



Published in final edited form as:

*Cogn Affect Behav Neurosci*. 2015 March ; 15(1): 145–154. doi:10.3758/s13415-014-0308-5.

## Cognitive effort avoidance and detection in people with schizophrenia

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### Abstract

Many people with schizophrenia exhibit avolition - a difficulty initiating and maintaining goal-directed behavior, considered to be a key negative symptom of the disorder. Recent evidence indicates that patients with higher levels of negative symptoms differ from healthy controls in showing an exaggerated cost of the physical effort needed to obtain a potential reward. We examined whether patients show an exaggerated avoidance of *cognitive* effort using the Demand Selection Task developed by Kool, McGuire, Rosen and Botvinick (2010). A total of 83 people with schizophrenia or schizoaffective disorder and 71 healthy volunteers participated in three experiments where instructions varied. In the standard task (Experiment 1), neither controls nor patients showed expected cognitive demand avoidance. With enhanced instructions (Experiment 2), controls demonstrated greater demand avoidance than patients. In Experiment 3, patients showed non-significant reductions in demand avoidance relative to controls. In a control experiment, patients showed significantly reduced ability to detect the effort demands associated with different response alternatives. In both groups, the ability to detect effort demands was associated with increased effort avoidance. In both groups, increased cognitive effort avoidance was associated with higher IQ and general neuropsychological ability. No significant correlations between demand avoidance and negative symptom severity were observed. Thus, it appears that individual differences in general intellectual ability and effort detection are related to cognitive effort avoidance and likely account for the subtle reduction in effort avoidance observed in schizophrenia.

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Many, but not all, people with schizophrenia have marked difficulties in the initiation and maintenance of goal-directed behavior. For many years, these motivational deficits were thought to be a consequence of anhedonia, or the reduced enjoyment of rewarding outcomes in patients (see Strauss & Gold, 2012, for a review). However, this understanding of motivational deficits in schizophrenia has been fundamentally challenged by a large body of experimental evidence suggesting that hedonic experience appears to be surprisingly intact in schizophrenia (Cohen & Minor, 2010). If the achieved “benefits” of actions appear to be

experienced "normally" in schizophrenia, that raises the question of whether overestimations of the "costs" associated with actions leads patients to a reduced willingness to engage in actions in the pursuit of goals and rewards (Barch & Dowd, 2010).

The question of how patients weigh effort costs versus benefits may be particularly salient in people with schizophrenia. In a series of studies we have found that patients appear to have difficulty representing the relative value of stimuli and response alternatives (Strauss et al. 2011, Gold et al., 2012), and in precisely translating value representations into action (Heerey and Gold, 2007). If value representations are degraded in schizophrenia, it would be reasonable to expect that effort costs might loom abnormally large.

We recently reported findings that patients show evidence of an increased estimated "cost" of physical effort: when faced with a low payout-low effort response alternative and a high payout-high effort alternative, patients were less likely to select the high effort choice as a function of negative symptom severity. Interestingly, this impairment varied as a function of payout probability: Patients did not differ from controls when payout was uncertain, but did differ in the certain pay-out condition. Thus, their overall allocation of effort deviated substantially from that of controls (Gold et al., 2013). This impairment likely implicates dysfunction in the dopamine-rich distributed neural system (prefrontal cortex, anterior cingulate cortex, striatum) that mediates how the cost of effort is weighed against possible anticipated benefits (Croxson, Walton, O'Reilly, Behrens, Rushworth, 2009; Salamone & Correa, 2012; Treadway et al., 2012). Interestingly, there is recent imaging evidence that the ventral striatum appears to play a critical function in representing the value of rewards that may be attained by physical or cognitive effort, and dynamically switches effective connectivity with cognitive and motor regions according to whether cognitive or physical effort is required (Schmidt, Lebreton, Clery-Melin, Daunizes, Pessiglione, 2012). Thus, it appears that physical and cognitive effort based decision making may be mediated by a similar neural system.

Here we seek to extend our work on physical effort by examining cognitive effort with the expectation that patients would show an aversion to higher levels of cognitive effort just as they had shown for physical effort, again expecting that effort avoidance would be amplified as a function of negative symptom severity. To examine cognitive effort we adopted the approach developed by Kool et al. (2010). In brief, the subject in this task environment is faced with a choice between two actions which involve the same amount of physical effort but which differ in the amount of mental effort involved. This effort manipulation was realized by varying the rate of task switching that was associated with each response alternative, reasoning that more frequent task switching would require more cognitive effort. Indeed, Kool et al. (2010) found that healthy young adults show a systematic preference for the response alternative associated with less frequent task switching. We hypothesized that patients with high levels of negative symptoms would evidence increased cognitive effort aversion, thereby extending our findings from the physical effort task.

