



Psychotic like experiences as part of a continuum of psychosis: Associations with effort-based decision-making and reward responsivity

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ABSTRACT

Research examining psychotic disorders typically involves comparison between individuals with a clinical disorder and healthy controls. However, research suggests that psychotic symptoms, such as delusions and hallucinations, may exist on a continuum ranging from variation in healthy individuals to diagnosable psychotic disorders. On this continuum, some individuals endorse occasional psychotic like experiences (PLEs) that do not cause sufficient impairment or distress to warrant a clinical diagnosis. Given this continuum model, one might expect to observe impairments in those with PLEs in the same behavioral domains impaired in schizophrenia. Thus, we examined two domains typically impaired in schizophrenia, effort allocation and reward responsivity, in a large university sample ($n = 126$). Participants completed tasks assessing effort-based decision-making, reward responsivity, and questionnaires assessing PLEs. Greater PLEs were associated with greater effort expenditure regardless of probability of receiving a reward or reward value. Higher PLEs were related to greater positive feelings when receiving rewards. Importantly, these relationships remained the same when controlling for other symptoms such as depression, anhedonia, and anxiety. These findings suggest that PLEs may be associated with hypersensitivity to reward at the less severe end of the psychotic continuum, with effort to attain a reward expended in a potentially inefficient manner. This pattern is consistent with models of hyperdopaminergic states in psychotic individuals not taking antipsychotic medications, given the role of dopamine in modulating effort allocation and reward anticipation.

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1. Introduction

Psychotic symptoms, such as delusions and hallucinations, are most common and debilitating in people with clinically diagnosed psychotic disorders. However, recent research suggests that psychotic like experiences (PLEs) do not just occur in those with diagnosable psychotic disorders; instead they exist on a continuum ranging from no psychotic like experiences to those with a clinically diagnosable disorder (van Os, 2003). It has been estimated that 8–20% of the population (Koike et al., 2018; Scott et al., 2006) considered to be clinically healthy also endorse having PLEs. The continuum model of PLEs suggests that people on one end of the continuum endorse few to no PLEs, but that as you move to the other end, the number of PLEs and degree of distress they elicit increases. In contrast to people with a diagnosed psychotic disorder, the experience of PLEs in nonclinical populations is typically not debilitating and does not cause frequent distress. Given this continuum

model, it is important to examine whether domains impacted in individuals with clinical disorders are also impaired in individuals with PLEs. Two domains implicated in psychotic disorders are impairments in effort-based decision-making and reward responsivity.

A central part of schizophrenia is a reduction in motivated behavior (Barch and Dowd, 2010; McCarthy et al., 2016). Effort-based decision-making involves the calculation of the amount of effort a task requires in comparison to the reward magnitude (Treadway et al., 2009; Westbrook and Braver, 2015). Research has shown that people with schizophrenia are less likely, in comparison to healthy controls, to choose high-effort conditions even as reward increases (Culbreth et al., 2017; Fervaha et al., 2013; Gold et al., 2013). Robust negative associations have been found between negative symptom severity and effort allocation in clinical samples (Barch et al., 2014; Culbreth et al., 2016; Hershenberg et al., 2016; Moran et al., 2017; Reddy et al., 2015; Yang et al., 2014). However, evidence for an association between positive symptom severity and effort among clinical samples is limited. Some studies have found significant associations between positive symptoms and effort-based decision-making (Barch et al., 2014; Serper et al., 2017), but many fail to find associations (Fervaha et al., 2013, 2015; Gold et al., 2012, 2015; Hartmann et al., 2015; Strauss

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et al., 2016; Wolf et al., 2014) and others do not report examining such relationships (Culbreth et al., 2016; Docx et al., 2015; Moran et al., 2017; Treadway et al., 2015). As of yet, there is no work examining the relationships between effort-based decision-making and PLEs in non-clinical samples, which could help inform relationships to positive symptoms.

