjects' beliefs in their news reporting affects their actual investment behavior. We have found that subjects' view of new information about their prior favored stock became inflated for undesirable outcomes as a result of motivated reasoning. It could be that subjects simply posture to make themselves feel better in the face of a bad outcome and that they are unwilling to make actual decisions with economic stakes in line with this posturing.

It is difficult to specify precisely how subjects ought to bet in our game both with and without belief persistence biases. This behavior will depend upon the particular valuation model employed by the subject whether a momentum or contrarian model, etc. We nonetheless attempt to devise a coherent set of conclusions by studying subjects' betting persistence. Specifically, we examine subjects' propensity to persist in their bets when winning versus when losing their prior bet.

We study the following two measures of betting persistence: *prob\_samebet*, the probability of betting on the same favored stock as the previous week, and *amount\_samebet*, the average amount bet on the same favored stock as the previous week. Specifically, we compute averages of the former variable by assigning a one to a given week if the favored stock is the same as the prior week and a zero if the favored stock changes. The latter variable is equal to the stock bet allocation if the favored stock is the same and is equal to minus the stock bet allocation if it changes. Summary statistics for these variables across subjects are given in panel A of table IV. The average probability of betting on the prior favored stock is 66.5%, which is significantly greater than a 50% chance of repeating the same bet at  $p < 1\%$ . The unconditional average of *amount\_samebet* is also positive and highly significant, indicating that subjects tended to persist in their bets in dollar terms as well.

Panel B of table IV reports averages of betting persistence variables for winning and losing weeks as well as the difference between the two. It is clear that subjects persist in their bets for both wins and losses. Namely, *prob\_samebet* is significantly greater than 50% while *amt\_samebet* is significantly greater than zero conditional on both winning and losing. This behavior is consistent with a long-term model of investment or arbitrage where the investor holds a consistent position over time. We also see in panel B that the difference in persistence between winning and losing weeks is insignificant for both measures. This result is consistent with a Bayesian-updating (or momentum) model of valuation with the addition of motivated reasoning.<sup>9</sup> Namely, subjects ought to update their valuation of assets based on returns, and persistence ought to be greater after gains than losses. The addition of motivated reasoning, however, would heighten persistence after losses. Hence, the fact that there is no significant difference in persistence between

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<sup>9</sup> This finding is not consistent with a contrarian model of valuation which predicts that betting persistence ought to be significantly greater for losses than gains and not that there is no significant difference.

wins and losses is consistent with our previous finding of greater distortions for undesirable events.

### 3.2 Self-Confidence

We have until this point studied belief persistence related to new information about assets. We now turn our attention to persistence in beliefs related to self and confidence in one's stock-picking ability. In particular, we study biased self-attribution or the documented tendency for people to attribute successes to ability and failures to bad luck. Daniel, Hirshleifer, and Subrahmanyam (1998), for example, feature this bias as the source of belief persistence and momentum in their model. If subjects learn their stock-picking ability over time as rational Bayesian updaters, their self-confidence should increase in response to winning and decrease in response in losing as it does in the model of Gervais and Odean (2001).<sup>10</sup> We conjecture that subjects' self-confidence should increase when winning the bet since they should attribute this success to their ability. Their self-confidence should not decrease, however, when losing the bet since they should attribute this failure to bad fortune. Hence, we have the following hypothesis:

*H4:* Subjects' confidence in winning the current stock bet will increase over the previous week when winning the prior bet but will not decrease when losing the prior bet.

We can also examine whether motivated reasoning influences inferences related self-confidence in stock-picking ability as it does to other inferences. We anticipate that

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<sup>10</sup> Alternatively, subjects' self-confidence should stay fixed over time if their prior beliefs are infinitely precise as would be the case if they were certain in their belief in market efficiency, for example.

subjects will refuse to accept and distort their failures to such an extent that changes in confidence in response to winning will not significantly exceed changes in confidence in response to losing. Hence, we have the following hypothesis:

*H5: Subjects' change in confidence in winning the current stock bet will not be significantly greater when winning than when losing their prior bet.*

Our first measure of subjects' confidence is their stated probability of winning the stock bet. Our second confidence variable attempts to measure confidence net of random chance by comparing the amount of the stock bet to that of the chance bet, which has a known probability of 50%. We name these confidence measures as follows:

- *Confidence 1*: stated probability of winning the stock bet.
- *Confidence 2*: stock bet allocation minus chance bet allocation.

