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Hypothetical decision making in schizophrenia: The role of expected value computation and "irrational" biases

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ABSTRACT

The aim of the present study was to examine the contributions to decision making (DM) deficits in schizophrenia (SZ) patients of expected value (EV) estimation and loss aversion. Patients diagnosed with SZ (n=46) and healthy controls (n=34) completed two gambling tasks. In one task, participants chose between two options with the same EV across two conditions: Loss frames and Keep frames. A second task involved accepting or rejecting gambles, in which gain and loss amounts varied, determining the EV of each trial. SZ patients showed a reduced "framing effect" relative to controls, as they did not show an increased tendency to gamble when faced with a certain loss. SZ patients also showed a reduced tendency to modify behavior as a function of EV. The degree to which choices tracked EV correlated significantly with several cognitive measures in both patients and controls. SZ patients show distinct deviations from normal behavior under risk when their decisions are based on prospective outcomes. These deviations are two-fold: cognitive deficits prevent value-based DM in more-impaired patients, and in less-impaired patients there is a lack of influence from well-established subjective biases found in healthy people. These abnormalities likely affect everyday DM strategies in schizophrenia patients.

1. Introduction

Cognitive and motivational problems are some of the most debilitating aspects of schizophrenia (SZ), contributing greatly to functional deficits in patients with the illness (Dickinson et al., 2007). Based, in part, on evidence that SZ patients exhibit normal hedonic responses to the experience of rewards (Heerey et al., 2008; Cohen and Minor, 2010), it has been suggested that motivational deficits in SZ may be driven by a relative inability to accurately and adaptively represent the expected value (EV) of response alternatives, outcomes, and stimuli predictive of reward availability. Such representations are needed to guide effective decision-making (DM).

A growing body of research points to abnormalities in value-based DM in SZ. Over the last decade, multiple studies have shown that chronic SZ patients make lower rates of optimal choices on tasks of risky DM (Hutton et al., 2002; Cheng et al., 2012; Fond et al., 2013). For example, most, but not all studies using the Iowa Gambling Task (IGT; Bechara et al., 1994) point to impaired value-based DM in SZ (for a review see Sevy et al., 2007). Because advantageous and disadvantageous decks in the IGT are distinguished by the magnitudes of punishments associated with each, poor performance on the IGT has been interpreted as reflecting reduced sensitivity to punishments in clinical populations (Bechara et al., 1995). With the IGT, however, it is difficult to discern whether DM abnormalities result from reduced sensitivity to punishments (and thus a preference for risky choices), or an inability to process the simultaneous rewards and punishments administered on every trial, or a reduced ability to update and integrate value representations based on a long series of outcomes.

To isolate alterations in DM, as opposed to alterations in outcome processing, it is useful to study risky DM under hypothetical conditions, in which learning from feedback does not play a role. Experimental work into this type of DM has determined that expected utility, as defined by von Neumann and Morgenstern (1947), is not the only factor influencing choice behavior, as healthy people often fail to choose options offering the highest EV (by virtue of either reward magnitude, probability of receipt, or both). Prospect theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1981; Trepel et al., 2005) accounts for these examples of non-rational DM by emphasizing the role of perceptual factors and subjective biases about the relative value of different outcomes. Most importantly, DM behavior in healthy subjects is often influenced by a greater bias to avoid losses, than to seek gains.

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That is, when faced with the choice between a certain loss and an uncertain loss that has a larger magnitude, but the same EV, most subjects are willing to gamble (i.e., take on risk) in order to avoid the certain loss. In contrast, when subjects have the choice between a certain gain and the chance for a larger, but uncertain, gain, loss aversion leads to an unwillingness to gamble (De Martino et al., 2006). To the same end, when faced with the choice to play a gamble or accept a neutral outcome, loss aversion leads subjects to avoid risking a loss, unless the proposed gamble offers a potential gain that is significantly greater than the potential loss (when the EV is significantly greater than zero; Tom et al., 2007). Thus, the same bias leads to different decisions depending on the context (a phenomenon called the “framing effect”; Kahneman and Tversky, 1979). While this bias is not “rational,” it is a well-established pattern of choice behavior in healthy subjects (Rabin and Thaler, 2001; Kahneman, 2003).

We were interested in examining this issue in schizophrenia for several reasons. First, there is suggestive evidence that people with schizophrenia may undervalue potential losses in uncertain DM contexts (Heerey et al., 2008), and show a reduced endowment effect (whereby people tend to overestimate the value of a good that is already in their possession; Tremeau et al., 2008). A reduced sensitivity to potential losses might result in abnormal (albeit more rational DM) in SZ patients. Interestingly, Heerey et al. (2008) reported that reduced loss sensitivity was related to measures of working memory capacity, suggesting that patients may lack some of the cognitive capacities that are needed to evaluate all the features involved in representing comparative choices, which might also be expected to impact the appearance of framing effects.