To preview, we failed to confirm this straightforward hypothesis. Because we were surprised by the results of our initial experiment, we went on to make two sets of changes in task directions that we believed might enhance the sensitivity of the task. In the course of

doing so, we uncovered evidence that cognitive demand avoidance is associated with general intelligence and additional evidence that people with schizophrenia appear to have a deficit in detecting differences in cognitive demand associated with response alternatives.

## General Methods

### Participant Characteristics

We used the same basic participant recruitment approaches and inclusion/exclusion criteria for the three experiments reported in this study. A total of 83 people with a DSM-IV (American Psychiatric Association, 2000) diagnosis of schizophrenia (N=72) or schizoaffective disorder (N=11) did one of the experiments. All were clinically-stable outpatients recruited from the MPRC Outpatient Research Program or from other nearby outpatient clinics. Diagnosis was determined by the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID; First, Spitzer, Gibbon, Williams, 1997), past medical records, and clinician reports. At the time of testing, all participants had been on stable medications (same type and dose) for a minimum of four weeks.

A total of 71 healthy participants with similar demographic features as the patient group completed one of the experiments. Healthy participants were recruited through a combination of random telephone number dialing, internet advertisements, and word of mouth among successfully-recruited controls. They all were screened with the SCID and the Structured Clinical interview for DSM-IV Personality Disorders (SIDP; First et al., 1997, Pfohl, Blum, & Zimmerman, 1997) and were free of a lifetime history of psychosis, current Axis I disorder, as well as Axis II schizophrenia spectrum disorders. Healthy participants all denied a family history of psychosis in first degree relatives. Participants from both groups denied a history of medical or neurological disease, including current or recent substance abuse or dependence that would likely impact cognitive performance.

Participants received the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) and the MATRICS Consensus Cognitive Battery (MCCB; Nuechterlein & Green, 2006) to assess overall level of cognitive ability. The participants with schizophrenia also received the Scale for the Assessment of Negative Symptoms (SANS; Andreasen, 1983), the Brief Negative Symptom Rating Scale (BNSS; Kirkpatrick et al., 2011), and the Brief Psychiatric Rating Scale (BPRS; Overall & Gorham, 1962) to assess symptom severity.

Participants provided written informed consent for a protocol approved by the University of Maryland School of Medicine Institutional Review Board and all were compensated for their participation. The sample sizes and demographic features of the study groups for each experiment are shown in Table 1, with significant between group differences noted in the table.

## Experiment 1

### Demand Selection Task (DST)

The procedure for this experiment was identical to that of Kool et al, 2010, Experiment 3. In the Demand Selection Task the participant is presented with 8 separate pairs of choice cues,

with different pairs presented in each 75-trial block over the course of a 600 trial session. The cues appeared as abstract color patches (see Figure 1). Subjects used the mouse to click on a cue, which caused it to reveal a colored numeral between 1 and 9. The numeral was presented in either yellow or blue. If the numeral was yellow, participants had to make a parity judgment, pressing the left key on a mouse for odd and press the right key if the number was even. If the numeral was blue, the participate were to make a magnitude judgment, pressing the left key if the number was less than five, and pressing the right key if it was greater than five.

Subjects initially practiced with single stimuli for 20 trials with feedback on the accuracy of every response to ensure they had learned the correct response mapping. They then did 6 practice blocks of 10 trials with feedback given at the end of the each block. Several subjects required additional practice to ensure they had fully acquired the response mappings. Subjects were then were exposed to 4 two-item displays, used the mouse to choose one of the items, and then performed the required action. This last stage was included to familiarize subjects with the display that was used in the actual task.

After these practice trials, subjects received the following instruction: "There are 8 blocks in the experiment, and each block starts with a new pair of patches. You should always begin by sampling them both randomly. You may notice differences between them. If you develop a preference, you can feel free to choose one patch more than the other. Please avoid using simple rules such as alternating back and forth between the patches. Instead, try to make a decision on every trial."

Importantly, participants were not informed of a critical difference between the color patches. In the "low demand" color patch, the color of the numeral matched that of the prior trial on 90% of trials. With the "high demand" patch, the color matched the previous trial on only 10% of trials, requiring much more frequent switching between the parity task and magnitude task, which is thought to require more cognitive effort (Monsell, 2003).