Summary statistics for confidence variables and their changes from the prior week are given in panel A of table V. Average changes in confidence over time were insignificant for all measures as indicated in this table. Panel B of table V reports average changes in confidence across subjects for weeks when each subject won and lost the stock bet in order to address hypothesis 4. We do, indeed, find evidence of biased self-attribution for our allocation-based measure of confidence. Namely, the average change in confidence 2 was positive and significant conditional on winning the prior bet at  $p < 5\%$ . The average change for confidence 2 conditional on losing was also positive and significant at  $p < 10\%$ , indicating that subjects' relative investment in the stock actually increased in response to losing. The fact that confidence increases by this measure when losing provides some evidence that subjects distort undesirable information consistent with motivated reasoning as we discuss further in a moment. We should note that this

average change conditional on winning and losing include only weeks where subjects were playing the stock bet unlike the unconditional averages in panel A. Hence, the unconditional average change in confidence 2 is insignificant while both conditional averages are significant and larger since subjects who didn't play the stock bet in a given week tended to increase their subsequent chance bet allocation, decreasing the unconditional average of confidence 2.

Results for our stated probability measure were weaker, however. Average changes in confidence 1 were statistically insignificant conditional on both winning and losing. These results are consistent with the conclusions from cognitive psychology of Miller and Ross (1975), who find little empirical evidence of biased self-attribution in people's stated attributions. It is interesting to note that although we also do not find evidence of this bias in stated self-assessments, we do find evidence in our measures based on actions. Hence, these biases may be more apparent in economic behavior than in statements to others where they may be mollified by social pressures to suppress egotistical self-assessments.

Finally, panel B of table V reports the average difference across subjects of changes in confidence between wins and losses in order to address hypothesis 5. The difference between confidence revisions when winning versus losing are insignificant for both measures. Subjects' changes in confidence when winning, therefore, are not significantly greater than when losing, consistent with motivated reasoning. We should note, however, that this result for confidence 1 is somewhat biased in favor of our hypothesis. Namely, the average difference is negative for confidence 1 and substantially lower than the difference between the averages conditional on winning and losing in panel B. One reason for the discrepancy comes from the fact that the average of the difference only includes subjects who both won and lost the stock bet at some point in the game. Hence, it tends to exclude subjects who lost in the initial weeks and consequently stopped playing the stock bet. The average difference between winning and losing,

therefore, understates this difference because it excludes these subjects for whom confidence tended to decrease after losses.<sup>11</sup>

In summary, we find evidence for both self-attribution bias and motivated reasoning in self-confidence about stock-picking ability as revealed by investment allocation while finding little evidence in terms of stated probabilities. Hence, these biases may distort actual investment behavior in spite of mixed evidence from cognitive psychology against such biases in self-assessments.

## **4 Discussion and Conclusion**

We have found that inferences in our experiment became more biased in the direction of prior beliefs when subjects incurred losses, consistent with the concept of motivated reasoning from psychology. In addition, this persistence in beliefs seems to have influenced investment behavior in our game. There are a number of implications that can be extracted from our findings. First, we found that subjects exhibited motivated reasoning only for their favored and not for their nonfavored stock. We conjecture, therefore, that investors adopt a passive frame toward assets that are avoided and an active frame for positions that are chosen or sought. Hence, investors may exhibit weaker attachments and cognitive biases for stocks sold from holdings than for stocks bought or sold short.

Our results may help explain certain documented patterns in markets and also suggest new predictions related to those patterns. For example, our results may be related to the fact that momentum is stronger for loser stocks than for winner stocks. Although

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<sup>11</sup> This omission biases our results against our hypothesis for confidence 2 since this variable increases after losses, on average. Indeed, the average difference of changes in confidence 2 for wins versus losses is greater than the difference of the average in panel B of table V.

there is some evidence that short-sales constraints contribute to momentum in stock returns (e.g., Ali and Trombley (2005)), several studies find that these costs do not fully account for the profitability of momentum strategies (e.g., Bushee and Raedy (2005)). Our findings suggest that loser momentum may not be caused entirely by short-sales constraints, but that motivated reasoning may also contribute to slow incorporation of information for loser stocks. If this hypothesis is true, short-sellers should be reluctant to accept good news about their investments because it causes them to lose money. One way of testing this hypothesis, therefore, is to determine whether stocks with higher short interest exhibit greater underreaction to good news and momentum in the positive return direction.

