Organizational Behavior and Human Decision Processes 131 (2015) 67–80

Contents lists available at ScienceDirect

Organizational Behavior and Human Decision Processes

journal homepage: www.elsevier.com/locate/obhdp

The prospect of a perfect ending: Loss aversion and the round-number bias

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ARTICLE INFO

Article history:
Received 26 January 2015
Revised 11 August 2015
Accepted 25 August 2015
Available online 23 September 2015

Keywords:
Analog value function
Round-number bias
Left-digit effect
Heuristics

ABSTRACT

Studies across a range of domains have shown that individuals tend to focus on round numbers as cognitive reference points; a so-called left-digit effect. We explain this effect by combining analog numerical heuristics with prospect theory in order to develop an analog value function that predicts the key characteristics of the left-digit effect. Most importantly, this value function predicts an unreported phenomenon, namely; that the left-digit effect will be more pronounced in situations involving losses (cf. gains). We confirm this prediction in both a laboratory experiment regarding hypothetical investments and analysis of buy–sell imbalances in over 15 million trades by investors in a financial market. We conclude that our analog value function is a promising explanation for the left-digit effect. Furthermore, we suggest that interventions aimed at reducing costly buy–sell imbalances in financial markets should focus on the decisions made by investors when they are facing loss.

1. Introduction

Research has revealed that small changes in prices can significantly influence individuals' perceptions of an item's cost. The left-digit effect (LDE) or "pricing in the nines" (Basu, 1997; Stiving, 2000) occurs when two prices that differ by 1 cent (e.g., $2.99 vs. $3.00) are encoded differently in the perceiver's mind due to differences in their left digits. This has clear applications in the pricing of commercial goods and services (Manning & Sprott, 2009; Stiving, 2000; Thomas & Morwitz, 2005). However, recent studies suggest that the LDE could play a role in a broad range of decision-making domains (e.g., in financial markets, see Bhattacharya, Holden, & Jacobsen, 2012). In light of the importance of this phenomenon, we develop a theory to explain the observed LDE. In particular, we combine dual-process theories of numerical processing during the encoding of price information (Gordon, 2004; Lemer, Dehance, Spelke, & Cohen, 2003) and prospect theory's value function (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992) to develop a new analog value function.

The analog value function is based on two ideas: (1) individuals may use changes in left-digits to inform their judgment of changes in value; and (2) changes in left-digits will bias choices more readily in situations involving losses than in situations involving gains. Under the dual-process paradigm, the use of simple left-digit heuristics implies a reliance on intuitive type 1 processing rather than the more deliberative type 2 processing associated with calculating the precise change in value (Evans & Stanovich, 2013a; Hogarth, 2001; Kahneman & Frederick, 2002; Payne, Bettman, & Johnson, 1993; Sloman, 1996; Stanovich & West, 2000). However, our theory is not based on the premise that there must be a change in reasoning strategy from more normative in the context of gains to heuristic in the context of losses. Rather, we consider prospect theory and propose that the salience of left-digit changes may be exaggerated by loss aversion. The higher salience of left-digits changes associated with losses is expected to lead to a greater biasing effect in the judgment of changes in value compared to left-digit changes associated with gains.

Fig. 1 illustrates the general structure of our model. Initially, the perceiver processes stimulus information and signals related to the changes in left digits are combined with signals related to changes in value (e.g. percentage change). The degree to which the changes in left digits bias the perceived change in value is determined by how much that signal is weighted in a given choice context (modulated by parameter k in Fig. 1). This combined signal is then processed according to prospect theory's value function (shown as v in Fig. 1), which results in our proposed analog value function. The final choice probabilities are some function of the comparison of the analog value functions produced by each of the choice alternatives.

We developed hypotheses derived from predictions based on the analog value function. These hypotheses were then tested by analyzing data drawn from a laboratory study in which

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http://dx.doi.org/10.1016/j.obhdp.2015.08.004
0749-5978/