One intriguing possibility is that the nature of effort-based decision-making deficits might be quite different among unmedicated individuals experiencing PLEs given the potential role of the dopamine system in effort-based decision-making (for a review, see (Fervaha et al., 2013)). There is a large body of research in rodents and non-human primates suggesting that intact dopamine function is critical for effort allocation (Assadi et al., 2009; Floresco et al., 2008; Kurniawan et al., 2011; Salamone et al., 2009; Salamone and Correa, 2012). Reducing dopamine availability reduces animal's willingness to work for reward (Assadi et al., 2009; Floresco et al., 2008; Kurniawan et al., 2011; Salamone and Correa, 2012), while augmenting it increases willingness to work for reward (Floresco, 2013). Antipsychotics block D2 receptors to varying degrees, modulating the dopaminergic pathway (Nordström et al., 1993; Richelson and Souder, 2000). As such, these medications may influence the amount of effort someone is willing to allocate towards a rewarding outcome. However, individuals with psychosis early in the course of illness and those not taking medications show indications of enhanced dopamine activity, including both increased presynaptic DA available, greater DA release in response to amphetamine, and increased D2 receptor availability (Laruelle et al., 1999). As such, individuals with frequent PLEs who are not taking medications may have increased DA function as well, potentially leading to greater willingness to exert effort, although this remains to be formally tested. This might contrast with a reduced willingness to work among individuals with schizophrenia who are taking medications intended to reduce enhanced activity in the DA system.

Another relevant domain impaired in schizophrenia is reward responsiveness. Anhedonia, a diminished ability to experience pleasure, is a negative symptom associated with schizophrenia (Wolf, 2006). However, while people with schizophrenia rate themselves as having high levels of anhedonia (Horan et al., 2008), when they are presented with emotional stimuli (e.g., money, positive pictures, tasty food) people with schizophrenia report just as much pleasure as healthy controls (Cohen and Minor, 2010). Instead, there is evidence that people with schizophrenia show impairments in their anticipatory response to pleasurable experiences (Arrondo et al., 2015; Gard et al., 2007; Moran and Kring, 2018; Radua et al., 2015; Wynn et al., 2010). In tasks assessing reward responsivity participants are asked to anticipate how they would feel when receiving a reward or loss (anticipatory) and then asked how they feel upon receiving the reward/loss (consummatory). Studies assessing both emotional experience (Chan et al., 2010; Gard et al., 2006; Moran and Kring, 2018; Mote et al., 2014) and physiologic responses (Arrondo et al., 2015; Moran and Kring, 2018; Radua et al., 2015; Wang et al., 2015; Wynn et al., 2010) during anticipation and receipt of reward suggest impairments in anticipatory responses but not consummatory responses to reward.

In schizotypy, which can be thought of as a phenotypic expression of PLEs (Fonseca and Debbané, 2017), having more negative symptoms is associated with higher unpleasant ratings to reward (Cohen et al., 2012). Examining anticipation in schizotypy, (Yan et al., 2016) found that those with negative schizotypy showed reduced activation in the ventral striatum during anticipation of reward, more similar to what is found in clinically diagnosed schizophrenia. However, they also found that those with positive schizotypy showed enhanced right ventral lateral prefrontal activity during anticipation of reward. Thus, it may be that the nature of reward responsivity patterns may be different among individuals with PLE in a non-clinical sample as compared to individuals with schizophrenia. Further, since the research on reward and schizotypy thus far has focused primarily on relationships to negative symptoms, it is important for research to

example potential relationships of reward responsivity to positive symptoms such as PLEs.

The goal of the current study was to examine the relationship between PLEs, effort-based decision-making and reward responsivity in a university sample. While previous research has focused on how negative symptoms relate to effort-based decision-making and reward responsivity, the current study looks to better understand the relationship between these mechanisms and PLEs in a nonclinical sample. First, we examined the relationship between PLEs and performance on an effort-based decision-making task. We also examined the relationship between anticipatory and consummatory response to reward and loss and its relationship to PLEs. Given the mixed and/or limited literature described above linking positive symptoms to either effort-based decision-making or reward responsivity, we focused on examining whether individuals with PLEs show the same patterns as shown in individuals with schizophrenia, which would be reduced effort-based decision making at higher reward and probability levels, but intact reward responsivity.

2. Methods

2.1. Participants & procedure

Participants were ($n = 126$) members of the Washington University in St. Louis community. Exclusion criteria included persons under the age of 18 and non-native English speakers. One participant was excluded for being two standard deviations above the mean on our PLE measure. These participants were participating in a larger study examining relationships between motivation, emotion, reward, and cognition to psychotic like experiences, mood symptoms and anhedonia. The Washington University Institutional Review Board approved the protocol used in this study and all participants provided written informed consent. Participants completed one 2-h visit to the laboratory and were compensated for their time and effort. During the visit, participants completed a task assessing consummatory/anticipatory pleasure, an effort-based decision-making task, and questionnaires assessing symptom domains, as described in more detail below.