Our findings also suggest avenues for future research. For example, existing theories of belief persistence should be modified to account for motivated reasoning so that these biases are stronger for losses than gains and not symmetric as they are in the model of Daniel, Hirshleifer, and Subrahmanyam (1998). Finally, one would ideally like to connect behavioral models of preferences that generate underreaction as a result of the disposition effect (e.g., Grinblatt and Han (2005)) to behavioral models of inference persistence. One significant challenge, however, would be to reconcile studies of inferences such as our own and Hales (2006) with the preference-driven experiment of Weber and Welfens (2007) which draw conflicting conclusions.

Figure 1: Betting Decisions Screenshot

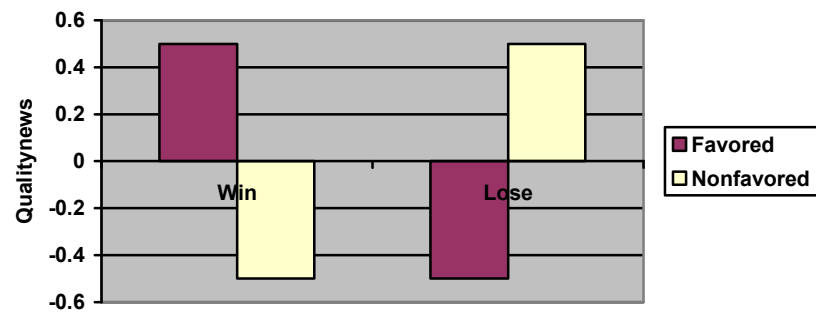
<b>Entry Form: Enter new allocation for the week 03/29 - 04/02</b>	
<b>Stock bet (currently: 110 on VOD &lt; NTT)</b>	
<input type="text" value="0"/>	<input type="radio"/> Vodafone ( <a href="#">VOD</a> ) will have a higher return than Nippon Tel ( <a href="#">NTT</a> ). <input type="radio"/> Nippon Tel ( <a href="#">NTT</a> ) will have a higher return than Vodafone ( <a href="#">VOD</a> ).
<b>Powerball bet (currently: 450 on Odd Powerball)</b>	
<input type="text" value="0"/>	<input type="radio"/> Even Powerball number. <input type="radio"/> Odd Powerball number. <input type="radio"/> Powerball number between 1 and 21. <input type="radio"/> Powerball number between 22 and 42.
<b>Cash (currently: 440)</b>	
<input type="text" value="1000"/>	
<input type="button" value="Submit"/> <input type="button" value="Clear"/>	

Figure 2: Questionnaire Screenshot

<b>1</b>	<b>Questionnaire: Please answer the following questions.</b>
<b>2</b>	Did you observe any new information regarding these stocks this week and if so, how would you generally characterize it?
<b>3</b>	VOD: <input type="radio"/> Good new information    NTT: <input type="radio"/> Good new information <input type="radio"/> Bad new information <input type="radio"/> Bad new information <input type="radio"/> Neutral new information <input type="radio"/> Neutral new information <input type="radio"/> No new information <input type="radio"/> No new information
<b>4</b>	With what probability do you think that VOD will outperform NTT next week?
	<input type="radio"/> No opinion. <input type="radio"/> Please enter a percentage between 0 and 100: <input type="text"/> %
	Please rate your mood on the following scale (from 1=Very Bad to 5=Very Good): 1    2    3    4    5 Very Bad <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> Very Good Which of the following best describes your current mood? <input type="text" value="Please select."/>
	Please describe anything that has significantly impacted your mood: <div style="border: 1px solid black; height: 80px; width: 100%;"></div>
	<input type="button" value="Submit"/> <input type="button" value="Reset"/>



Figure 3: Rational Information Processing



**Table I**  
**Experimental Stock Pairs**

*Stock Pairs* are the pairs of stocks, on which subjects bet for the fall and spring semester studies. They were generated by matching the two stocks in the same quintile for their three-factor loadings and idiosyncratic volatility based on regressions of monthly returns from the prior sixty months of available data as well as the same 3-digit SIC code. *N* refers to the number of subjects betting on that pair for their stock bet.

