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Study of positive and negative feedback sensitivity in psychosis using the Wisconsin Card Sorting Test

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Abstract

Background: Schizophrenia involves marked motivational and learning deficits that may reflect abnormalities in reward processing. The purpose of this study was to examine positive and negative feedback sensitivity in schizophrenia using computational modeling derived from the Wisconsin Card Sorting Test (WCST). We also aimed to explore feedback sensitivity in a sample with bipolar disorder.

Methods: Eighty-three individuals with schizophrenia and 27 with bipolar disorder were included. Demographic, clinical and cognitive outcomes, together with the WCST, were considered in both samples. Computational modeling was performed using the R syntax to calculate 3 parameters based on trial-by-trial execution on the WCST: reward sensitivity (R), punishment sensitivity (P), and choice consistency (D). The associations between outcome variables and the parameters were investigated.

Results: Positive and negative sensitivity showed deficits, but P parameter was clearly diminished in schizophrenia. Cognitive variables, age, and symptoms were associated with R, P, and D parameters in schizophrenia. The sample with bipolar disorder would show cognitive deficits and feedback abnormalities to a lesser extent than individuals with schizophrenia.

Conclusion: Negative feedback sensitivity demonstrated greater deficit in both samples. Idiosyncratic cognitive requirements in the WCST might introduce confusion when supposing model-free reinforcement learning. Negative symptoms of schizophrenia were related to lower feedback sensitivity and less goal-directed patterns of choice.

1. Introduction

During the last decade, the study of reinforcement learning in schizophrenia has been on the increase as an exemplary area for the integration of theory and experiment. This impulse is based on the idea that schizophrenia is associated with a specific reward-guided learning abnormality e.g. [1,2], where the dopamine system – a primary target of current pharmacological treatment approaches in schizophrenia – plays a critical role [3]. Previous studies have indicated that individuals with schizophrenia are less able than controls to use positive and negative feedback to learn an optimal response; and participants with primary and enduring negative symptoms had the most difficulty [2,4]. In particular, some have found that patients with high levels of negative symptoms showed abnormalities when representing the expected value of rewards, e.g. [5,6]; while others have reported the presence of these abnormalities in both reward and punishment sensitivity, suggesting heterogeneity in terms of behavioral learning patterns [7,8]. Furthermore, reward-related signals in fronto-striatal circuits have been shown to correlate with the severity of symptoms in schizophrenia [9], such as with an association

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between clinical ratings of avolition/anhedonia and the magnitude of punishment-reward contrasts in the ventral striatum [2]. Generally, there appear to be increasing reasons to suspect that the study of reward and punishment sensitivity in schizophrenia may shed new light on the functional disability and neurobiology of the illness. For example, from the research in this field emerges the idea that treatments for negative symptoms (pharmacological and nonpharmacological) should seek to enhance neural signals related to valuation, as well as to adaptively modulate the value attached to stimuli and actions. So one could imagine that psychosocial interventions aimed at helping people better weigh the costs and benefits of choices could lead to improvements in clinical status and real-world functioning [9]. In addition, as mentioned by Waltz et al. [2], the question remains regarding the extent to which reinforcement learning abnormalities are central and/or specific to schizophrenia, or whether negative symptoms have common underlying mechanisms across other syndromes and illnesses, for instance bipolar disorder.

One of the main methods to study reinforcement learning is called 'model-free' because it avoids the representation of task structure, and progressively acquires estimates of the long-range values of circumstances and actions from retrospective experience, working directly by reinforcing successful actions through a process of trial and error [10]. Based on this approach, there has been a surge of interest in modeling the Wisconsin Card Sorting Test (WCST) in the attempt to stimulate general qualitative patterns of data. Distinct updating mechanisms in the WCST appear to be consistent with neuroimaging studies: neural regions specifically correlated with wrong choices in the WCST include the anterior cingulate cortex and cortical basal ganglia; and the dorsolateral prefrontal cortex has been associated with both right and wrong feedback [11]. Overall, reinforcement learning approaches have led to explicit models of the roles of dopamine and cortico-basal ganglia-thalamo-cortical loops in learning about reinforcers (rewards and punishments) and in guiding behavior so as to acquire rewards and avoid punishments [12].

In the present study, a sequential learning model specifically designed by Bishara et al. [11] using the WCST was formulated to infer three computational parameters: reward sensitivity (R), punishment sensitivity (P), and decision consistency (D). Accordingly, choices on the task depend on the perceived relevance of different dimensions (e.g., color, form, and number), which increases or decreases across trials. As such, R and P parameters reflect the degree to which a participant adaptively adjusts relevance weights based on reinforcing and punishing trial-by-trial feedback. Respectively, R parameter represents how quickly choices change in response to positive feedback ("Right!"), and P parameter represents how quickly these weights change in response to negative feedback ("Wrong!"). Finally, higher values in D parameter represent more deterministic patterns of choice while lower values signify more random or exploratory responses. This model was validated with healthy controls and substance-dependent individuals by Bishara et al. [11], and was recently utilized in schizophrenia by Cella et al. [7] in order to identify possible changes in computational parameters of reinforcement learning following cognitive remediation. Therefore, our first aim was to further investigate positive and negative feedback sensitivity in schizophrenia through calculating the reinforcement learning parameters based on the WCST-64 cards computer version [13]. Further, a second purpose was to study the association between feedback sensitivity parameters and symptoms, cognitive outcomes, and antipsychotic medication, as well as to find possible confounding variables linked to the cognitive requirements of the WCST. A final goal was to study R, P, and D parameters in a sample of outpatients with bipolar disorder evaluated with the modified WCST [14] prior to inclusion in an independent study. Our hypothesis was that if reinforcement learning abnormalities are critically involved in the pathophysiology of negative symptoms [6,15], these could be absent or presented differently in other psychoses such as bipolar disorder.

2. Material and methods

2.1. Subjects

A sample of 83 outpatients with a diagnosis of schizophrenia was randomly selected from five community mental health services (CMHS) which belong to Parc Sanitari Sant Joan de Déu. Inclusion criteria were: (a) fulfillment of DSM-IV criteria for a diagnosis of schizophrenia [16] confirmed by two psychiatrists, (b) age between 18 and 65 years, and (c) residence in the catchment areas of the participating CMHS. Patients that were illiterate or had a diagnosis of intellectual disability, substance abuse, or neurological disorder were excluded. All the participants were on antipsychotic treatment.

A sample of 27 outpatients with a diagnosis of bipolar disorder [16] was recruited from three CMHS in the Barcelona metropolitan area registered at Parc Sanitari Sant Joan de Déu. These participants were included if: (a) they fulfilled DSM-IV criteria for a diagnosis of bipolar disorder confirmed by two psychiatrists, (b) they were between 18 and 65 years old, and (c) they were euthymic (Hamilton Depression Rating Scale <8; Young Mania Rating Scale <6). Patients were excluded if they had intellectual disability or any neurological disorder, a diagnosis of alcohol or drug dependence, or were illiterate.

Both investigations were approved by the local ethics and research committee, and written informed consent was obtained from all participants prior to their inclusion.

2.2. Measures

2.2.1. Clinical

The Spanish validation [17] of the ***Positive and Negative Syndrome Scale* (*PANSS*)**[18] was used. We applied the 5-factor consensus model from Wallwork et al. [19]. The *Negative* factor includes 6 items: blunted affect, emotional withdrawal, poor rapport, passive-apathetic social withdrawal, lack of spontaneity, and motor retardation. The *Positive* factor includes 4: delusions, hallucinations, grandiosity, and unusual