2.2. EEfRT task

We used a modified version of the Effort Expenditure for Rewards Task originally created by Treadway and colleagues (Barch et al., 2014; Treadway et al., 2009) and used in previous studies (Moran et al., 2017). We used this task to assess participants' willingness to expend effort, based on the likelihood of winning various amounts of monetary reward. On each trial, participants were asked to choose between two different task difficulty levels (easy or hard) in order to obtain a monetary reward. The hard task required the participant to use their non-dominant pinky finger to press a key approximately 100 times in 21 s giving the participant a chance to win a reward between \$1.10–\$4.20. The easy task required the participant to use their dominant hand to press a key 20 times in 7 s giving the participant a chance to win a reward of \$1. At the start of each trial, participants were informed as to whether the current trial gave them a 50% or 88% probability of earning the reward if successfully completed. Participants completed 3 practice trials and 54 regular trials. Participants were told at the start of the trial that the computer would select and summate three randomly selected trials to count as payment at the end of the task. Participants were paid between \$3 and \$13 for completing this task. Outcome variable was percentage of total hard choices within reward levels. We chose to group reward levels into quartiles, with low (<\$1.86), medium (\$1.96 to <\$2.77), high (\$2.77 to <\$3.58) and highest (≥\$3.58).

2.3. Gambling task

We modified a Gambling task used in previous studies to assess neural response during anticipatory and consummatory reward (Forbes et al., 2009). In the modified version, we assessed participant's self-reported pleasure while anticipating and receiving gains and losses. Each trial began with the participant being asked to guess whether the number on a card to be revealed would be higher or lower than 5, with possible numbers ranging from 1 to 10. Next, participants were presented with a cue indicating trial type. On potential reward trials participants were shown the amount of money they could win if they guessed correctly (large reward = +\$1.00; smaller reward = +\$0.50). On potential loss trials they were shown the amount of money they could lose if they guessed incorrectly (larger loss = −\$0.50; smaller loss −\$0.25). Participants were then asked how much pleasure they anticipated feeling given the current trial type. Participants then received feedback based on the outcome of their choice (on reward trials win or not win; on loss trials lose or not lose) and were shown the amount of money won/loss. Lastly, participants rated how much pleasure or displeasure they felt after receiving feedback on their gains and losses (consummatory). Participants rated their feelings on a 5-point scale ranging from 1 “unhappy” to 5 “happy.” During the task, participants were unaware that the outcomes were fixed and predetermined such that each participant received \$5.25 for completing this task. We calculated average response ratings for the anticipatory and consummatory conditions within the high and low reward and loss conditions.¹

2.4. Psychotic like experience measure and participant selection

We used the Youth Psychosis At-Risk Questionnaire (YPARQ; (Ord et al., 2004)) to assess psychotic like experiences. On this questionnaire, participants are asked if they have experienced a variety of positive symptoms (e.g. Do you hold beliefs that others would find unusual or different or bizarre?) and asked to answer either “yes”, “no”, or “maybe.” We summed the total score for each participant (Chronbach's alpha in our sample was equal to 0.84 representing good internal consistency for the measure).

2.5. Self-report measures of anhedonia, depression and anxiety

Participants also completed the following self-report measures: (a) Snaith-Hamilton Pleasure scale (Snaith et al., 1995); higher equals less anhedonia), (b) Center for Epidemiologic Studies Depression Scale Revised (CESD-R-10) (Radloff, 1977) to assess depression and the (c) Mood and Anxiety Symptoms Questionnaire (MASQ) (Wardenaar et al., 2010) to assess anxiety.

2.6. Data analysis

We conducted a repeated measures ANOVA examining probability (50% and 88%) and reward (low, medium, high, and highest reward value) for the EFFRT task. We also included YPARQ score, age, education, and gender as covariates. For the gambling task data, we conducted paired samples *t*-tests to examine differences between self-reported emotional response after receiving a reward and after losing money. We also conducted linear regressions using YPARQ, age, education and gender to predict total hard choice and reward responsivity. Finally, we conducted partial correlations controlling for depression, anhedonia, and anxiety to see if these symptom domains had an effect on our initial correlations between effort, reward, and PLEs.