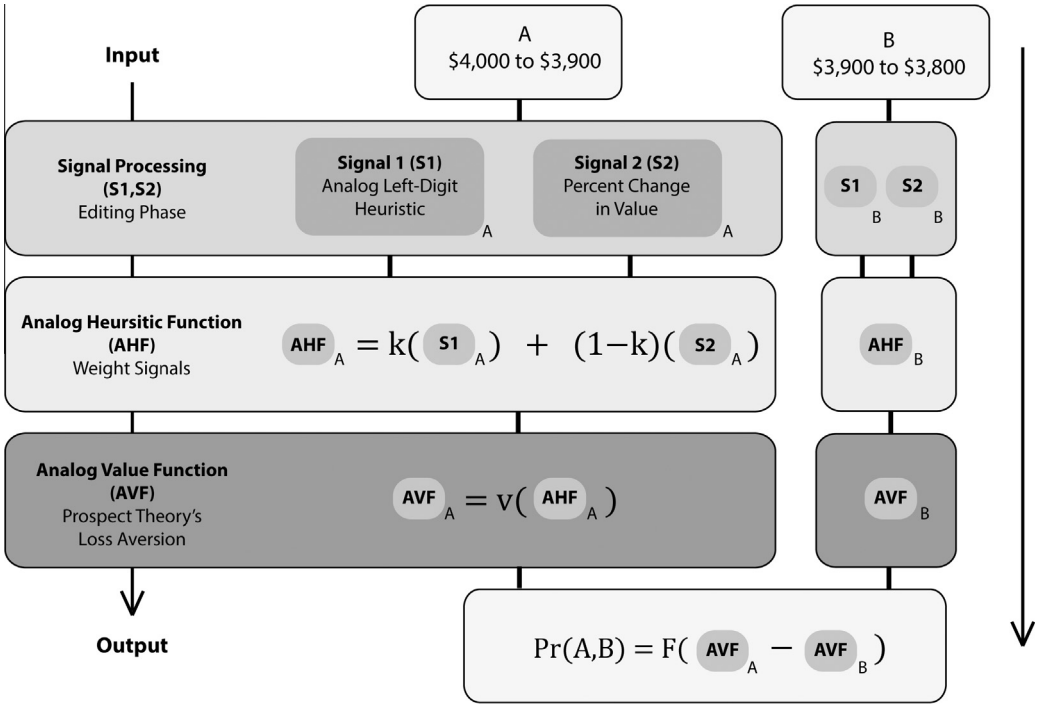

Fig. 1. An illustration of the integration of analog heuristic processing with prospect theory to model the LDE bias when comparing two changes in value (A and B). The parameter k determines the extent that changes in left digits are incorporated into the perception of changes in value. Parameter v is prospect theory's value function applied to this heuristic signal to produce an analog value function. Choice probabilities are a function (F) of a comparison of the analog value functions for each alternative.

participants evaluated the performance of investments that gained in value and those that decreased in value. In accordance with our hypotheses, changes in left digits had a greater biasing effect on participants' judgments of investment performance for losing (vs. winning) investments. In particular, when judging the change in value of investments that decreased in value, if the change in left-digits did not coincide with the true change in value participants were more likely to make errors when selecting the best performing asset. However, when the change in left digits did coincide with the best performing asset, error rates were lower – albeit clearly for the wrong reasons. This effect was only marginally significant for gains, suggesting a weaker LDE for gains, as predicted by our model.

Recent studies have discovered buy–sell imbalances on round numbers in real-world stock transactions (see, Bhattacharya et al., 2012; Kuo, Lin, & Zhao, 2014). These imbalances suggest that investors in financial markets have a tendency to over-buy or over-sell at specific price points that end in round numbers. The findings of these studies indicated the use of heuristics by investors, whereby they focus on the change in left digits rather than on the more mentally costly strategy of calculating accurate changes in value (e.g., percentage returns). Arbitrary characteristics of prices, such as whether the prices are round numbers, are unrelated to the fundamental value of the security. Consequently, a preference for round numbers could be detrimental to investors' profitability. Indeed, Bhattacharya et al. (2012) estimated that such irrational behavior could lead to an aggregated wealth transfer of $813 million a year in the New York Stock exchange alone. Critically, however, their theory did not account for the role that loss aversion could play in this effect.

To determine whether decision makers in real world settings also tend to be more biased by changes in left digits in the context of a loss, we examined individual financial spread-trading account data. The transactions were separated into trades relating to investments that gained in value and trades that decreased in value and then examined the degree of LDE in the buy–sell imbalances for these trades. Consistent with the predictions of our analog value function we observed greater buy–sell imbalances on round numbers for investments that decreased in value, confirming that loss-induced round-number biases have an impact on real-world decisions.

The potential costs of the LDE, as revealed by Bhattacharya et al. (2012), demonstrate its importance. From a theoretical perspective, our findings offer an important modification to prospect theory, suggesting that the analog value function could play an important role in a broad range of everyday decisions. This analog value function is valuable in providing a means of measuring the extent that individuals may suffer from round number bias and when they might be most susceptible to its effects (i.e. when facing losses). Hence, this could enable the targeting of psychological interventions (e.g., via decision-support systems) at appropriate individuals and situations, in order to reduce the costly round-number bias in financial markets; potentially fostering improvements in investor performance and market efficiency.

Our paper proceeds as follows. We first describe the conceptual background and theories related to the LDE and we show how analog numerical processing may affect investor behavior. We then develop an analog value function to account for the LDE and outline why we expect loss aversion to exacerbate the LDE. Next we develop hypotheses based on the analog value function. We then describe the laboratory experiments and the real-world trading data that we employ to test these hypotheses. In this section, we also present our results. Next we discuss the results and we draw conclusions regarding the theoretical and practical implications of our theory and findings.

2. Literature review

2.1. The left-digit-effect

Laboratory studies have revealed that prices ending in nine (e.g., $2.99, $399) are perceived to be disproportionately smaller