



Inefficient effort allocation and negative symptoms in individuals with schizophrenia



Julie M. McCarthy^{a,b,*}, Michael T. Treadway^{b,1}, Melanie E. Bennett^c, Jack J. Blanchard^a

^a Department of Psychology, University of Maryland College Park, College Park, MD 20742, United States

^b McLean Hospital/Harvard Medical School, Belmont, MA 02478, United States

^c Department of Psychiatry, University of Maryland School of Medicine, Baltimore, MD 21201, United States

ARTICLE INFO

Article history:

Received 18 September 2015

Received in revised form 24 December 2015

Accepted 28 December 2015

Available online 4 January 2016

Keywords:

Schizophrenia

Negative symptoms

Motivation

Effort

Reward

ABSTRACT

Negative symptoms like avolition and anhedonia are thought to involve difficulties with reward processing and motivation. The current study aimed to replicate and extend prior findings that individuals with schizophrenia display reduced willingness to expend effort for rewards and that such reduced effort is associated with negative symptoms, poor functioning, and cognitive impairment. The present study compared the effortful decision making of individuals with schizophrenia ($n = 48$) and healthy controls ($n = 27$) on the Effort Expenditure for Rewards Task (EEfRT). Individuals with schizophrenia chose a smaller proportion of hard tasks than healthy controls across all probability and reward levels with the exception of trials with a 12% probability and low or medium reward magnitude wherein both groups chose similarly few hard tasks. Contrary to expectations, in individuals with schizophrenia, greater negative symptoms were associated with making more effortful choices. Effortful decision making was unrelated to positive symptoms, depression, cognition, and functioning in individuals with schizophrenia. Our results are consistent with prior findings that revealed a pattern of inefficient decision making in individuals with schizophrenia relative to healthy controls. However the results did not support the hypothesized association of negative symptoms and reduced effort in schizophrenia and highlight prior inconsistencies in this literature. Future research is needed to understand what factors may be related to diminished effortful decision making in schizophrenia and the clinical significance of such performance deficits.

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1. Introduction

Negative symptoms, such as anhedonia and avolition, are problematic for individuals with schizophrenia, as they are often persistent (Möller, 2007), correspond to worse social functioning (e.g., Milev et al., 2005), and are an unmet treatment need (e.g., Fusar-Poli et al., 2015). In order to improve treatments, it is important to better understand how negative symptoms are related to mechanisms that could serve as targets for interventions such as neural processes associated with reward processing (Dowd and Barch, 2012) or effortful decision making (Gold et al., 2013).

Motivational deficits are central to the definition of negative symptoms (Horan et al. 2011). Many individuals with schizophrenia demonstrate motivational impairments on laboratory tasks relative to healthy controls (e.g., Barch and Dowd, 2010). In understanding these

motivational deficits it is useful to consider that acting on motivation by allocating effort requires a cost-benefit assessment of task difficulty and reward magnitude (Gendolla and Krüsken, 2002). Individuals with schizophrenia have demonstrated reduced effort allocation or impaired effort-cost computations (Gold et al., 2013) in laboratory tasks such that, compared to healthy controls, they are less likely to choose high-effort options when probability or magnitude of reward is increasing (Barch et al., 2014; Fervaha et al., 2013; Gold et al., 2013; Reddy et al., 2015; Treadway et al., 2015). These findings suggest that individuals with schizophrenia do not display a complete failure to respond to reward, but that they often have difficulty with anticipatory pleasure and recruiting effort to pursue rewards in trials with the greatest probability of reward or reward magnitude.

There are some important inconsistencies in results and methods across these effort studies (Green et al., 2015). The association between negative symptom severity and reduced effort allocation has been quite variable; some studies have shown this association (Barch et al., 2014; Gold et al., 2013; Reddy et al., 2015), but others have not (Fervaha et al., 2013). Gold et al. (2013) found that the association between negative symptoms and effort allocation was only evident in categorical comparisons (high negative symptom individuals versus controls), but correlational analyses examining negative symptoms dimensionally were not significant. Treadway et al. (2015) found a non-significant

* Corresponding author at: Department of Psychology, University of Maryland College Park, College Park, MD 20742, United States.

E-mail addresses: jmccarth@umd.edu (J.M. McCarthy), mtreadway@emory.edu (M.T. Treadway), mbennett@psych.umaryland.edu (M.E. Bennett), jblancha@umd.edu (J.J. Blanchard).