¹ We collapsed ratings for high and low reward, but we saw a similar pattern of findings when independently analyzing ratings based on reward value.

3. Results

3.1. Effort allocation on the EFFRT task

Table 1 presents the demographic characteristics of the sample and the means and standard deviations for scores on the measures. We found significant main effects of Probability ($F(1, 112) = 8.40, p < .01, \eta_p^2 = 0.07$) and Reward ($F(3, 112) = 8.13, p < .001, \eta_p^2 = 0.07$) with a greater chance of the participants choosing the hard task choice on the 88% versus 50% condition and greater willingness to expend effort in higher reward versus lower reward conditions. There was also a Probability X Reward interaction, ($F(3, 112) = 4.26, p < .01, \eta_p^2 = 0.04$). As can be seen in Fig. 1, while the effect of reward was present for both probability levels, simple effect tests demonstrated that it was stronger in the 88% condition ($F(3, 112) = 10.07, p < .001, \eta_p^2 = 0.08$) than in the 50% condition ($F(3, 112) = 3.45, p < .017, \eta_p^2 = 0.03$). There was a main effect of YPARQ ($F(1, 112) = 4.94, p < .05, \eta_p^2 = 0.04$) suggesting that individuals with greater YPARQ scores were more likely to choose the hard task. This main effect is illustrated in Fig. 2, which shows a linear effect between hard task choice and YPARQ such that greater PLEs were associated with greater effort expenditure ($r = 0.19, p < .05$).

However, this main effect of YPARQ was modified by a significant three-way interaction with Reward X Probability X YPARQ interaction, ($F(3, 112) = 4.38, p < .01, \eta_p^2 = 0.04$). Fig. 3 provides a graphical illustration of this interaction, by creating high and low YPARQ groups based on a median split. Follow up simple effects tests indicated that the largest differences between the high and low YPARQ individuals was in the highest reward condition at 50% probability ($t(119) = -2.90, p = .004$), followed by the next highest reward condition at 50% probability ($t(119) = -1.81, p = .07$). There was also a trend for high YPARQ individuals to allocate greater effort at the lowest reward value at 88% probability ($t(119) = -1.76, p = .08$).

3.2. Anticipatory and consummatory responses on the gambling task

As expected, participants reported more positive consummatory responses to reward ($M = 4.45, SD = 0.39$) versus loss ($M = 1.88, SD = 0.52$); $t(124) = 36.29, p < .001$). The linear regression examining the relationship between YPARQ and consummatory responses showed that higher YPARQ scores were related to more positive ratings when experiencing reward ($t = 2.17, \beta = -0.024, p = .009$ see Fig. 4) and more negative ratings when experiencing loss ($t = 2.64, \beta = -0.026, p = .032$ see Fig. 5).

Also as expected, participants reported more positive anticipatory responses to reward, ($M = 3.81, SD = 0.62$) versus loss ($M = 2.35, SD = 0.49$); $t(124) = 19.40, p < .001$). However, the linear regression examining the relationship between YPARQ and anticipatory responses did not reveal any significant relationship between YPARQ scores and either anticipation of rewards reward ($t = -0.38, \beta = -0.005, p = .70$) or anticipation of loss ($t = 0.14, \beta = 0.002, p = .89$).

Table 1
Demographic Characteristic and Questionnaire Means and Standard Deviations.

Characteristics	M	SD
Demographics		
Age (years)	20.5	4.85
Sex (% female)	70.6%	
Ethnicity (% Caucasian)	50.0%	
Education (years)	14.62	1.76
Parental education (years)	17.70	2.75
Running span (total # of items recalled correctly)	58.92	14.06
Symptom measures		
YPARQ	3.90	4.02
Snaith Hamilton pleasure	36.27	5.53
Center for epidemiology studies depression scale (CESD 10)	9.48	5.67
Mood and anxiety symptoms questionnaire (MASQ)	22.95	8.78