In addition, subjects performed a 75-trial task switching condition (note, not all subjects in Experiment 1 performed this task as it was added after data collection had begun). In this task, colored numbers appeared at fixation with one color being associated with making a parity judgment and the other color associated with making a magnitude judgment as in the DST. The color of the number was selected at random with a 50% probability for each color. Switch costs were calculated (in seconds) by contrasting the reaction times observed on switch trials from those of repeat condition trials on trials with a correct response. This task was administered on a different day from the Demand Selection Task. This condition was administered as a type of control as we anticipated that subjects who experienced greater switching costs might be more effort averse, and further expected that patients, as a group, might show increased switching costs (although the evidence in the literature on this point is conflicting; see Greenzang, Manoach, Goff, Barton, 2007; Ravizza, Moua, Long, Carter, 2010; Wylie, Clark, Butler, Javitt, 2010).

## Results

As seen in Figure 2 (left panel), both groups showed low-demand selection rates quite similar to each other at near chance levels - well below the level documented in the experiments of Kool et al. (2010). The group difference on overall effort avoidance did not approach significance (control  $M = 0.53$ ,  $SD = 0.14$ ; patient  $M = 0.54$ ,  $SD = 0.14$ ,  $t(20) = -0.275$ ,  $p = 0.78$ ,  $d = -0.10$ ). Further, one-sample t-tests showed that neither group showed a significant demand avoidance effect, i.e., low-demand selection over 50% (control  $t(12) = 0.74$ ,  $p = 0.47$ ,  $d = 0.21$ ; patient  $t(17) = 1.33$ ,  $p = 0.20$ ,  $d = 0.32$ ). Switch-cost data were only available from 6 controls and 13 patients. These costs were higher in patients ( $M = 0.53$ ,  $SD = 0.23$ ) than in controls ( $M = 0.50$ ,  $SD = 0.27$ ), but meaningful statistical comparisons are not possible with this small number of control subjects.

Both groups showed high levels of accuracy on the magnitude/parity judgment task that were not significantly different between the groups (control  $M = 97\%$  correct responses,  $SD = 2.1$ ; patient  $M = 94\%$ ,  $SD = 12$ ,  $t(29) = 0.83$ ,  $p = 0.41$ ,  $d = 0.30$ ).

We used Spearman correlations to examine if overall effort avoidance was associated with negative symptom ratings using the total scores from the SANS and BNSS, as well as the subscores for Avolition/Anhedonia from both scales, as these symptoms have the clearest conceptual relationship with effort avoidance. None of these correlations approached significance (largest of 4 correlations,  $\rho(16) = -0.24$ ,  $p = 0.34$ ).

## Discussion

There were three major surprises in the results of Experiment 1. First, neither group showed the systematic effort avoidance previously documented using this precise task and instructions in a healthy undergraduate population. Second, we saw no hint of a patient difference from controls, and no evidence of the predicted symptom effect. Third, the three testers who worked with the participants reported that many spontaneously verbalized that they were confused by the task. Upon hearing these reports, we decided to examine the results well before our planned recruitment target. After seeing that both groups were performing near chance, we decided to end this first round of data collection and develop a new set of instructions that might enhance comprehension of the task. In essence, we were concerned that this experiment, developed with healthy young adults, had not “translated” well into a clinical and general population sample and that it was not possible to interpret our null results with any degree of confidence. Clearly, we can only speculate about why the task did not translate well with our healthy controls. As discussed below, there is evidence that overall cognitive ability is related to performance on the DST, and it is reasonable to suspect that a Princeton undergraduate sample has higher general cognitive ability than our community control sample, perhaps explaining our failure to see significant effort avoidance in these subjects.

## Experiment 2

### Demand Selection Task (DST)

The initial practice and training conditions for Experiment 2 were identical to those from Experiment 1 with the exception of decreasing the number of practice trials from 60 to 30 after observing very high levels of performance in the initial cohort. However, in order to make the differences between the choice cues more salient, we used more explicit instructions, with the differences from Experiment 1 shown with underlining:

There are 8 blocks in the experiment. You should begin each block by sampling both patches randomly. There are differences between the two patches: one patch will reveal numbers that change color less often, and the other patch will reveal numbers that change color more often. Remember: every time the color of the number changes, so does the rule.

If you develop a preference for one of the patches, feel free to continue to choose it for the rest of the block. Remember to try both patches in the beginning of each block before developing a preference, and try to avoid choosing patches based on how they look or where they are located.

Thus, these changes were intended to highlight the task switching differences between the two tasks. After these instructions, all subjects again performed eight 75-trial free-choice blocks.