¹ Present address: Department of Psychology, Emory University, Atlanta, GA 30322, United States.

trend between negative symptoms and an index of expected value when covarying for medication dosage. Studies have also differed in the exploration of a range of probability of reward. Some studies have examined effortful decision making at only two probability levels (50% and 88% Barch et al., 2014 and Reddy et al., 2015; 50% and 100% Gold et al., 2013), whereas other studies have examined performance across three probability levels to investigate responding in the context of very low reward probability (12%, 50% and 88%) (Fervaha et al., 2013; Treadway et al., 2015). Three studies reported that individuals with schizophrenia displayed less effortful decision making only in the context of high reward value and/or high probability of reward (Barch et al., 2014; Gold et al., 2013; Treadway et al., 2015); one study found that these individuals chose to expend more effort than controls in trials of low probability and reward value (Fervaha et al., 2013). Beyond exploring symptom correlates, only two studies (Barch et al., 2014; Horan et al., 2015) have examined the relationship of laboratory assessed effort allocation and functioning, finding that reduced effort was associated with worse community functioning. The contribution of cognitive impairment to performance on effort-based assessments in schizophrenia is unclear, though people generally display a bias toward avoiding cognitive effort (preserving cognitive resources) until incentives offset such demands (e.g., Kool et al., 2010). Better cognitive ability has been shown to be associated with a greater likelihood of selecting high-effort response options in individuals with schizophrenia in two studies (Gold et al., 2013; Horan et al., 2015) but cognitive functioning was not related to effort in another study (Fervaha et al., 2013). Given these mixed results, further exploration is critical.

The present study examined how individuals with schizophrenia process reward and probability cues and choose to allocate physical effort for monetary reward across the full range of probability levels on the Effort Expenditure for Reward Task. Given the limitations of other negative symptom rating scales (Blanchard et al., 2011) we utilized the Clinical Assessment Interview for Negative Symptoms (CAINS; Blanchard et al., 2011; Horan et al., 2011; Kring et al., 2013). We also assessed the relationship between EEfRT performance, role functioning, and cognition. Based on prior findings (Barch et al., 2014; Fervaha et al., 2013; Gold et al., 2013; Horan et al., 2015; Reddy et al., 2015; Treadway et al., 2015), we hypothesized that 1) individuals with schizophrenia who are presented with reward and probability cues would choose to complete “easy” tasks more frequently than “hard” tasks compared to controls across reward levels, and 2) that, in individuals with schizophrenia, more severe negative symptoms (especially those involving motivation and pleasure) would be related to less effortful choices, and 3) that less effortful decision making would be related to worse social functioning and cognition impairment.

2. Methods

2.1. Participants

Participants were 48 individuals with schizophrenia ($n = 35$) or schizoaffective disorder ($n = 13$) and 27 controls recruited from outpatient community mental health clinics and flyers posted throughout the greater Baltimore metropolitan area as part of the Collaboration to Advance Negative Symptom Assessment of Schizophrenia (Blanchard et al., 2011; Horan et al., 2011; Kring et al., 2013). Inclusion criteria included 1) ages 18–60, 2) English proficiency, and 3) clinically stable for the schizophrenia group. Exclusion criteria included 1) any co-occurring DSM-IV Axis I disorder; 2) DSM-IV substance abuse within the past month or dependence within the past 6 months; 3) history of intellectual disability; 4) significant head trauma; or 5) neurological disease. Additional exclusion criteria for controls included 1) history of psychiatric diagnosis and 2) taking psychiatric medication.