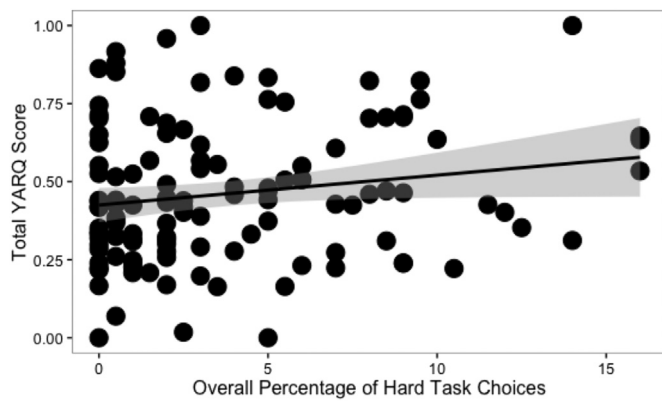


Fig. 1. Percentage of hard task choices as a function of probability and reward magnitude in the whole sample.

We conducted a Fishers r -to- z to examine whether the magnitude of the relationships between YPARQ scores and consummatory versus anticipatory responses differed significantly. The relationship between YPARQ scores and consummatory responses to rewards was significantly stronger than the relationship between YPARQ scores and anticipatory responses to rewards ($Z = 3.02, p = .001$). Similarly, the relationship between YPARQ scores and consummatory responses to losses was significantly stronger than the relationship between YPARQ scores and anticipatory responses to losses ($Z = 2.38, p = .009$).

3.3. Relationship between effort allocation and Consummatory responses

As higher YPARQ scores were related to both greater effort allocation and stronger consummatory responses to both rewards and losses, we examined their relationships to each other. Somewhat surprisingly, there were no significant correlations between either overall effort allocation or effort allocation in the high reward 50% probability condition and consummatory responses ($r_s < |0.11|$), though stronger consummatory responses to reward were correlated with stronger consummatory responses to loss ($r = -0.51, p < .001$).

3.4. Addressing potential confounds

Higher YPARQ scores were related to both higher depression levels as measured by the CESD-R-10 ($r = 0.34, p < .001$) and higher anxiety as measured by the MASQ ($r = 0.57, p < .001$), though not with anhedonia as measured by the SNAITH ($r = 0.12, p = .19$). The measures of depression, anhedonia, and anxiety did not correlate with either effort allocation

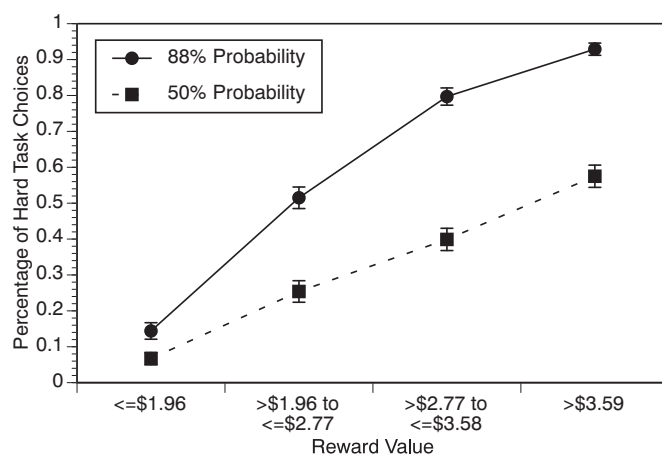


Fig. 2. Graph illustrating the relationship between the overall percentage of hard task choices across reward and probability levels and total YPARQ score.

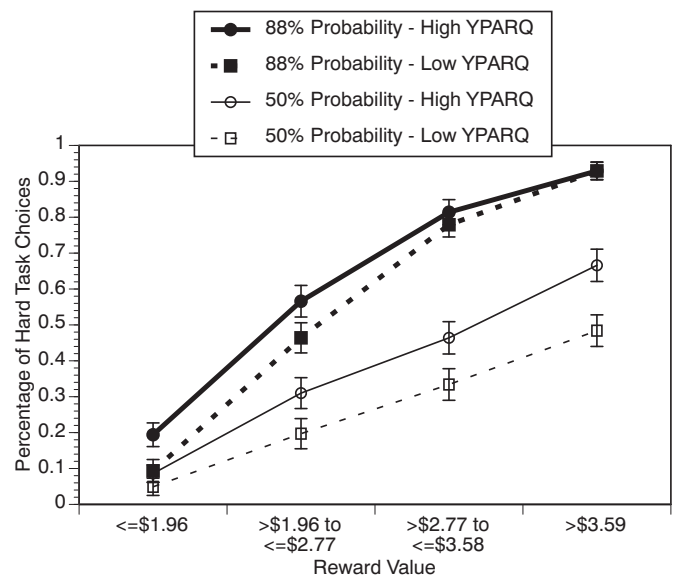


Fig. 3. Graph illustrating the relationships between hard task choice and reward value in high and low YPARQ groups. Groups were based on a median split to illustrate the significant three-way interactions between reward, probability and YPARQ score.

