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Alternative outcomes create biased expectations regarding the received outcome: Evidence from event-related potentials

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ABSTRACT

After choosing between uncertain options, one might get feedback on both the outcome of the chosen option and the outcome of the unchosen option (the alternative). Behavioral research has shown that in such cases people engage in outcome comparison, and that the alternative outcome influences the way one evaluates his own received outcome. Moreover, this influence differs whether one was responsible or not for the choice made. In two studies, we looked for the electrophysiological correlates of outcome comparison. Subjects chose one of two boxes shown on the screen, each box contained a gain or a loss. The alternative outcome was always revealed first, followed by the received outcome. In half of the trials the software picked one box instead of subjects. We tested whether the feedback-related negativity (FRN) and the P3 elicited by the received reflect outcome comparison. As expected, we found that the FRN and P3 were more positive when the received outcome was a gain (vs. a loss). The FRN and P3 were also sensitive to the value of the alternative outcome, but contrary to our predictions, they were more positive when the alternative outcome was a gain (vs. a loss). As the FRN and P3 are sensitive to expectations, we hypothesized that our findings might result from subjects' biased expectations: subjects might have wrongly believed that a good (bad) alternative outcome signaled a bad (good) received outcome. This hypothesis, coined as the Alternative Omen Effect, was confirmed in parallel in a series of behavioral experiments: people see an illusory negative correlation between the uncorrelated outcomes of choice options (reported in Marciano-Romm et al. (2016)). A challenge for future research will be to disentangle the effects of expectation from those of outcome comparison.

1. Introduction

1.1. The alternative outcome and counterfactual thinking

We make choices between uncertain options on a daily basis. For example, we might have to decide whether to drive to work via the expressway or via the city roads, not knowing which way will be less prone to traffic; or we might have to choose whether to invest in stocks from firm A or firm B. In "total feedback" situations (Mellers et al., 1999), we eventually get feedback on outcomes of both the unchosen option (hereinafter *the alternative outcome)* and the chosen option *(the received outcome)*. For instance, you might hear that the stocks you bought from Firm A earned you $1000 in the last trimester, and that had you chosen to invest in Firm B, you would have lost $200. In such situations, individuals are likely to engage in counterfactual thinking. Counterfactual thinking is the process by which people compare what *is* to what *might have been* (Roese, 1997; Zeelenberg et al., 1998). Past research have shown that people's satisfaction is greatly affected by how their received outcomes compare to these alternative outcomes (Bell, 1982; Loomes and Sugden, 1982; Inman et al., 1997; Mellers et al., 1999). To quote Mellers et al. (1997): "the same outcome can feel very pleasant or very unpleasant, depending on the counterfactual comparisons". That is, satisfaction increases as the value of the alternative outcome decreases. The effect of the alternative outcome is so strong that individuals who are objectively better off might nonetheless feel worse (Medvec et al., 1995).

Electrophysiological measures of brain activity may provide insight into the processes underlying outcome comparison and outcome evaluation. Two event-related potentials (ERPs) in particular have been used as measure of reward evaluation, the Feedback Related Negativity (FRN, also known as the Medial Frontal Negativity, MFN), and the P3.

The FRN is a negative deflection of the feedback-related ERP

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peaking within 250–350 ms after feedback is provided, over the scalp's midline, presumably generated in the anterior cingulate cortex (Gehring and Willoughby, 2002; Hauser et al., 2014; Nieuwenhuis et al., 2005b). It is valence-sensitive, being typically larger[2] following losses than gains (Hajcak et al., 2006; Gehring et al., 2002; Nieuwenhuis et al., 2004), and is sensitive to the degree to which the outcome (negatively) deviates from what was expected (Bellebaum et al., 2010b; Hajcak et al., 2007). The FRN is also modulated by the level of agency experienced by the person making the decision (Li et al., 2010, 2011).

The association of the FRN with feelings such as regret, disappointment, or satisfaction, is bolstered by findings showing that the FRN amplitude correlates with subjective feelings of pleasantness or ratings of emotions (Rigoni et al., 2010; Li et al., 2011) and that it appears to be highly dependent on context. It varies as a function of the outcomes sequence (Osinsky et al., 2012), and is influenced by the variety of possible outcomes in a task (Holroyd et al., 2004). It could thus be assumed that in situations of choice between two options, the FRN elicited by the received outcome is influenced by the alternative outcome. However, as detailed in Section 1.2 below, the existing literature on the subject is not conclusive.