2.2. Measures

The Effort Expenditure for Reward Task (EEfRT; Treadway et al., 2009) is a computerized monetary reward task that allows participants to engage in effortful decision making in response to reward and probability cues to form an objective assessment of effort. The duration of the task is 20 min, and participants view a pre-randomized fixed series of trials that each include reward cues that range from \$1 (easy task) to \$1.24–\$4.12 (hard task; low = \$1.24 to \$2.00; medium = \$2.01 to \$3.00; high = \$3.01 to \$4.12) and probability cues (low = 12%, medium = 50%, high = 88%) signifying the chance to receive the reward in each trial. Based on this information, participants decide whether to perform an easy task (pressing a computer key 30 times in 7 s) with the second digit of their dominant hand or a hard task (pressing a computer key 100 times in 21 s) using the fifth digit of their non-dominant hand. After each trial, participants receive feedback about whether they won the reward.² Participants reviewed task instructions and demonstrated the ability to select easy and hard tasks based on probability and reward cues in practice trials under the supervision of a research assistant. The assistant asked participants if they had any questions and if they understood the probability levels, providing additional clarification as needed. Participants were told that they would receive money from two of randomly selected “incentive trials” in addition to base-compensation as part of the larger study, and all participants actually received \$8 for the incentive trials (the maximum reward rounded to the nearest dollar) at the end of the study.

To confirm eligibility and diagnostic status, participants completed the Structured Clinical Interview for DSM-IV (SCID-I/P; First et al., 1996). The Clinical Assessment Interview for Negative Symptoms (CAINS; Blanchard et al., 2011; Horan et al., 2011; Kring et al., 2013) was used to assess negative symptoms. The CAINS is a 13-item interview that assesses negative symptoms in two domains, 1) motivation and pleasure (MAP) and 2) expression (EXP). The MAP subscale includes items of avolition and anhedonia tapping into perceived value and effort, as well as anticipatory and consummatory pleasure across social, recreational, and work/education contexts, whereas the EXP subscale assesses the expression of emotion (e.g., alogia, blunted affect). Higher CAINS scores indicate more severe negative symptoms. The positive symptom subscale from the 24-item Brief Psychiatric Rating Scale (BPRS; Ventura et al., 1993) was used to measure positive symptoms, and the Calgary Depression Scale for Schizophrenia (CDSS; Addington et al., 1992, 2014) was used to assess depressive symptoms (a score of 6 indicates probable depression).

The Role Functioning Scale (RFS; Goodman et al., 1993; McPheeters, 1984) was administered to assess functioning in four areas: Working Productivity, Independent Living/Self Care, Immediate Social Network Relationships, and Extended Social Network Relationships. Cognitive functioning was assessed with the Brief Cognitive Assessment Tool for Schizophrenia (BCATS, Hurford et al., 2011), which includes category fluency, digit symbol, and trail making tests. Overall intelligence was estimated using the Full Scale Intelligence Quotient (FSIQ) from the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001).

2.3. Procedure

This study was approved by the Institutional Review Board at the University of Maryland School of Medicine. Assessments were administered by trained, master's level interviewers. Participants completed the above measures in a fixed order as part of a larger battery of assessments, and they received \$50.00 compensation for their time.

² Based on pilot data in patients suggesting difficulty in discriminating the details of each trial, we used text rather than only color to specifically indicate probability level and hard vs. easy choices in each trial. The task was also modified to pause to allow participants to choose the hard vs. easy task instead of randomly assigning them to one or the other if they did not choose quickly enough.

2.4. Data analysis

Analyses were conducted in SPSS 21. One-way ANOVAs and Pearson Chi-Squared analyses were used to examine demographic and clinical characteristics across groups. We used generalized estimating equation (GEE) models to test the effects of probability, reward, and group on effortful decision making. For each participant, up to the first 50 EEfRT trials were included in analyses, which is consistent with the original EEfRT study (Treadway et al., 2009). Participants who attempted less than 50 trials were included in analyses, and the difference between 50 and the number of trials that these participants attempted was missing data that comprised only 2.6% of the total effortful decision making data. Pearson correlations were conducted to examine the relationship between the proportion of hard tasks chosen on the EEfRT with clinical and functioning variables. We examined relationships with EEfRT trials in the high reward and high probability conditions, as well as the difference between high and low reward and probability to increase comparisons with similar studies (e.g., Barch et al., 2014; Horan et al., 2015); individuals who chose either all hard or all easy tasks were excluded from the difference score analyses.

3. Results

3.1. Sample characteristics

Demographic and clinical characteristics are presented in Table 1. The control group reported significantly more years of education, better performance on the BCATS category fluency, digit symbol coding, and trail making tests, and greater estimates of FSIQ compared to the schizophrenia group. Independent t-tests and chi-square analyses indicated no significant differences with respect to age, gender, or race across groups.

Table 1
Demographic and clinical characteristics.