Panel A: Fall 2003 Study			
Stock Pair	N	Stock A	Stock B
1	5	Dell	Apple
2	4	Texas Instruments	Cisco
3	4	Kellogg	Ralcorp
4	4	Exxon Mobil	Chevron Mobil
5	4	Wal Mart	BJ's Wholesale
6	4	Southwest Airlines	Fedex Corp
7	1	Bristol-Myers Squibb	Alberto Culver Co
8	3	Knight-Ridder	Scripps E.W. Co
9	4	Ruby Tuesday	Applebee's

Panel B: Spring 2004 Study			
Stock Pair	N	Stock A	Stock B
1	8	Deswell Industries	Tupperware
2	8	Yellow Corp	USA Truck
3	7	Coors Adolph	Diageo
4	8	Vodafone	Nippon Tel
5	8	Sportsline Com	Identix
6	7	Mercury Interactive	Siebel Systems
7	8	Ryan's Family Steakhouse	Wendy's Intl.
8	9	Ruby Tuesday	Applebee's

**Table II**  
**Summary Statistics: Portfolio Allocations**

This table presents summary statistics of portfolio allocation variables. Statistics are computed across subjects on time-series averages of these variables for each subject. *Stock*, *Chance*, and *Cash* are the amounts allocated to the stock bet, chance bet, and cash, respectively where each unit is equal to \$0.01.  $\Delta Stock$ ,  $\Delta Chance$ , and  $\Delta Cash$  are the changes in these variables between the current and prior weeks (for weeks 2-6). *N* refers to the number of subject observations used to compute each average. P-values are given in parentheses.

Variable	N	Mean	Std Dev	Min	Max
Stock	96	450	289.54	0	1000
Chance	96	200	206.37	0	750
Cash	96	350	331.16	0	1000
$\Delta Stock$	95	11.13 (0.515)	165.82	-330	1000
$\Delta Chance$	95	-2.99 (0.735)	85.61	-250	250
$\Delta Cash$	95	-8.14 (0.650)	174.28	-1000	500

\*, \*\*, \*\*\* denotes significance at the 10%, 5% and 1% level respectively

**Table III**  
**News Reporting**

Panel A presents summary statistics of news reporting variables. Statistics are computed across subjects on time-series averages of these variables for each subject. *Qualitynews\_(non)favored* has values 1,0, or -1 if good news, neutral news, or bad news was reported that week for the prior (non)favored stock, respectively. *Observe news\_(non)favored* has value 1 if any news was reported for the prior (non)favored stock and 0 otherwise. Panel B presents unconditional and conditional average differences in news reporting between the prior week's favored and nonfavored stocks. Each average is computed across subjects on the difference between two time-series averages for each subject. *Win* and *Lose* include only weeks where the subject won and lost the stock bet, respectively. *Positive* and *Negative* include only weeks for which the relevant stock had positive and negative returns, respectively.

Panel A: Summary Statistics: Information Processing					
Variable	N	Mean	Std Dev	Min	Max
Qualitynews_favored	78	0.535*** (0.000)	0.510	-1	1
Qualitynews_nonfavored	73	0.543*** (0.000)	0.484	-0.667	1
Observe news_favored	90	0.698*** (0.000)	0.371	0	1
Observe news_nonfavored	90	0.710*** (0.000)	0.391	0	1

Panel B: Differences in Information Processing between Favored and Nonfavored Stocks					
Variable	Unconditional	Win	Lose	Positive	Negative
Qualitynews_favored – Qualitynews_nonfavored	0.043 (0.357) N=73	0.106* (0.100) N=55	-0.009 (0.817) N=64	-0.067 (0.174) N=61	0.135* (0.054) N=50
Observe news_favored – Observe news_nonfavored	-0.013 (0.487) N=90	-0.031 (0.337) N=81	0.042 (0.150) N=87	-0.032 (0.329) N=83	-0.026 (0.481) N=73

\*, \*\*, \*\*\* denotes significance at the 10%, 5% and 1% level respectively

**Table III**  
**News Reporting, Cont.**

Panel C presents average differences in news reporting between wins and losses for the stock bet and between positive and negative returns. Each average is computed across subjects on the difference between two time-series averages for each subject. *N* refers to the number of subject observations used to compute each average. P-values are given in parentheses.