($r_s < |0.12|$) or consummatory ($r_s < |0.18|$) or anticipatory responses ($r_s < |0.13|$) in the gambling task. Nevertheless, to ensure that anxiety and depression were not confounding the results, we conducted partial correlations controlling for depression, anhedonia, and anxiety. When examining YPARQ and effort, our findings remained the same even with the addition of these covariates, suggesting that greater willingness to expend effort was related to higher YPARQ scores ($r = 0.22, p < .05$) even when controlling for anhedonia, depression and/or anxiety. Further, higher scores on the YPARQ were still significantly related to average consummatory response to reward ($r = 0.21, p < .05$) and loss ($r = -0.23, p < .05$) even when controlling for depression, anhedonia and anxiety.

4. Discussion

The goal of the current study was to examine the relationship between psychotic like experiences, effort-based decision-making and reward responsivity. On average, higher PLEs were associated with higher likelihood of choosing the hard task. Additionally, participants with higher PLEs had a stronger positive consummatory response to reward and a stronger negative consummatory response to loss during the gambling task, though there was no relationship between PLEs and anticipatory response to reward or loss. Importantly, these relationships were not accounted for by anhedonia, depression, or anxiety.

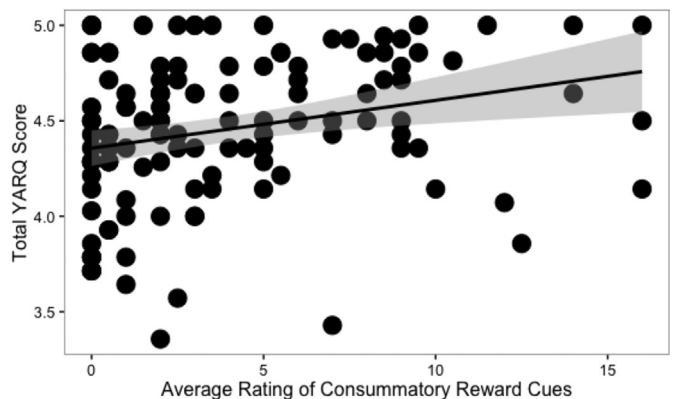


Fig. 4. Graph illustrates the relationship between average rated consummatory reward and total YPARQ score.

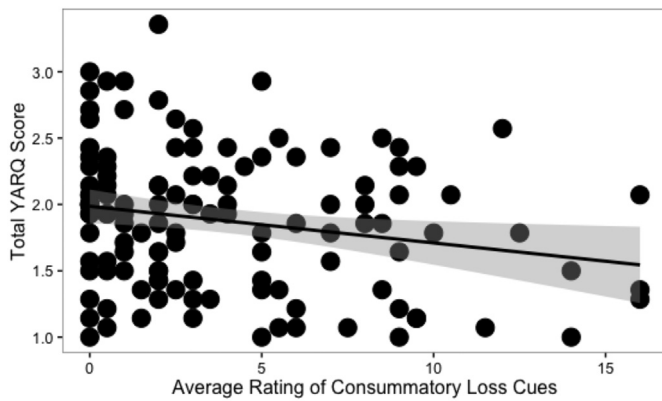


Fig. 5. Graph illustrates the relationship between average rated consummatory loss and total YPARQ score.