	Schizophrenia (n = 48)		Control (n = 27)		P
	M	SD	M	SD	
Age	48.27	7.51	44.22	13.12	>.05
Gender (% (frequency))					>.05
Male	62.5%	(30)	51.9%	(14)	
Female	37.5%	(18)	48.1%	(13)	
Race (% (frequency))					>.05
African-American	89.6%	(43)	70.4%	(19)	
Caucasian	8.3%	(4)	25.9%	(7)	
American Indian	2.1%	(1)	0%	(0)	
Multiracial	0%	(0)	3.7%	(1)	
Education	11.02	2.19	14.04	3.06	<.001
BCATS					
Category fluency	38.96	8.67	47.15	10.45	<.001
Digit symbol	5.70	5.99	8.96	3.26	<.05
Trail making	161.00	62.24	76.48	34.99	<.001
Estimated FSIQ	87.46	8.72	104.30	13.39	<.001
CAINS	17.78	8.42	4.22	4.19	<.001
MAP	11.26	6.13	3.56	2.13	<.001
EXP	6.44	3.89	.67	1.78	<.001
BPRS positive	11.75	5.96	7.07	.27	<.001
CDSS	6.90	6.18	.41	.84	<.001
RFS total	19.02	4.14	27.37	1.47	<.001
Working productivity	2.79	2.05	6.70	1.17	<.001
Independent living, self-care	5.71	1.50	7.00	.00	<.001
Immediate social network	5.71	1.86	6.85	.36	<.001
Extended social network	4.81	2.33	6.81	.68	<.001

BCATS = Brief Cognitive Assessment Tool for Schizophrenia; CAINS = Clinical Assessment Interview for Negative Symptoms; MAP = Motivation and Pleasure; EXP = Expression; BPRS = Brief Psychiatric Rating Scale; CDSS = Calgary Depression Scale for Schizophrenia; RFS = Role Functioning Scale.

3.2. Effortful decision making

Estimated marginal means and odds ratios for the EEfRT are presented in Table 2. We conducted GEE analyses using an unstructured correlation matrix and a binary logistic distribution to model the dichotomous outcome of selecting the hard vs. easy task in the EEfRT. Wald Chi-Square statistics with a two-tailed Type III sum of squares approach were used to assess main effects and interactions. We conducted a full-factorial GEE analysis that included main effects of group (schizophrenia vs. controls), probability (12% vs. 50% vs. 88%), and reward (low vs. medium vs. high), two-way interactions of interest (group × probability, group × reward, probability × reward), and the three-way interaction between group, probability, and reward. Between subjects variables included group, probability, and reward, whereas the trial number served as the within subjects variable.

3.2.1. Main effects

The main effect of group was significant in that the control group displayed greater effort (proportion of hard tasks chosen) than the schizophrenia group on the EEfRT, $\chi^2(1) = 21.05, p < .001$. The main effects of probability and reward on choosing to complete the hard task were also significant, $\chi^2(2) = 34.33, p < .001$ and $\chi^2(2) = 23.97, p < .001$, respectively, in that participants overall chose the hard task more often in the context of increasing probability of reward (12%, 50%, 88%) and greater reward amount (low, medium, high) (p 's < .001). Additionally, there were no significant group differences in total trials attempted, but controls completed (the required number of button presses within the time limit for up to 50 trials) significantly more trials than individuals with schizophrenia. The proportion of completed trials did not significantly correlate with the proportion of hard tasks chosen within or across diagnostic groups ($p > .05$).

3.2.2. Group effects and interactions

The two-way interactions between group and probability, $\chi^2(2) = 57.59, p < .001$, group and reward $\chi^2(2) = 18.39, p < .001$, and probability and reward $\chi^2(4) = 10.73, p < .05$, were all significant. Planned comparisons revealed that controls chose the hard task significantly more

Table 2
Proportion of hard tasks chosen on the EEfRT.

