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Avolition in schizophrenia is associated with reduced willingness to expend effort for reward on a Progressive Ratio task

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ABSTRACT

The current study examined whether effort-cost computation was associated with negative symptoms of schizophrenia (SZ). Participants included outpatients diagnosed with SZ (n = 27) and demographically matched healthy controls (n = 32) who completed a Progressive Ratio task that required incrementally greater amounts of physical effort to obtain monetary reward. Breakpoint, the point at which participants was no longer willing to exert effort for a certain reward value, was examined as an index of effort-cost computation. There were no group differences in breakpoint for low, medium, or high value rewards on the Progressive Ratio task. However, lower breakpoint scores were associated with greater severity of avolition and anhedonia symptoms in SZ patients. Findings provide further evidence that impaired effort-cost computation is linked to motivational abnormalities in SZ.

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1. Introduction

Negative symptoms have long been considered a core component of the schizophrenia (SZ) diagnosis (Kraepelin, 1919). Two distinct negative symptom dimensions have been identified, one reflecting reduced motivation (avolition, anhedonia, and asociality) and the other diminished expressivity (alogia, restricted affect) (Blanchard and Cohen, 2006; Horan et al., 2011; Strauss et al., 2012b). There is growing evidence that motivational symptoms play a greater role than expressivity symptoms in determining a range of clinical outcomes (e.g., work and social function, recovery, subjective well-being) (Foussias and Remington, 2010; Strauss et al., 2010; Strauss et al., 2013; Strauss et al., 2012c). Unfortunately, attempts to remediate motivational symptoms via pharmacological treatment have proven ineffective (Fusar-Poli et al., 2015).

Given limited progress in treating motivational symptoms, there has been increased interest in identifying mechanisms leading to reduced goal-directed behavior in SZ (Barch and Dowd, 2010; Strauss et al., 2014). The most straightforward explanation of avolition is that patients do not engage in activities because they do not find them enjoyable. However, experience sampling and laboratory-based studies do not support this hypothesis, indicating that SZ patients have a normal hedonic capacity (Cohen and Minor, 2010; Gard et al., 2007; Kring and Moran, 2008; Llerena et al., 2012; Oorschot et al., 2013; Strauss and Gold, 2012). Rather, motivational symptoms appear to be more closely tied to a range of reward processing abnormalities, such as impaired reward anticipation (Juckel et al., 2006; Waltz et al., 2010), reinforcement learning (Culbreth et al., 2015; Gold et al., 2012; Strauss et al., 2011a; Waltz et al., 2007), and difficulty generating, updating, or maintaining mental representations of value (Gard et al., 2011; Heerey et al., 2007; Kring et al., 2011; Strauss et al., 2011b; Ursu et al., 2011) (for reviews see Barch and Dowd, 2010; Kring and Barch, 2014; Strauss et al., 2014).

Fewer studies have examined the association between motivational symptoms and another aspect of reward processing, effort-cost computation (i.e., determining whether the benefits of an action outweigh the costs needed to obtain them). Pre-clinical studies indicate that dopamine plays a key role in determining the amount of effort an animal will expend to obtain rewards of differing value, with evidence that focal dopamine depletion in the acumbens reduces willingness to exert high effort for higher value rewards and that effort can be increased via the administration of amphetamine (Hodos, 1961; Salamone et al., 1994). Human studies mirror these effects, indicating that individual differences in dopamine release predict willingness to expend effort for high value rewards and that amphetamine administration increases effortful behavior (Treadway et al., 2012; Wardle et al., 2011). Anterior cingulate cortex (ACC) structure and function also predicts effort-cost computation in animal and human studies, potentially via interactions with the dopamine system (Croxson et al., 2009; Endepols et al., 2010; Prevost et al., 2010; Walton et al., 2002; Walton et al., 2009).

There are several reasons to expect that SZ patients would display abnormalities in effort-cost computation, including structural and

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functional ACC abnormalities and over-expression of postsynaptic D2 receptors that influence dopamine function (see Fervaha et al., 2013a; Green et al., 2015 for reviews). Prior studies have primarily examined effort-cost computation in SZ using decision-making tasks that examine the rate of selecting between high effort/high value and low effort/low value options (e.g., Effort Expenditure for Reward Task: Treadway et al., 2009). Results have provided mostly consistent evidence that SZ patients are less willing to select high-effort/high-value options, and that reduced willingness to expend effort for high value rewards predicts greater negative symptom severity or poor functional outcome (Barch et al., 2014; Fervaha et al., 2015; Fervaha et al., 2013b; Gold et al., 2013; Hartmann et al., 2015; Horan et al., 2015; Reddy et al., 2015; Treadway et al., 2015; Wolf et al., 2014); however, Docx et al. (2015) did not find differences between patients and controls. Only one published study has administered a different kind of effort-cost task, the Progressive Ratio paradigm, which is well-validated in the animal literature. In Progressive Ratio tasks, subjects (animal or human) are required to perform an effortful task (e.g., button pressing or climbing a barrier) for certain reward values. Critically, the level of effort needed to obtain the reward is parametrically increased from trial to trial to find the subject's "breakpoint", i.e., the point at which the subject is no longer willing to put forth effort to obtain the reward offered. Wolf et al. (2014) administered a cognitive Progressive Ratio task to SZ patients that required completing incrementally greater numbers of mathematical operations (e.g., 6, 12, 26, 45, 100, 167, 500 trials) to obtain monetary rewards. They found that SZ had lower breakpoint scores than controls, and that lower breakpoint was significantly associated with greater severity of motivational, but not expressivity negative symptoms. Additionally, lower breakpoint scores were predicted by reduced activation of the ventral striatum on a separate reinforcement-learning task. Thus, findings in the literature to date provide relatively consistent evidence for impaired effort-cost computation in SZ and that this deficit is associated with greater severity of negative symptoms and neural mechanisms associated with approach motivation.