As expected, we found that in general, participants were more likely to choose the hard task as reward increased. Interestingly, higher PLEs related to greater effort expenditure, particularly in the lower probability conditions. These findings differ from the results of previous research with populations of medicated individuals diagnosed with schizophrenia. Prior research has found that having schizophrenia is related to less effort expenditure compared to controls (Barch et al., 2014; Fervaha et al., 2013; Gold et al., 2013; Hartmann et al., 2015; McCarthy et al., 2016; Reddy et al., 2015; Treadway et al., 2015). As noted above, research conducted in animals has shown that stimulating the dopaminergic pathway is associated with increased effort expenditure for rewards (Salamone and Correa, 2012; Trifileff et al., 2013). There is also evidence that people with schizophrenia have increased activity in their dopaminergic pathways when not on medications, including enhanced presynaptic dopamine availability and greater release of dopamine when given amphetamine (Breier et al., 1997; Fusar-Poli and Meyer-Lindenberg, 2013a, 2013b; Howes et al., 2012; Kegeles et al., 2010; Laruelle et al., 1996). However, antipsychotic medications are thought to reduce both of these effects (Nordström et al., 1993). It is possible that in the absence of medication, individuals with greater PLEs experience greater activity in the dopamine system, and this may lead to greater willingness to expend effort even at lower levels of probability of obtaining reward. However, this strategy may not be an efficient use of cognitive resources, as it may be more beneficial for one to save one's cognitive resources for the most rewarding and highest probability trials. Further research recruiting both medicated and unmedicated individuals with schizophrenia is needed to better understand how and why the nature of effort expenditure deficits differ between people with high PLEs and those with schizophrenia.

Higher PLEs were also related to stronger consummatory responses to both reward and punishment. If individuals with higher PLEs find rewards more pleasurable, they may be more willing to exert effort in order to gain reward. We theorize that these participants may be overly sensitive to reward such that, even when it is more logical to conserve their effort, they are willing to expend more effort in order to receive a higher reward and feel more pleasure. We acknowledge that one might also have expected a relationship between PLEs and anticipatory responses given this hypothesis, and thus further work will be needed to confirm the dissociation that we found of a relationship of PLEs to consummatory and not anticipatory responses. As noted above, it is thought that an over stimulation of the dopaminergic pathway plays a role in positive symptoms, and it may also play a role in sensitivity to reward (Treadway et al., 2012; Wardle et al., 2011). Prior research has found disorganized schizotypal personality traits to be positively correlated with *d*-amphetamine-induced dopamine release (Wardle et al., 2011; Woodward et al., 2011). This is consistent with the hypothesis that positive symptoms are associated with an enhanced dopamine availability and dopamine release when compared to controls

(Kegeles et al., 2010). Additionally, when participants take doses of *d*-amphetamine prior to being administered the EffRT, they become more willing to exert effort especially during low and medium reward probabilities (Wardle et al., 2011), consistent with our findings that higher YPARQ scores were associated with greater effort allocation particularly at lower probabilities. Wardle et al. interpret this finding as an amphetamine-induced decrease in reward threshold, which subsequently results in oversensitivity to reward (Wardle et al., 2011). Our current study extends prior research and supports the theory that individuals with nonclinical PLEs have an increased sensitivity to reward and a greater willingness to work for reward.

Our results have a number of potential limitations. One limitation of our study is that participants were a university sample not recruited specifically for PLEs. Thus, future studies may benefit from recruiting samples with higher frequency and severity of PLEs. Second, because we recruited a university sample, our findings may not generalize to the general population. Future research should be done using a more representative sample and participants recruited for varying levels of PLE status. In addition, we did not have a direct measure of dopamine function/availability, and future research that incorporates such measures would allow a more direct test of the hypothesis that individuals with greater PLEs are experiencing a hyper-dopaminergic state.

In conclusion, the current study adds to the literature suggesting that the symptoms vary along a continuum. The study extended the current literature by providing evidence that greater willingness to expend effort, regardless of dollar amount or probability of getting reward, is related to PLEs in a university sample. Moreover, PLEs were associated with greater pleasure during receipt of reward suggesting an overall sensitivity to receiving or working towards reward. These findings differ from the previous literature in medicated individuals with schizophrenia, and future work will be needed to determine whether this difference reflects altered dopaminergic function among individuals with high PLEs who are not taking medications that regulate the function of the dopamine system.

Conflict of interest

JAE, EKM and AJC have no conflicts to report. DMB is a consultant for Pfizer on studies related to the treatment of negative symptoms in schizophrenia.

Contributors

Authors EKM, AJC and DMB designed the study and wrote the protocol. Authors JAE and EKM managed the literature searches and the statistical analysis. JAE wrote the first draft of the manuscript, and authors EKM, AJC and DMB provided critical revision. All authors contributed to and have approved the final manuscript.

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