	Schizophrenia (n = 48)		Control (n = 27)		p	Odds ratio
	Estimated marginal means (SE)					
Probability					>.05	
12%	.22 (.03)		.32 (.04)			.73
50%	.20 (.04)		.57 (.06)		<.001	.90
88%	.21 (.04)		.62 (.05)		<.001	–
Reward level						
Low	.19 (.04)		.43 (.05)		<.001	.52
Medium	.18 (.03)		.53 (.55)		<.001	.52
High	.26 (.04)		.55 (.51)		<.001	–
Probability × reward						
12%						
Low	.21 (.03)		.29 (.04)		>.05	1.74
Medium	.23 (.04)		.24 (.03)		>.05	1.75
High	.23 (.04)		.46 (.06)		<.01	–
50%						
Low	.18 (.04)		.47 (.06)		<.001	1.16
Medium	.15 (.03)		.69 (.07)		<.001	.83
High	.27 (.04)		.55 (.05)		<.001	–
88%						
Low	.18 (.04)		.56 (.06)		<.001	–
Medium	.19 (.04)		.68 (.05)		<.001	–
High	.29 (.04)		.63 (.06)		<.001	–
	M (SD)					
Total trials	56.40 (12.15)		56.70 (9.12)		.90	
Percent completed	89.75% (17.02)		97.04% (5.47)		.003	

often than individuals with schizophrenia across reward and probability levels, with the exception of no group difference on trials with only a 12% probability of reward (see Table 2). Controls displayed a pattern of increasing proportion of hard tasks chosen with both higher probability and reward magnitude, but only the increase from 12% to 50% was significant ($p < .001$). On the other hand, individuals with schizophrenia demonstrated relatively little change between the three probability levels (approximately 2% difference), yet planned comparisons indicated that these individuals chose significantly more hard tasks in trials with 12% relative to 50% probability of reward ($p < .05$); the difference between 50% and 88% probability was non-significant. Individuals with schizophrenia also chose the hard task significantly more often in trials with high reward relative to medium reward ($p < .001$), but the difference in effort allocation between low and medium reward trials was negligible. Additionally, the two-way probability and reward interaction suggested that participants chose significantly more hard tasks when the probability of reward increased from 12% to 50% regardless of reward amount (p 's $< .05$). However, when the probability of reward increased from 50% to 88%, participants also chose the hard task significantly more than the easy task but only for high reward trials ($p < .05$).

Finally, the three-way group \times probability \times reward interaction was significant, $\chi^2(4) = 55.65, p < .001$. Planned comparisons indicated that healthy controls chose the hard task significantly more often than individuals with schizophrenia across probability and reward levels (p 's $< .01$)³ with the exception of both groups choosing similar proportions of the hard task in trials with low and medium reward magnitude and only a 12% probability of receiving the reward (Fig. 1).⁴

3.3. Correlations with effortful decision-making

3.3.1. Clinical symptoms

Within individuals with schizophrenia, the expression domain of negative symptoms was significantly correlated with effortful decision making on the EEfRT at the high probability and reward levels but not with the difference between high and low probability levels or the difference between high and low reward levels (see Table 3). Given that depression and the motivation and pleasure domain of negative symptoms share related constructs (e.g., anhedonia), we hypothesized that greater depression may be related to elevated negative symptoms and worse performance on the EEfRT. Because depression was significantly correlated with motivation and pleasure ($r = .38, p < .01$) but not expression negative symptoms ($r = -.08, p > .05$), we controlled for depression and conducted partial correlations between the CAINS_MAP and proportion of hard tasks chosen. After controlling for depression, the motivation and pleasure domain of negative symptoms was

partially correlated with effortful decision-making in the high 88% probability ($r = .35, p < .05$) and reward conditions ($r = .33, p < .05$). Notably these correlations were in the opposite direction that was predicted, with more severe MAP symptom ratings associated with making greater effortful choices. In the schizophrenia group, positive symptoms and depression were not significantly correlated with effortful decision making.⁵

3.3.2. Cognition and functioning

In the schizophrenia group, the proportion of choosing the hard task on the EEfRT was not significantly correlated with cognitive ability (BCATS; estimated FSIQ) or role functioning (RFS) (p 's $> .05$).⁶