### Results

As seen in Figure 2 (right panel), the enhanced instructions led to a robust increase in demand avoidance in the healthy control group, with a less dramatic increase among patients (relative to levels seen in both groups in Experiment 1). Both groups demonstrated beyond chance levels of demand avoidance (control  $M = 0.74$ ,  $SD = 0.20$ ,  $t(22) = 6.00$ ,  $p < 0.001$ ,  $d = 1.25$ ; patient  $M = 0.57$ ,  $SD = 0.16$ ,  $t(24) = 2.37$ ,  $p < 0.05$ ,  $d = 0.47$ ). However, controls showed significantly greater effort avoidance than patients,  $t(46) = 3.22$ ,  $p = 0.002$ ,  $d = 0.93$ .

Average accuracy on the magnitude/parity judgment task was high for both the control group,  $M = 98\%$ ,  $SD = 1.4$ , and the patients,  $M = 95\%$ ,  $SD = 6.9$ , but the controls showed significantly higher accuracy than the patients,  $t(46) = 2.35$ ,  $p < 0.05$ ,  $d = 0.68$ .

The patients showed significantly elevated task switching costs in the control task when compared to the control group (patients  $M = 0.63$ ,  $SD = 0.44$ ; control  $M = 0.35$ ,  $SD = 0.30$ ;  $t(46) = -2.55$ ,  $p < 0.05$ ,  $d = 0.74$ ). Interestingly, switch costs did not correlate significantly with effort avoidance in either group (Spearman  $\rho(23) = -0.04$ ,  $p = 0.83$  in patients,  $\rho(21) = 0.30$ ,  $p = 0.16$  in controls) although the results in controls are in the expected direction.

As in Experiment 1, we found no evidence of a negative symptom correlation with DST performance (largest of four correlations,  $\rho(23) = -0.14$ ,  $p = 0.52$ ).

## Discussion

In this experiment, we saw evidence of decreased effort avoidance in the patient group but no evidence to suggest any enhancement of effort avoidance as a function of negative symptom severity. Thus, the enhanced directions appear to have been sufficient to elicit expected performance levels in the healthy volunteers but less so in the patient group, although the overall patient mean exceeded chance, constituting evidence of effort avoidance.

At this point, another potential explanation for the patient results occurred to us: might patients fail to avoid effort because they simply do not detect the cognitive effort difference between the two response alternatives? Further, might our changes in instructions have increased awareness of the effort differences between the conditions leading to increased effort avoidance amongst the controls but not the patient group? There is ample suggestive evidence that people with schizophrenia have difficulties in performance monitoring, as seen, for example, in studies of error-detection and correction, where patients show reduced awareness of having made incorrect responses, eliciting attenuated response ERNs (error-related negativities; Mathalon et al., 2002; Morris, Holroyd, Mann-Wrobel, Gold, 2011). Might the same process be implicated in monitoring cognitive effort expenditure? Or might patients have difficulty attending to their own actions (Frith, Blakemore, Wolpert, 2000)? Further, it is widely believed that schizophrenia involves a compromise in cognitive control (Lesh, Niendam, Minzenberg, Carter, 2011), especially with regard to making adjustments to task performance to meet changes in task demands. In essence, if patients fail to detect the differences in effort required by the two different color patches, there would be little reason to think they would avoid the more effortful choice. New task conditions were developed to assess this possibility in Experiment 3.

## Experiment 3

### Demand Selection Task (DST)

To examine the above issues we made a number of changes for the design of Experiment 3. First, we reduced block length from 75 to 35 trials after examining data from the Experiments 1 and 2 and determining that most subjects reached asymptotic performance levels by trial 35. Subjects performed four free-choice blocks using slightly different instructions as follows (changes noted by underline):

There are eight blocks in the experiment. For the first four blocks you should start by choosing both patches randomly. The patches are different: one patch will show you numbers that change color more often, and the other patch will show you numbers that change color less often. Remember: every time the color of the number changes, so does the rule. After trying both patches, if you prefer one over the other you should choose it for the rest of the block. Please avoid using simple rules such as alternating back and forth between the patches or choosing the patch based on how it looks or where it is located.

These small changes were intended to encourage subjects to explore both options initially and then stick with their preferred response for the rest of the block. These free choice

blocks were followed by “forced-choice” blocks where we directed subjects to identify the “harder patch” and stick with it:

In next two blocks, the patches are still different: one patch will show you numbers that change color more often, and the other patch will show you numbers that change color less often. People tend to find one patch harder than the other patch. You should try and figure out which patch is **harder** and stick with it for the rest of the block.

After completing these two blocks, we presented the following instructions for the final two blocks:

In the final two blocks, the patches are still different: one patch will show you numbers that change color more often, and the other patch will show you numbers that change color less often. This time, you should try and figure out which patch is **easier** and stick with it for the rest of the block.