The P3 is a large positive component occurring in the 300–600 ms time window after stimulus onset when the stimulus has behavioral consequences, with generators in the frontal and temporo-parietal sites (Soltani and Knight, 2000). The P3, typically elicited by infrequent targets in an oddball situation, has been implicated in a multitude of cognitive and affective processes and is usually associated with allocation of mental resources (Polich, 2007). In the context of decision-making, the P3 has been shown to be sensitive to reward magnitude (Yeung et al., 2004; Bellebaum et al., 2010b) as well as expectation towards reward magnitude (Wu et al., 2009). While past research suggested the P3 is not sensitive to reward valence (Yeung et al., 2004), recent studies showed that it has more positive amplitudes for positive outcomes than for negative outcomes (Wu et al., 2009; Bellebaum et al., 2010b; Li et al., 2010). Due to the inconsistency of the findings, this study reexamines whether the P3 amplitude is sensitive to the valence of the alternative outcome and/or to the valence of the received outcome.

1.2. Existing literature on the electrophysiological correlates of counterfactual comparison

Several recent electrophysiological studies have used the FRN and P3 to look at situations of total feedback following choice. In all studies, participants were asked to make a choice between several options. The studies differed in the way the feedback was displayed: both outcomes could be revealed simultaneously (SIM); the alternative outcome could be presented first, followed by the received outcome (Alternative First) or the received outcome could be presented first, followed by the alternative outcome (Received First). In the Received First paradigm (Yeung and Sanfey, 2004), the alternative could not have possibly affected the response to the outcome and therefore is not of interest in the present article.

1.2.1. Presenting both outcomes simultaneously (SIM)

Mixed results were found in the SIM condition. Some studies have found that the FRN amplitude reflected the valence of the received outcome, but was indifferent to whether choosing the alternative would have been preferable or not (Gehring and Willoughby, 2002; Masaki et al., 2006). Others have found that the FRN amplitude was partially explained by the valence and the magnitude of both the alternative outcome and the received outcome (Goyer et al., 2008). While the latter results could indicate that the FRN reflects some comparison process, it is unclear whether participants, when presented simultaneously with both outcomes, paid equal attention to both on each trial. It is possible that in some trials participants focused first on the option they chose and ignored for a short time the outcome of the alternative, and that in other trials they did the contrary. In the former case, the FRN entered in the analysis would be elicited by the received outcome only, while in the latter, it would be elicited by the alternative outcome. If this were to happen, even if the FRN was not sensitive to any comparison process, the average FRN would show that the FRN encodes simultaneously the alternative and the received outcomes. Conversely, if the subjects only looked or covertly paid attention to the chosen option, then no comparison could take place by definition, congruent with the studies that did not find comparison effects for the FRN. Unfortunately, none of the studies cited controlled for attention or eye movements during SIM conditions.

1.2.2. Presenting the alternative outcome first (Alternative First)

A possible solution to the issues raised above would be to use an Alternative First paradigm (Rigoni et al., 2010).[3] In this case, the FRN can be time locked specifically to the revelation of the received outcome, and the alternative outcome has the opportunity to affect the experienced valence of the received outcome. According to behavioral research, any received outcome should elicit a more satisfying response after a *bad* alternative outcome has been revealed, than following a good alternative outcome: it is more enjoyable to win when you could have lost than if you would have won anyway, and it is less painful to lose when you would have lost anyway than when you could have won (e.g. Mellers et al., 1997). If the FRN elicited by the received outcome encodes the result of this comparison, we should expect the FRN to be *smaller* for received gains as compared to received losses (Gehring et al., 2002; Hajcak et al., 2006), but *larger* in response to received outcomes which follow alternative gains than in response to received outcomes which follow alternative losses.

In fact, Gu et al. (2011) used an Alternative First paradigm and found that the FRN elicited by the received outcome was influenced by the valence of the alternative outcome, but not in the expected direction. That is, received outcomes following alternative gains elicited a smaller FRN, as compared to received outcomes following alternative losses. Thanks to the temporal separation between the alternative outcome and the received one, the authors could also look at the FRN elicited by the alternative outcome itself. They found that the FRN elicited by a positive alternative outcome was larger than the FRN elicited by a negative alternative outcome, suggesting the subjects were not "happy" when seeing a good alternative. This unexpected result was recently reported again in study investigating counterfactual comparison in a group of patients with depression (Feng et al., 2015). Gu et al. suggested that despite the fact that the alternative outcome had no predictive value, the participants might have evaluated a positive alternative outcome as a "bad sign" regarding their yet-to-be-revealed outcome. That is, participants might have perceived an illusory negative correlation between the received and the alternative outcomes when in fact none existed. By this account, a bad received outcome is even more disappointing after a bad alternative (because of the broken positive expectation) than after a good alternative outcome (where the bad received outcome was the expected result), putatively explaining the surprising FRN results.

The present studies had two goals. First, we wanted to verify that the FRN and P3 are sensitive to outcome comparison, using a simple choice task in which participants always saw the first the alternative outcome (in fact, the study was already running when Gu et al.'s results were published). Importantly, we stated very clearly in the instructions

[2] Since FRN is nominally a negativity, in the following, we use "larger" to indicate more negative and smaller to indicate a less negative FRN.

[3] Rigoni et al. used an Alternative First paradigm (Rigoni et al., 2010), but did not look into the comparison between the received and the alternative outcomes.