Panel C: Difference in Information Processing between Wins and Losses and between Positive and Negative Returns		
Variable	Win – Lose	Positive – Negative
Qualitynews_favored	-0.1997** (0.0181) N=53	0.0442 (0.4230) N=49
Qualitynews_nonfavored	-0.3415*** (0.0003) N=51	0.2753*** (0.0003) N=56
Observenews_favored	-0.0844* (0.0536) N=78	-0.0228 (0.5660) N=73
Observenews_nonfavored	-0.0053 (0.8922) N=78	-0.0299 (0.3685) N=78

\*, \*\*, \*\*\* denotes significance at the 10%, 5% and 1% level respectively

**Table IV**  
**Betting Persistence**

This table presents results for persistence of betting decisions as measured by *prob\_samebet* and *amount\_samebet*, where the former is equal to one and the latter is equal to the stock bet allocation if the favored stock was the same as the prior week while the former is zero and the latter is minus the stock bet allocation if the favored stock changed. *Panel A* reports summary statistics across subjects of time-series averages of betting persistence variables for each subject. *Panel B* reports averages of betting persistence variables for wins versus losses. *Win* and *Lose* are averages across subjects of time-series averages for weeks in which the subject won and lost the stock bet, respectively. *Win – Lose* is the average difference across subjects of time-series averages for weeks in which the subject won and lost the stock bet. *N* refers to the number of subject observations used to compute each average. P-values are given in parentheses, and *prob\_samebet* is tested against a null of 0.5.

Panel A: Betting Persistence Summary Statistics					
Variable	N	Mean	Std Dev	Min	Max
Prob_samebet	79	0.665*** (0.000)	0.325	0	1
Amount_samebet	79	196*** (0.000)	427	-1000	1000
Panel B: Betting Persistence for Wins vs. Losses					
Variable	Win	Lose	Win – Lose		
Prob_samebet	0.705*** (0.000) N=65	0.622*** (0.000) N=64	0.01 (0.8915) N=50		
Amount_samebet	261*** (0.000) N=65	110* (0.078) N=64	48.7 (0.5844) N=50		

\*, \*\*, \*\*\* denotes significance at the 10%, 5% and 1% level respectively

**Table V**  
**Self-Confidence**

This table presents results for self-confidence in stock-picking ability. *Confidence 1* is the subjects' stated probability of winning the stock bet while *Confidence 2* is the stock bet allocation minus the chance bet allocation.  $\Delta$ *Confidence 1* and  $\Delta$ *Confidence 2* are the changes in these variables between the current and prior week (for weeks 2-6). *Panel A* reports summary statistics across subjects of time-series averages of confidence variables and their changes for each subject. *Panel B* reports averages of changes in confidence variables for wins versus losses. *Win* and *Lose* are averages across subjects of time-series averages for weeks in which the subject won and lost the stock bet, respectively. *Win – Lose* is the average difference across subjects of time-series averages for weeks in which the subject won and lost the stock bet. *N* refers to the number of subject observations used to compute each average. P-values are given in parentheses, and *confidence 1* is tested against a null of 0.5.

Panel A: Confidence Summary Statistics					
Variable	N	Mean	Std Dev	Min	Max
Confidence 1	89	60.89*** (0.000)	10.02	50	94.67
Confidence 2	96	250*** (0.000)	378	-667	1000
$\Delta$ Confidence 1	80	-0.122 (0.901)	8.78	-25	40
$\Delta$ Confidence 2	95	14.12 (0.489)	198	-400	1000
Panel B: Confidence Revisions for Wins vs. Losses					
Variable	Win	Lose	Win – Lose		
$\Delta$ Confidence 1	0.6134 (0.6826) N=66	-1.474 (0.1802) N=64	-0.4983 (0.8359) N=50		
$\Delta$ Confidence 2	74.18** (0.0493) N=78	67.06* (0.0748) N=75	35.61 (0.5054) N=67		

\*, \*\*, \*\*\* denotes significance at the 10%, 5% and 1% level respectively

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