4. Discussion

We hypothesized that individuals with schizophrenia would exhibit overall less effortful decision making on the EEfRT (choosing fewer hard tasks) compared to healthy controls. Our results supported this hypothesis: healthy controls chose the hard task more often than individuals with schizophrenia across all trials except in cases with the lowest probability (12%) of receiving low and medium reward values where both groups allocated a similar amount of effort. Additionally, the schizophrenia group chose the hard task more often with 12% probability relative to 50% probability of reward collapsing across reward levels, and they chose the hard task more often than controls in trials with 12% probability regardless of reward level when excluding invariant responders. Thus, individuals with schizophrenia displayed inefficient effort allocation for trials in which it would be most advantageous to put forth more effort, as well as trials when it would appear strategic to conserve effort. These findings are consistent with previous studies that have found less effortful behavioral choices in individuals with schizophrenia compared to controls, especially in trials with the most certain and highest reward (Barch et al., 2014; Fervaha et al., 2013; Gold et al., 2013; Treadway et al., 2015). These results depart from some prior studies that found group differences in effort only in the condition with the highest probability of reward (Barch et al., 2014; Gold et al., 2013) but our findings are consistent with the Treadway et al. (2015) study showing group differences extending to lower probability levels. Relatedly, individuals with schizophrenia showed essentially the same response selections across all probability levels, failing to show any increase in effort with increasing probability of reward; a pattern observed in several prior using the EEfRT or similar tasks (e.g., Treadway et al., 2015), though not all (e.g., Reddy et al., 2015).

We also hypothesized that negative symptoms would be related to less effortful decision making in the schizophrenia group. However, more severe expression negative symptoms (e.g., *alogia*) were unexpectedly related to choosing the hard task *more* often, but they were unrelated to the difference scores in proportion of hard tasks chosen between high and low levels of probability and reward. Additionally, motivation and pleasure negative symptoms showed a similar relationship with effortful decision making only when controlling for depression. As summarized above, prior findings regarding the correlation between negative symptoms and reduced effortful choices in schizophrenia are variable. Two studies found this association (Barch et al., 2014; Horan et al., 2015), but others have found an association between negative symptoms and effort allocation only in categorical comparisons (high negative symptom individuals versus controls and no difference between high and low negative symptom individuals) but not correlational analyses (Gold et al., 2013), non-significant trend results

³ This finding held when examining group differences of how expected value of reward (EV = probability of reward \times reward amount) impacted decision making in a subsample (27 HC, 31 SZ) with varied effortful decision making necessary to calculate beta weights. We calculated betas from subject level regressions of EV predicting easy/hard choices; larger betas indicating greater association between EV and effortful decision making. Similar to the GEE analysis, HC had significantly higher EV betas than individuals with SZ. Within groups, HC betas were significantly greater than zero, whereas there was no difference in the SZ group, consistent with other studies (e.g., Treadway et al., 2015). EV betas were not significantly correlated with CAINS_MAP, but they were significantly correlated with CAINS_EXP $r = 0.235, p < .05$.

⁴ Of note, 17 (35.4%) of the SZ group and 0% of HC chose only hard or only easy tasks on the EEfRT. Within these invariant responders, 13 (76.5%) exclusively chose the easy task, but there were no significant differences in negative symptoms, depressive symptoms, estimated Full Scale IQ, or education between variant and invariant responders within the SZ group. When including only variant responders in the GEE analyses, there was a significant three-way interaction of group, probability, and reward. For trials with 12% probability, SZ group chose the hard task more often than HC regardless of reward amount. For trials with 50% probability, the SZ group chose the hard task more often HC for low rewards, but the HC group chose the hard task more often than SZ for medium rewards; no difference for high rewards. For trials with 88% probability, SZ and HC groups were similar except HC chose the hard task more often for trials with medium reward. When excluding invariant responders, correlations between effortful decision making and negative symptoms became non-significant.

⁵ Of note, two SZ participants with missing data on the CAINS_MAP and one SZ participant with missing data on the CAINS_EXP were excluded from the correlational analyses. Additionally, the proportion of hard tasks chosen on the EEfRT, the BPRS positive symptom scale, and the CDSS were not normally distributed, but results remained significant when we ran the analyses with arcsine, log10, and natural log transformations, respectively.

⁶ The estimated FSIQ and RFS variables were not normally distributed, but when the analyses were rerun with log10 transformations, the results remained non-significant.