Thus, the two forced-choice conditions were designed to determine if subjects could detect the differences in the cognitive effort demands of the two response alternatives. On a different day, the task-switching control task was administered using a total of 35 trials to match the other block lengths.

## Results

As seen in Figure 2 (right panel), this cohort of patients and controls showed very similar levels of effort avoidance in the first four free-choice blocks, with both groups performing similarly to those studied by Kool et al. (2010). This impression was confirmed statistically, as the two groups did not differ significantly in the proportion of low-demand choice (control  $M = 0.62$ ,  $SD = 0.17$ ; patient  $M = 0.57$ ,  $SD = 0.15$ ,  $t(73) = 1.24$ ,  $p = 0.22$ ,  $d = 0.29$ ). Both groups showed reliable effort avoidance effects, controls  $t(34) = 4.06$ ,  $p < 0.001$ ,  $d = 0.69$ , and patients  $t(39) = 2.97$ ,  $p = 0.005$ ,  $d = 0.47$ .

Again, both control and patients accuracy scores were high (control  $M = 98\%$ ,  $SD = 2.3$ , patients  $M = 95\%$ ,  $SD = 8.1$ ), and we again found that controls had higher accuracy than the patients,  $t(73) = 2.30$ ,  $p < 0.05$ ,  $d = 0.53$ .

As in Experiments 1 & 2, we saw no correlational evidence of a negative symptom relationship with free-choice performance (largest of 4 correlations,  $\rho(38) = -0.16$ ,  $p = 0.33$ ). We observed higher switch-costs in the patient group (patient  $M = 0.65$ ,  $SD = 0.60$ ; control  $M = 0.40$ ,  $SD = 0.30$ ,  $t(73) = -2.34$ ,  $p < 0.05$ ,  $d = 0.53$ ). Switch-costs did not correlate with effort avoidance in the patients ( $\rho(38) = -0.13$ ,  $p = 0.42$ ) but did in controls ( $\rho(33) = 0.37$ ,  $p < 0.05$ ). Thus, controls that experienced greater switch-costs tended to avoid effort in the free-choice condition.

However, we found robust evidence that patients have difficulty identifying the harder/easier response alternatives when directed to do so. In controls, 83% of choices ( $SD = 14\%$ ) were consistent with the instruction, whereas only 67% of choices ( $SD = 22\%$ ) by patients were consistent with instructions, a significant difference,  $t(73) = 3.71$ ,  $p < 0.001$ ,  $d = 0.86$ . In both healthy controls and patients, performance in the forced-choice condition correlated



with the tendency to avoid effort in the free-choice condition (in controls, Spearman  $\rho(33) = 0.34, p < 0.05$ ; in patients  $\rho(38) = 0.35, p < 0.05$ ). Thus, subjects who were better able to detect the differences in cognitive effort demands were more likely to avoid the more demanding response in the free-choice blocks.

In both patients and controls, performance in the forced-choice condition was correlated with WASI IQ and MCCB composite score (in patients, Spearman  $\rho(37) = 0.54$  and  $0.42$  respectively,  $ps < 0.01$ ; in controls  $\rho(34) = 0.45$  and  $0.49$  respectively,  $ps < 0.01$ ). Thus, the ability to detect differences in cognitive effort demands appears to be related to general intellectual ability in both groups.

## Discussion

Experiment 3 provided an important replication of the earlier two experiments in showing that DST performance does not appear to be mediated by negative symptom severity in people with schizophrenia. Indeed, the overall patient cohort did not differ from controls in their preference for low-demand options with a relatively small effect size ( $d = 0.29$ ) difference suggesting greater effort-avoidance in controls. However, the forced-choice condition added important new information, as it appears that people with schizophrenia have difficulty detecting the relative difficulty and cognitive effort demand differences between the two response alternatives. It is also possible that patients, unlike controls, understood the instruction to identify the harder and easier patches as one of detecting differences in objective task difficulty rather than in subjective effort expenditure. This appears to be somewhat unlikely given that effort detection performance correlated with effort avoidance at very similar levels across groups suggesting that both groups processed the instructions in a similar fashion. Further, the ability to detect effort demands appears to be related to broad measures of general cognitive ability in both groups, measures where the patient group performs more poorly than controls. If patients have difficulty detecting effort differences between response alternatives, it would be surprising if they would show fully normative effort avoidance. Yet, surprisingly, patients showed only small effect size difference in effort avoidance from controls, despite the robust difference in the forced-choice effort detection condition.