In the current study, we aimed to extend the literature on effort-cost computation by administering a physical effort variant of the Progressive Ratio task to evaluate differential associations with motivational and expressivity negative symptom dimensions. Consistent with prior studies (Barch et al., 2014; Fervaha et al., 2013b; Gold et al., 2013; Hartmann et al., 2015; Horan et al., 2015; Reddy et al., 2015; Treadway et al., 2015; Wolf et al., 2014), we hypothesized that SZ would have a lower breakpoint than healthy controls (CN) and that lower break point would predict greater severity of motivational, but not expressivity symptoms on the Brief Negative Symptom Scale (BNSS: Kirkpatrick et al., 2011; Strauss et al., 2012a; Strauss et al., 2012b).

2. Method

2.1. Participants

Participants included 27 outpatients meeting Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR) criteria for schizophrenia or schizoaffective disorder (SZ) and 32 healthy controls (CN). Participants with SZ were recruited from outpatient mental health clinics in upstate New York and advertisements presented on television or the Internet. Patients were evaluated during periods of clinical stability as indicated by no change in medication type of dose within the past 6 weeks. Diagnosis was established via a best-estimate approach based on psychiatric history and the Structured Clinical Interview for DSM-IV (SCID: First et al., 2001). A total of 20 patients were prescribed second-generation antipsychotics, 2 were on first-generation antipsychotics, and 1 was on both first and second generation antipsychotics. Four patients were stably unmedicated and not receiving antipsychotics at the time of testing.

Healthy control participants (CN) were recruited through printed and online advertisements and word of mouth among enrolled participants. All CN underwent a diagnostic interview, including the SCID-I and SCID-II (Pfohl et al., 1997) and did not meet criteria for any current Axis I or Axis II schizophrenia-spectrum personality disorder. CN also had no family history of psychosis and did not meet lifetime criteria for psychotic disorders. No participants met criteria for substance dependence in the last 6 months and all denied lifetime history of neurological disorders associated with cognitive impairment (e.g., Traumatic Brain Injury, Epilepsy).

Individuals with SZ and CN did not significantly differ in age, parental education, sex, or ethnicity; however, SZ had lower personal education than CN (see Table 1).

2.2. Procedures

Participants completed a standard clinical interview that was performed by a clinical psychologist (GPS) or a Master's level clinical psychology doctoral student (SKS) trained to reliability standards (>0.80) using gold standard training videos developed by the first author (GPS). After this interview, patients were rated on the BNSS (Kirkpatrick et al., 2011; Strauss et al., 2012a; Strauss et al., 2012b), Brief Psychiatric Rating Scale (BPRS: Overall and Gorham, 1962), and Level of Function Scale (LOF: Hawk et al., 1975). After the interview, the MATRICS Consensus Cognitive Battery (MCCB: Nuechterlein et al., 2008) was administered and participants completed the Progressive Ratio task.

2.3. Progressive Ratio task

Participants completed a Progressive Ratio task that examined the effects of reward value on willingness to expend physical effort. The task structure, trial sequencing, and reward/effort ratios were modeled after Wolf et al. (2014) (see Table 2). Similar to our earlier paper that used a 2 forced-choice effort-cost paradigm (Gold et al., 2013), the effortful task involved using a videogame controller to make rapid left-right alternating button presses to inflate a single balloon presented on the computer screen until it popped (see Fig. 1). Participants were told that they could choose to play each trial, skip that trial altogether, or quit the trial once it was started if they no longer wished to complete it.

Table 1
Participant demographic and clinical characteristics.

	SZ (n = 27)	CN (n = 32)	Test statistic, p-value
Age	40.30(12.90)	38.06(11.15)	$F = 0.51$, $p = 0.48$
Participant education	12.39(2.14)	14.61(2.16)	$F = 15.65$, $p < 0.001$
Parental education	13.28(2.05)	13.65(2.26)	$F = 0.40$, $p = 0.53$
% male	66.7%	65.6%	$\chi^2 = 0.01$, $p = 1.00$
Race %			$\chi^2 = 1.61$, $p = 0.66$
Caucasian	70.4%	75.0%	
African-American	18.5%	12.5%	
Hispanic	3.7%	9.4%	
Mixed-race	7.4%	3.1%	
BNSS			
Total	22.04(18.94)	–	–
Volition dimension	2.05(1.72)	–	–
Expressivity dimension	1.45(1.67)	–	–
BPRS			
Positive	3.33(1.27)	–	–
Negative	2.18(1.25)	–	–
Disorganized	2.08(0.86)	–	–
Total	46.62 (8.90)		
LOF			
Social	5.92(2.90)	–	–
Work	1.00(2.02)	–	–
Total	16.83(7.19)	–	–

Note. SZ = schizophrenia; CN = control; BNSS = Brief Negative Symptom Scale; BPRS = Brief Psychiatric Rating Scale; LOF = Level of Function Scale.

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