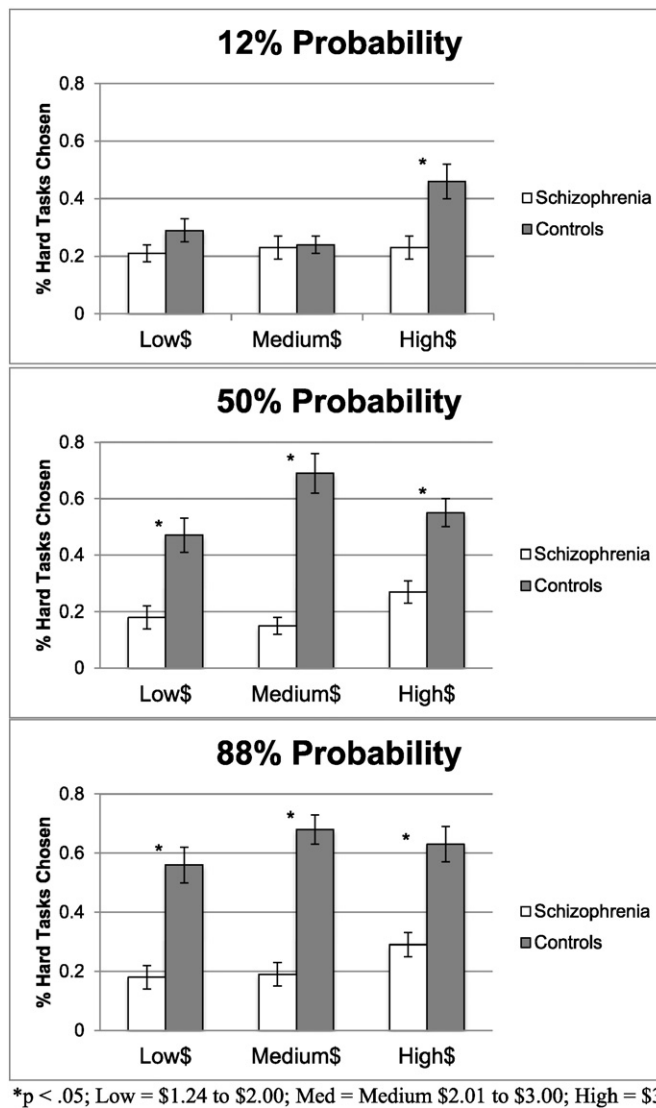


Fig. 1. Proportion of hard tasks chosen on the EEfRT. *p < .05; Low = \$1.24 to \$2.00; Med = Medium \$2.01 to \$3.00; High = \$3.01 to \$4.12.

when covarying for medication (Treadway et al., 2015), or no relationship (Fervaha et al., 2013). Put in this context, our results raise questions about why negative symptoms in the present schizophrenia sample were associated with choosing the hard task more often.

Although unexpected, our results are consistent with similar EEfRT research conducted in non-schizophrenia samples. We recently reported that greater social anhedonia in a non-clinical sample was associated with more effortful response choices in conditions when the probability of reward is uncertain (McCarthy et al., 2015). It may be that for those individuals who experience deficits in expression and experience/anticipation of pleasure and motivation in their daily lives, the opportunity to engage in a novel game-like task that involves winning money by

completing a task within their ability is a uniquely rewarding experience worth the effort of the hard task. This would be consistent with findings that individuals with elevated social anhedonia value money similarly to controls (Xie et al., 2014) and that individuals with schizophrenia value money as much and even more than controls for small amounts (\$10) (Horan et al., 2015), though these findings were unrelated to measures of negative symptoms. Additionally, our sample characteristics may have contributed to our unexpected findings and limited variability of low effortful responding across probability and reward levels in the schizophrenia group relative to prior studies. Individuals with schizophrenia in the present study were older (mean = 48.27) and less educated (mean = 11.02 years) than participants in prior

Table 3

Bivariate correlations between proportion of hard tasks chosen and symptoms.

	High probability 88%	High reward (\$3.01 to \$4.12)	High-low probability	High-low reward
CAINS_MAP	.27	.25	.09	.02
CAINS_EXP	.31 ^a	.35 ^a	-.13	.16
BPRS positive	.19	.12	.21	-.10
CDSS	-.14	-.13	-.12	-.03

CAINS_MAP = Clinical Assessment Interview for Negative Symptoms – Motivation and Pleasure Scale; CAINS_EXP = CAINS Expression Scale; BPRS = Brief Psychiatric Rating Scale – Positive Symptoms; CDSS = Calgary Depression Scale for Schizophrenia. Of note, correlations examining difference scores (e.g., high-low probability) exclude invariant responders.

