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Path dependence in risky choice: Affective and deliberative processes in brain and behavior☆

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ABSTRACT

Decision-makers show an increased risk appetite when they gamble with previously won money, the *house money effect*, and when they have a chance to make up for a prior loss, the *break even effect*. To explore the origins of these effects, we use functional magnetic resonance imaging to record the brain activities of subjects while they make sequential risky choices. The behavioral data from our experiment confirm the path dependence of choices, despite the short trial duration and the many task repetitions required for neuroimaging. The brain data yield evidence that the increased risk appetite after gains and losses is related to an increased activity of affective brain processes and a decreased activity of deliberative brain processes.

1. Introduction

The question of how individuals make decisions under risk is fundamental to economics and has captivated researchers for centuries. Over the past 25 years or so, behavioral studies have convincingly demonstrated that risk attitudes are path dependent, a notion that is at odds with rational choice theory. Most notably, Thaler and Johnson's (1990) experiments show

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that people tend to take more risk if they have a chance to make up for a prior loss, a phenomenon known as the break even effect (BEE). Conversely, people also display a greater risk appetite after a prior gain that is large enough to cover potential losses. Thaler and Johnson label this effect the house money effect (HME), referring to gamblers' feelings that they are not playing with their own money when they are ahead. In the present study, we employ functional neuroimaging techniques to examine the neural mechanisms that underlie this path dependence in risky choice.

Path dependence in risky choice has been observed in various settings. For example, McGlothlin (1956) reports that gamblers at racetracks display an increased propensity to bet on long shots at the end of the racing day, presumably in an attempt to recover earlier losses. Post et al. (2008) observe an increased risk appetite after gains and losses in the large-stake TV game show "Deal or No Deal", where contestants make a series of choices between cashing out with a certain lump sum or taking a risk for a larger reward by continuing to play. Studies by Smith et al. (2009) and Coval and Shumway (2005) point out that path dependence even extends to situations where decision-makers are experts in the domain: experienced online poker players take more risk after big losses, and Chicago Board of Trade proprietary traders display a greater risk appetite in afternoon trading sessions after morning losses. Barberis et al. (2001) show that path-dependent risk attitudes can have a substantial effect on asset returns.

Behaviorally, path dependence in risky choice can be explained within the framework of Kahneman and Tversky (1979). A distinguishing feature of their descriptive Prospect Theory relative to the more normative Expected Utility Theory (von Neumann and Morgenstern, 1947) is the reference-dependent valuation of outcomes: preferences are defined over gains and losses (relative to a reference point) rather than final wealth states. In general, people tend to show moderate risk-averse behavior in the gain domain and risk-seeking behavior in the loss domain, as well as a relatively strong risk aversion for mixed gambles due to loss aversion, that is, a greater sensitivity to losses than to gains. The value function in Prospect Theory captures these tendencies through diminishing sensitivity to increments in gains and losses and a steeper slope for losses than for gains of a similar size.[1] In a dynamic context, these properties entail a relatively high risk tolerance after both gains and losses if people do not update their reference point. If the reference point is sufficiently high after prior losses or low after gains, decision-makers display the risk-seeking behavior that is predicted by the convex shape of the value function for losses, or the moderate risk-averse behavior that is predicted by the concave value function for gains, respectively. In both cases, the impact of loss aversion is mitigated or absent.

Psychological evidence suggests that decisions are the result of both an affective (or "intuitive") and a deliberative (or "reflective") system of thinking (Chaiken and Trope, 1999; Kahneman, 2003). The former system is assumed to be fast, effortless, automatic and associative, while the latter is characterized by slower and more effortful processing. In this light, preferences are proposed to reflect a combined result of these two systems, with the affective system driving nonlinearities in valuation and the deliberative system valuing outcomes more linearly (Hsee and Rottenstreich, 2004; Mukherjee, 2010). As a consequence, choices can vary and depend on how strongly the two systems are involved in solving the decision problem.

Findings from neuroimaging research support the idea that two different brain systems drive choice behavior. De Martino et al. (2006) show that people's sensitivity to the manner in which choice options are presented is driven by affective neural processes, and that cognitive control mechanisms are more active when the behavior of the decision-maker is less sensitive to framing. A study by Roiser et al. (2009) finds that a subject group that exhibits only weak behavioral framing effects has increased connectivity between control and affective brain regions, suggesting the presence of dynamic regulatory control over emotional reactions, whereas a subject group exhibiting strong behavioral effects has weaker connectivity within this brain network. Similarly, loss aversion has been related to affective mechanisms in the brain. Knutson et al. (2008b) suggest that affective reactions in the brain, specifically in the insula, strengthen the endowment effect (Kahneman et al., 1991; Thaler, 1980) and thus increase loss aversion in selling situations. De Martino et al. (2010) report that patients with brain damage in another affect-related region, the amygdala, show a dramatically lower level of loss aversion than healthy people do.

Previous neuroscience and behavioral studies have also investigated how positive and negative experiences can influence subsequent choice behavior, with mixed findings reported to date. Kuhnen and Knutson (2005, 2011) show that negative (positive) affective states precede future tendencies to avoid (accept) uncertain prospects. In contrast, the findings of Andrade and Iyer (2009) and Demaree et al. (2012) suggest that a negative affective state entails an increased risk appetite.

The role of deliberative processes also remains unclear. Xue et al. (2011) report that the tendency to take more risk after a loss than after a gain is associated with higher activity of cognitive control processes, while Campbell-Meiklejohn et al. (2008) find increased cognitive control-related and anxiety-related activity when people decide to stop chasing previous losses.

In the light of this literature and given the key roles of framing and nonlinear preferences for path dependence, we conjecture that the BEE and HME are driven by affective processes and suppressed by deliberative processes.[2] A number of recent behavioral studies have already found some evidence in this direction (Andrade and Iyer, 2009; Demaree et al., 2012;

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[1] We ignore the effect of probability weighting here. Prospect Theory actually describes a fourfold pattern of risk aversion, as probability weighting can lead to risk aversion for low-probability losses and risk seeking for low-probability gains. The relevant choice problems in our experiment always use 50/50 gambles.

[2] To some degree it is still an open question as to whether "affective processes" form a unitary system that is activated after both gains and losses, or whether there is a complex network of affect-related mechanisms that are different for gain and loss situations. Similarly, we consider it an open question whether the "deliberative process" is truly a single mechanism, or rather an aggregate description of a network of different processes involved in controlling behavior.

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