This apparently contradictory pattern of results suggests that individual differences in the Demand Selection Task are not fully determined by sensitivity to cognitive effort. Factors other than effort cost and cognitive ability impact appear to impact decision-making in this task environment, such as idiosyncratic preferences for certain stimulus patterns, locations, or a desire to switch choices to avoid boredom. The impact of these additional factors may reduce the between group effect that might be expected on the basis of differences in effort detection or general cognitive ability alone.

## Combined Analyses Across Experiments

We observed substantial heterogeneity in performance across subjects in each of the three experiments, each with limited sample size for examining the role of individual differences. Therefore, we decided to examine the role of cognitive and symptomatic variables combining groups across experiments despite differences in instructions and numbers of

trials. We reasoned that by combing data across experiments, we were most likely increasing our chances of false negative rather than false positive results. That is, any cognitive or symptom relationships that might be seen in the overall group would likely be quite robust given methodological differences across experiments.

In the combined sample, patients showed much larger switch costs than controls (patient  $M = 0.62$ ,  $SD = 0.50$ ; control  $M = 0.39$ ,  $SD = 0.29$ ,  $t(140) = -3.44$ ,  $p = 0.001$ ,  $d = .56$ ). Switch-costs correlated with effort avoidance in the combined group of healthy controls,  $r(62) = 0.25$ ,  $p < 0.05$ , but not in patients,  $r(76) = -0.025$ ,  $p = 0.83$ . The difference in this correlation approached significance ( $Z = 1.63$ , 1-tailed  $p = 0.052$ ).

Is cognitive effort avoidance related to general cognitive ability? To address this question we examined Pearson correlations (given our increased sample sizes) between overall effort avoidance across blocks with two variables: the WASI 2 subtest IQ score as a measure of general intelligence and the MCCB composite score as a measure of overall neuropsychological performance. These correlations were significant in both controls ( $r(68)$  with IQ = 0.41,  $p < 0.001$ ;  $r(67)$  with MCCB = 0.40,  $p = 0.001$ ) and in patients ( $r(81)$  with IQ = 0.23,  $p = 0.039$ ;  $r(81)$  with MCCB,  $r = 0.31$ ,  $p = 0.004$ ). Thus higher levels of cognitive ability are associated with greater effort avoidance in both groups.

In light of the relationships between general ability and effort detection and effort avoidance, we performed a mediation analysis to explore if effort detection mediated the effect of IQ on effort avoidance using the three-step method of Baron and Kenny (1986). Two participants (one control, one patient) were excluded from this analysis, because their IQ scores were missing. First, a linear regression showed that IQ reliably predicted effort avoidance:  $\beta = 0.36$ ,  $t(71) = 3.21$ ,  $p = 0.001$ ,  $R^2 = 0.13$ . A second linear regression model revealed that IQ also predicted the degree of effort detection,  $\beta = 0.63$ ,  $t(71) = 6.87$ ,  $p < 0.001$ ,  $R^2 = 0.40$ . In the third and final step, when both IQ and effort detection were used to predict effort avoidance, the overall model is significant,  $F(2,70) = 5.81$ ,  $p = 0.005$ ,  $R^2 = 0.14$ . However, neither effort detection,  $\beta = 0.16$ ,  $t(70) = 1.12$ ,  $p = 0.27$ , nor IQ,  $\beta = 0.26$ ,  $t(70) = 1.79$ ,  $p = 0.08$ , achieved significance as individual predictors in the presence of the other. Thus, while the total effect of IQ and effort detection on effort avoidance was significant, neither the direct effect of IQ nor the indirect effect through mediation were significant by themselves. Consistent with these findings, the Sobel test was not significant,  $Z = 1.151$ ,  $p = 0.27$ . Thus, we have clear evidence that IQ is related to both effort detection and effort avoidance. However, it appears that the impact of IQ on avoidance is not reliably mediated by effort detection.

When we looked at ratings of positive and disorganization symptoms (based on factor analyses of the BPRS), no significant correlations were observed with effort avoidance in the patient group. The Pearson correlations between overall effort avoidance and negative symptoms approached zero for both the BNSS total score ( $r(80) = -0.04$ ), and the SANS total score ( $r(79) = -0.008$ ).

## Overall Discussion

These three experiments yield a combination of clear and ambiguous findings. First, and most importantly, we found no support for the straightforward prediction that the negative symptoms of schizophrenia are associated with an avoidance of cognitive effort as assessed by the DST (as previously seen with physical effort). However, this conclusion needs to be qualified in light of the evidence that patients have difficulty detecting the effort costs associated with different response alternatives. It would be surprising for patients to show enhanced effort avoidance given that they have difficulty detecting the effort differences associated with different response alternatives. Thus, our conclusion that cognitive effort avoidance is unrelated to negative symptom severity is provisional, and the issue remains to be explored using methods where the effort costs are more self-evident.

