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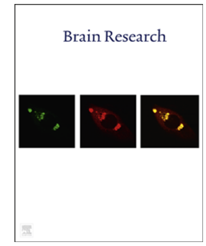

Research Report

Optimistic, pessimistic, realistic: Event-related potential evidence for how depressive symptoms influences expectation formation in the Human brain

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ABSTRACT

Recent research suggested a link between the prediction mechanism and depressive symptoms. While healthy people tend to maintain unrealistic optimism in the face of reality challenging their beliefs, depressed people show systematic pessimism. However, it remains unclear at which stage these individual differences in optimism/pessimism arise in the brain. In the current study we designed a simple gambling task with two difficulty levels, the easy game and the hard game. Participants were required to press one of four keys to gain a bonus signalled by a sinusoidal tone. For three of the four keys, the probability of getting a large bonus was 80% in the easy game and 8% in the hard game. In both games, the fourth key, randomly determined in each trial, yielded a large bonus with a probability of 100%. This arrangement allowed us to observe less/more depressed participants' optimistic/pessimistic expectations about hitting the key that guarantees a large bonus. The opposite expectation patterns of less/more depressed participants were reflected on the N1 amplitude. Meanwhile, all participants were well aware of the true probability of obtaining certain bonus in each game as reflected on the P3 amplitude. The results suggest that the subjective system (tracking subjective beliefs) and the objective system (tracking objective evidence) are dissociable in the human brain, with the former feeding information into sensory areas and the latter representing prediction errors on a higher level. Moreover, individual differences arise from variability in the former rather than the latter.

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1. Introduction

The predictive coding model of perception postulates that the brain constantly attempts to match sensory inputs with internal predictions (Friston, 2005, 2009). Neuronal responses index how much of the sensory inputs cannot be accounted for by the internal predictions (i.e., prediction errors), which will be communicated forward to update internal predictions (Summerfield et al., 2008; Egner et al., 2010; Clark, 2013). This notion has been corroborated, for example, by the N1 event-related potential (ERP) component being attenuated when triggered by expected relative to unexpected auditory stimuli (Schafer and Marcus, 1973; Schafer et al., 1981; Lange, 2009, 2013; Todorovic, 2012; SanMiguel et al., 2013; Timm et al., 2013; Hsu et al., 2014). The predictive coding model of perception offers a new way to understand the neurobiological basis of mental illness. For example, deficits in predictive coding in the auditory system might underlie psychotic symptoms, such as hallucinations and delusions (Fletcher and Frith, 2009; Horga et al., 2014). Moreover, the degree of impairment in such basic auditory plasticity seems to correlate with markers of schizophrenia severity, such as cognitive and functional impairment (Baldeweg et al., 2004; Baldeweg, 2006).

A similar association between the prediction mechanism and depressive symptoms was reported in the literature, although the prediction mechanism investigated then did not concern the updating of perception but the updating of beliefs. When it comes to estimating how likely certain events are to occur to them, healthy people tend to maintain unrealistic optimism in the face of reality challenging their beliefs (Sharot, 2011; Blair et al., 2013). This unrealistic optimism is associated with selective update in the prefrontal cortex, tracking prediction errors for positive but not for negative updates (Sharot et al., 2011, 2012a, 2012b). On the other hand, people reporting depressive symptoms lack unrealistic optimism but show systematic pessimism (Strunk et al., 2006; Strunk and Adler, 2009; Korn et al., 2014).

While it has emerged that both perception of the world and beliefs about the world are dependent of predictions (Fletcher and Frith, 2009), it remains unclear at which level of the processing hierarchy the optimistic/pessimistic expectation and the ensuing prediction errors are registered. Prediction errors resulted from optimistic/pessimistic expectations might be encoded at low processing hierarchy. Alternatively, prediction errors resulted from optimistic/pessimistic expectations might be encoded at all levels of the processing hierarchy. This would mean to say that people having optimistic/pessimistic expectations differ in their ability to process the statistical regularity in the environment. Using electroencephalography (EEG), the current study looked into the prediction errors resulted from less/more depressed people's optimistic/pessimistic expectations to investigate this issue.

We designed a simple gambling task, where participants were required to press one of four keys to gain a bonus signalled by a sinusoidal tone. The task had two difficulty levels, the easy game and the hard game. For three of the four keys, the probability of getting a large bonus was 80% in the easy game and 8% in the hard game; otherwise a small bonus would be delivered. In both games, the fourth key, randomly determined in each trial, yielded a large bonus with a probability of 100%. Thus, if participants "realistically" track the statistical regularities of the two games, they should expect a large bonus in the easy game and a small bonus in the hard game. However, the instruction that there is a 100% key allowed us to observe less/more depressed participants' optimistic/pessimistic expectations about hitting the key that guarantees a large bonus. Less depressed people's optimistic expectations would result in prediction errors to the presence of a small bonus. More depressed people's pessimistic expectations would result in prediction errors to the presence of a large bonus.

As will be discussed in more detail below, we found that the opposite patterns of less/more depressed participants' expectations were reflected on the N1 amplitude. On the other hand, the pattern of the later brain activity (i.e., the P3 amplitude) suggested that all participants were well aware of the true probabilities of obtaining certain bonus in each game. The findings demonstrate that subjective beliefs and objective evidence are dissociable in the human brain. Moreover, individual differences are due to variability in the former, not the latter.

2. Results

2.1. Behavioural data

When the 18 participants were split into two groups (i.e., less/more depressive symptoms) using the severity cutpoint for minimal/mild depression in the patient health questionnaire-9 (PHQ-9) instruction manual (i.e., score of 5), 9 participants were assigned to the less depressed group (mean=3.00, range=1–5) and 9 participants were assigned to the more depressed group (mean=9.22, range=6–13). Participants' response time (RT) in each condition was listed on Table 1. There was no significant RT difference between conditions (depressive symptoms × game × bonus: $F(1,16)=2.03$, $p=0.17$; game × bonus: $F(1,16)<0.001$, $p=0.99$; depressive symptoms × game: $F(1,16)=0.65$, $p=0.43$; depressive symptoms × bonus: $F(1,16)=0.01$, $p=0.94$; depressive symptoms: $F(1,16)=0.58$, $p=0.46$; game: $F(1,16)=3.48$, $p=0.08$; bonus: $F(1,16)=0.92$, $p=0.35$).

Table 1 – Mean and standard deviation of RT in each condition.

		Easy game Large bonus	Easy game Small bonus	Hard game Large bonus	Hard game Small bonus
Less depressive symptoms	Mean Standard deviation	457.26 (156.76)	458.47 (171.47)	501.85 (219.95)	491.59 (210.51)
More depressive symptoms	Mean Standard deviation	535.28 (157.85)	524.42 (171.33)	545.13 (121.51)	545.45 (134.15)