Suspicion that SZ patients might show altered loss aversion in DM is bolstered by recent neuroimaging studies that have examined the neural basis of this phenomenon and implicated a set of regions, many of which are likely to be compromised in schizophrenia. For example, a functional magnetic resonance imaging (fMRI) study by Tom et al. (2007) has linked loss aversion to the targets of the mesolimbic and mesocortical dopamine (DA) pathways, such as the ventral striatum (VS), ventromedial prefrontal cortex (VMPFC), and medial orbitofrontal cortex (OFC). Other fMRI studies (De Martino et al., 2006, 2010) have found activity in the amygdala – a region involved in processing affective information (for a review see Phan et al., 2004) – to be most predictive of loss-averse behavior. Evidence that all of these brain areas may be implicated in schizophrenia (Grace, 2000) further supports the idea that many patients with SZ may not exhibit normal DM behavior based on loss-aversion biases.

In order to examine the issue of loss aversion in SZ, we adapted two tasks from the recent functional imaging literature on loss-aversion biases. In one task, adapted from De Martino et al. (2006), subjects were given a varying amount of money at the start of each trial and were asked to choose between a certain outcome, which was to retain a portion of the original amount, and a probabilistic outcome, which was to accept a gamble. On two-thirds of trials, both options had the same EV and were presented in either a certain gain (or Keep frame) or a certain Loss frame (Fig. 1). The task was designed to test the effect of the framing of the choice (independent of the EV of the choice) on subjects' willingness to gamble. In a second task, adapted from Tom et al. (2007), subjects chose either to accept or reject a gamble involving a 50% chance of gaining a certain amount and a 50% chance of losing a certain amount. In this task, potential gains and losses varied from trial to trial, such that the absolute value of the potential gain magnitude could exceed, be the same as, or be less than, the absolute value of the potential loss magnitude. This task was designed to identify the ratio of potential loss magnitude to potential gain magnitude at which each individual subject was indifferent to accepting or rejecting a gamble. This ratio serves as a quantitative measure of loss aversion in individual subjects.

We predicted that loss aversion would be attenuated in schizophrenia, resulting in a reduced framing effect. In short, we expected that SZs would gamble more or less equally in Keep and Loss frames, and not exhibit the “irrational bias” observed in controls in the De Martino et al. (2006) task. In the context of the Tom et al. (2007) task, we expected SZ patients to show less

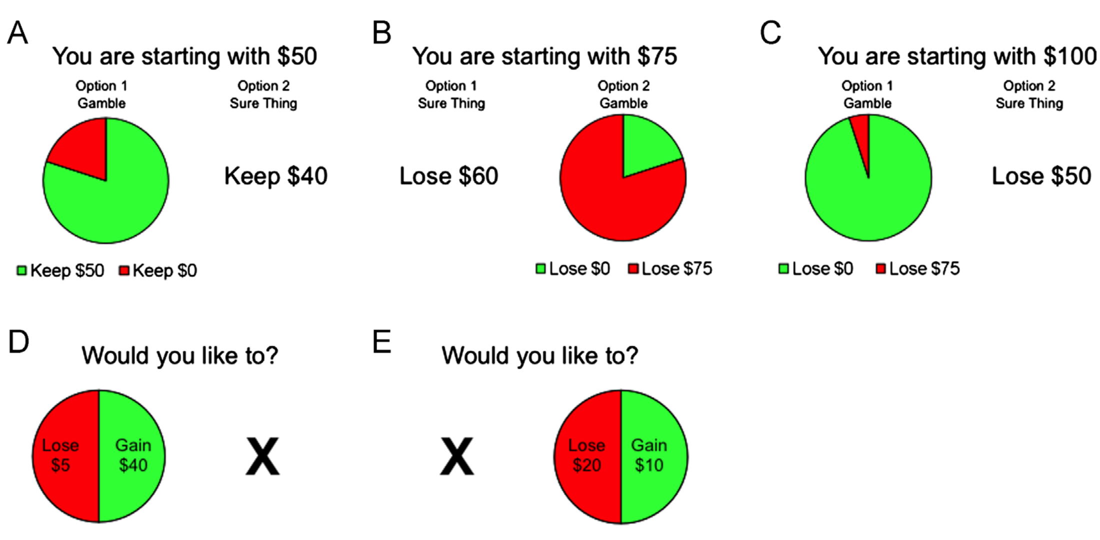

Fig. 1. Illustration of behavioral tasks. (A) A trial involving a Keep frame from the DeMartino Framing Task (2006). In this example, participants started with $50 and had to decide whether they would rather keep $40 certainly, or accept a gamble with an 80% of keeping the entire $50 and a 20% chance of keeping nothing. (B) A trial involving a loss frame from the DeMartino Framing Task (2006). In this example, participants started with $75 and had to decide whether they would rather lose $60 certainly, or accept a gamble with an 80% of losing the entire $75 and a 20% chance of losing nothing. (C) Illustration of a “Catch” trial from the DeMartino Framing Task (2006). In this example, participants started with $100 and had to decide whether they would rather lose $50 certainly, or accept a gamble with a 5% chance of losing the entire $100 and a 95% chance of losing nothing. (D) Trial with an advantageous gamble from Tom et al. (2007). The gamble option from this trial had a very positive EV (17.5), due to large potential gain and small potential loss. (E) Trial from Tom et al. (2007) with a disadvantageous gamble (EV=−5), due to large potential loss and small potential gain.