The inability of patients to detect differences in cognitive demand when explicitly instructed to do so is remarkable given that, across experiments, the patient group showed substantially elevated switch costs on the control task. Thus, it is clear that task switching is much more “costly” to people with schizophrenia. However, this increased cost does not appear to impact their performance in free-choice blocks. Indeed, among controls higher switch costs were related to effort avoidance whereas this relationship was not observed in patients. Thus, it appears that patients have difficulty monitoring the “cognitive costs” of their actions, and this deficit may impact decision making and the ability to adjust cognitive control in a variety of tasks. Whether this is an impairment specific to integrating cognitive effort costs when considering response alternatives or an example of a more general failure to consider all relevant information in order to guide decision-making remains to be explored in future work.

We found mixed results across experiments on the broader question of whether patients, as a group, independent of symptom severity, differ from controls in effort avoidance. We can confidently conclude that patients do not show heightened effort avoidance on the DST as we had expected. Indeed, there is suggestive evidence that patients may show reduced effort avoidance with effect sizes of 0.93 and 0.29 in Experiments 2 and 3 respectively.

Such a between-group difference might be expected given the correlations between cognitive ability and effort avoidance. In both groups, higher levels of cognitive ability were associated with a greater degree of effort avoidance. On the basis of the large between-group differences in cognitive ability alone, one would therefore expect between-group differences in effort avoidance. Given that cognitive impairment is a core feature of schizophrenia, it is inappropriate to use ANCOVA or other similar approaches to address the question of whether schizophrenia, *per se*, is associated with impaired effort avoidance, above and beyond the contribution of cognitive impairment. It is striking that similar correlations between cognitive ability and effort avoidance were seen in the two groups, given that the groups are at very different mean levels of cognitive ability. Further, in both groups, the ability to detect the effort demands associated with the two response alternatives was correlated with general cognitive ability. Again, it is unclear if the impaired effort detection performance of the patient group is simply a reflection of overall cognitive impairment or whether there is a specific effect of the psychopathology of schizophrenia to the process of

detecting effort demands. While inferential, the fact that we observed no correlations with symptom severity of any type may be evidence in favor of a cognitive ability explanation for both the effort detection and effort avoidance deficits documented in the patient group.

To our knowledge, this is the first evidence for a role of general intellectual ability in effort avoidance in healthy controls. This may be responsible for our failure to see effort avoidance in the healthy control group in Experiment 1, as it is likely the case that Princeton undergraduates have higher IQs than our community controls. The fact that the relationship between general ability and effort avoidance was observed in both groups should enhance confidence in the finding. General intellectual ability also correlated with the ability to detect effort differences. Thus, it appears that intellectual ability is related to the ability to monitor the “costs” of response alternatives and utilize these costs in guiding decision-making. In essence, smarter people notice differences in effort demands and often prefer to take the easier way, conserving their available effort, at least when there is no benefit associated with the more effortful alternative. It remains for future work to test if this bias changes when tangible benefits are at stake and must be weighed against effort costs. The methods recently developed by Westbrook, Kester and Braver (2013) may offer a very powerful approach to address this question.

The present results would appear to be at odds with our prior report of increased physical effort avoidance in people with schizophrenia (Gold et al., 2013). One potential explanation is that the physical effort task did not involve the detection of subtle differences in effort: the difference was large (20 versus 100 alternating button presses) and was displayed on the screen in front of the subject. Thus, the differences in physical effort were highly salient and repeated choice of the more difficult alternative resulted in finger fatigue. In our view, the differences in cognitive effort involved in the Demand Selection Task are more subtle. Indeed some patients had difficulty discriminating which response was more difficult when instructed to do so. In addition, the physical effort task also involves temporal discounting (it takes longer to press 100 times than 20 times) and we have previously documented increased temporal discounting in people with schizophrenia (Heerey, Robinson, McMahon, Gold, 2007; Heerey, Matveeva, Gold 2011). Alternatively, it is logically possible that schizophrenia involves an aversion to physical but not mental effort. This type of dissociation would be more compelling if it was demonstrated within the same subjects, accompanied by evidence that the patients were capable of detecting the differences in cognitive effort required by differing responses but were simply indifferent to those differences.