^a p < .05.

studies using the EEfRT with mean age ranging from 28 to 41 years and mean education ranging from 12.9–13.7 years (Barch et al., 2014; Fervaha et al., 2013; Treadway et al., 2015) in the schizophrenia group. Perhaps these characteristics yield different appraisals of which rewards are worth expending effort. Additionally, our findings raise concerns about the robustness and replicability of the association between clinician rated and self-reported measures of negative symptom severity and diminished effort for rewards in schizophrenia (as measured by physical effort for monetary rewards) across task variations and data analytic strategies, as there is no one consensus or gold standard effortful decision making task nor a consistent strategy to examine its relationship with negative symptoms (Reddy et al., 2015). Differences in negative symptom assessments and effort task formats across studies (see Green et al., 2015 for review), as well as findings that self-reported negative symptoms may be greater than hedonic deficits observed in the laboratory (e.g., Pizzagalli, 2010) may impact the association between negative symptoms and effortful decision making. Moreover, a recent ecological momentary assessment study observed a marked disconnect between patient reports of anticipatory pleasure and subsequent completion of effortful action, raising questions about how well self-reported negative symptoms should be expected to map onto behavioral responses (Gard et al., 2014).

Interestingly, functioning and cognition were not significantly correlated with effort allocation in individuals with schizophrenia. In the present study, effortful performance was not merely secondary to cognitive impairment in schizophrenia and may not directly translate to role functioning. Our findings are consistent with one study (Fervaha et al., 2013) but not others that reported associations between effortful choices and cognitive ability (Gold et al., 2013; Horan et al., 2015) and functioning (Barch et al., 2014), particularly work functioning (Horan et al., 2015). It may be that the monetary focus of the EEfRT has limited utility in accurately measuring the effort involved with negative symptoms and functioning that assesses social and recreational domains in addition to work/educational contexts.

5. Limitations and conclusions

This study has several limitations. Our sample was largely male, African-American and demonstrated low educational achievement and cognitive impairment. These characteristics, although representative of an urban outpatient setting, may limit generalizability. All individuals with schizophrenia were receiving medications, which may have an impact on cognitive functioning or response to reward. Because medication types and dosages were clinically determined, it is not possible to meaningfully examine the potential contribution of medications on task performance or symptoms (Blanchard and Neale, 1992; Green et al., 2015). The version of the EEfRT used in the present study was similar to the original study in that it did not individually calibrate the number of button presses required for successful completion of hard and easy tasks. The task may have been more difficult for participants with motor difficulties, potentially impacting task completion, but finger tapping ability appears to be unrelated to choosing the hard task (Barch et al., 2014). Further, consideration of the definition of reward, differences in effortful decision making across reward types (e.g., physical, social, monetary), transdiagnostic patterns, and variations in such decisions over time in response to past experience is warranted to clarify the specificity of our results and enhance generalizability of laboratory findings to community functioning.

This study sought to assess the relationship between negative symptoms and effort in individuals with schizophrenia. Our results contribute to a growing literature suggesting that individuals with schizophrenia inefficiently choose to expend effort relative to controls, particularly in conditions when it would be most advantageous to allocate more effort. The fact that negative symptoms were associated with effortful decision making in an unexpected direction emphasizes the need to carefully

disentangle the factors involved with assessing effort and valuing reward.

Role of funding source

Funding for this research project was provided by the National Institute of Mental Health (NIMH) grants (ROOMH102355 to MTT, K02-MH079231 and R01-MH082839 to JJB) and the National Institutes of Health/NIMH Schizophrenia Research Training Program (T32-MH20075) to JJB.

Contributors

Julie McCarthy completed the literature search and conducted analyses. Jack Blanchard and Julie McCarthy were responsible for study design/development and drafting of the manuscript. Michael Treadway designed the study task and assisted with manuscript preparation. Melanie Bennett oversaw data collection and assisted with manuscript preparation. All authors contributed to and have approved the final manuscript.

Conflict of interest

Dr. Blanchard has consulted with and served on a scientific advisory board for Genentech/Roche. MTT has served as a paid consultant to Avanir Pharmaceuticals and the Boston Consulting Group. No funding or sponsorship was provided by these companies for the current work, and all views expressed herein are solely those of the authors. All other authors declare that they have no conflicts of interest.

Acknowledgment

We thank our research assistant, Asia Malik, M.S., and the research participants who made this project possible.

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