It is important to recognize an important qualification to our conclusions. The standard DST is an “unstructured” task, leaving participants to make their own decisions about how to approach performing the task. This results in highly variable performance as seen most clearly in Experiment 1 where the healthy control group did not reliably avoid effort. Some of this variability is systematic as we found clear effects of general cognitive ability, effects of the ability to detect cognitive effort demands, and perhaps, subtle effects of diagnostic group. However, all of these effects are relatively modest, suggesting that a large portion of the variance in the DST remains unexplained by the variables we examined. It remains for future work to determine if these findings generalize to more structured task environments

where task instructions and goals are explicitly established and where relative costs and benefits are more tangible. In schizophrenia, it will be useful to revisit the role of negative symptoms and cognitive effort with tasks that highlight the effort differences between response alternatives, thereby avoiding the impact of the patient deficit in effort detection.

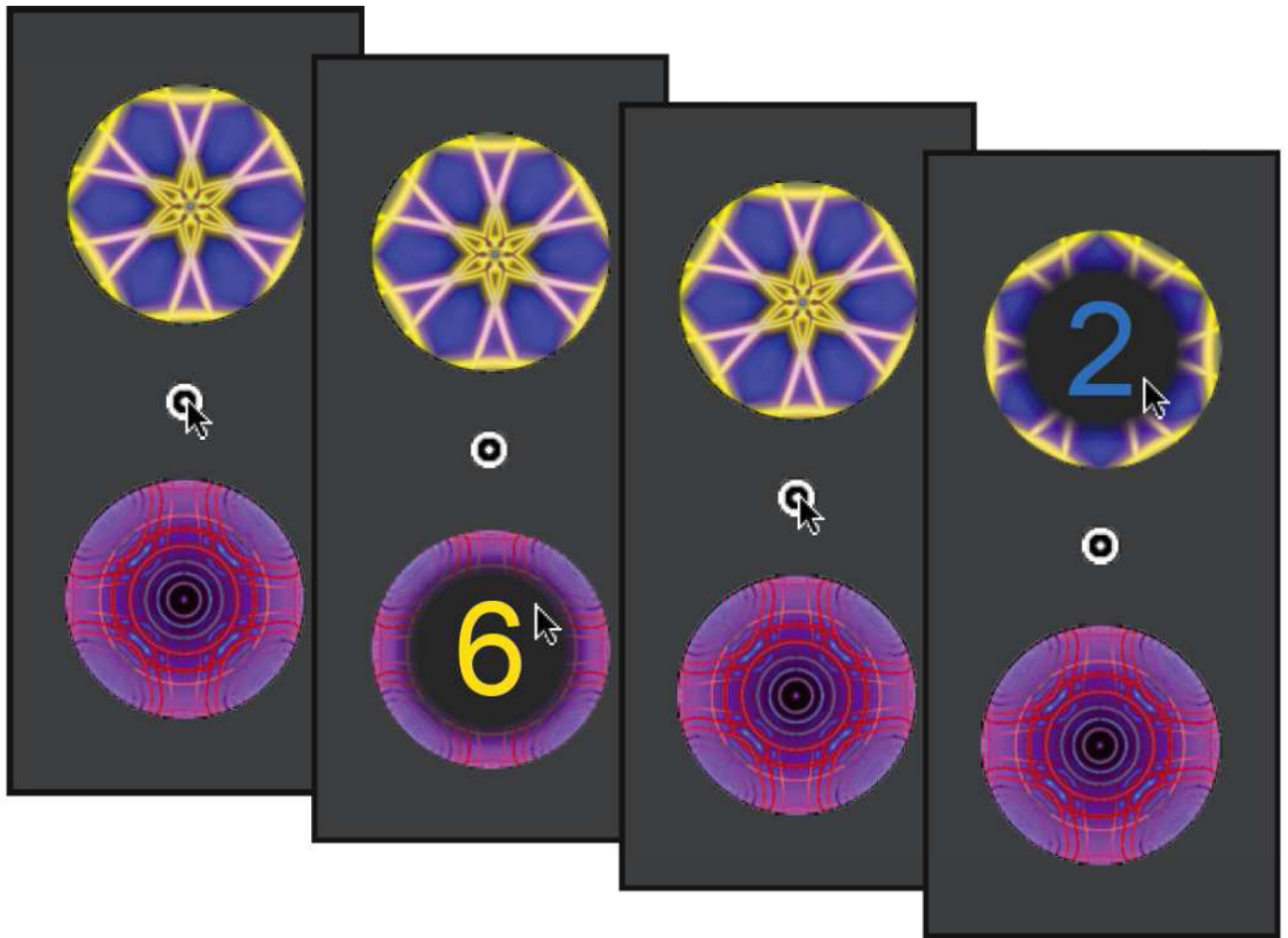
## Acknowledgments

This work supported by NIMH R01 MH080066.

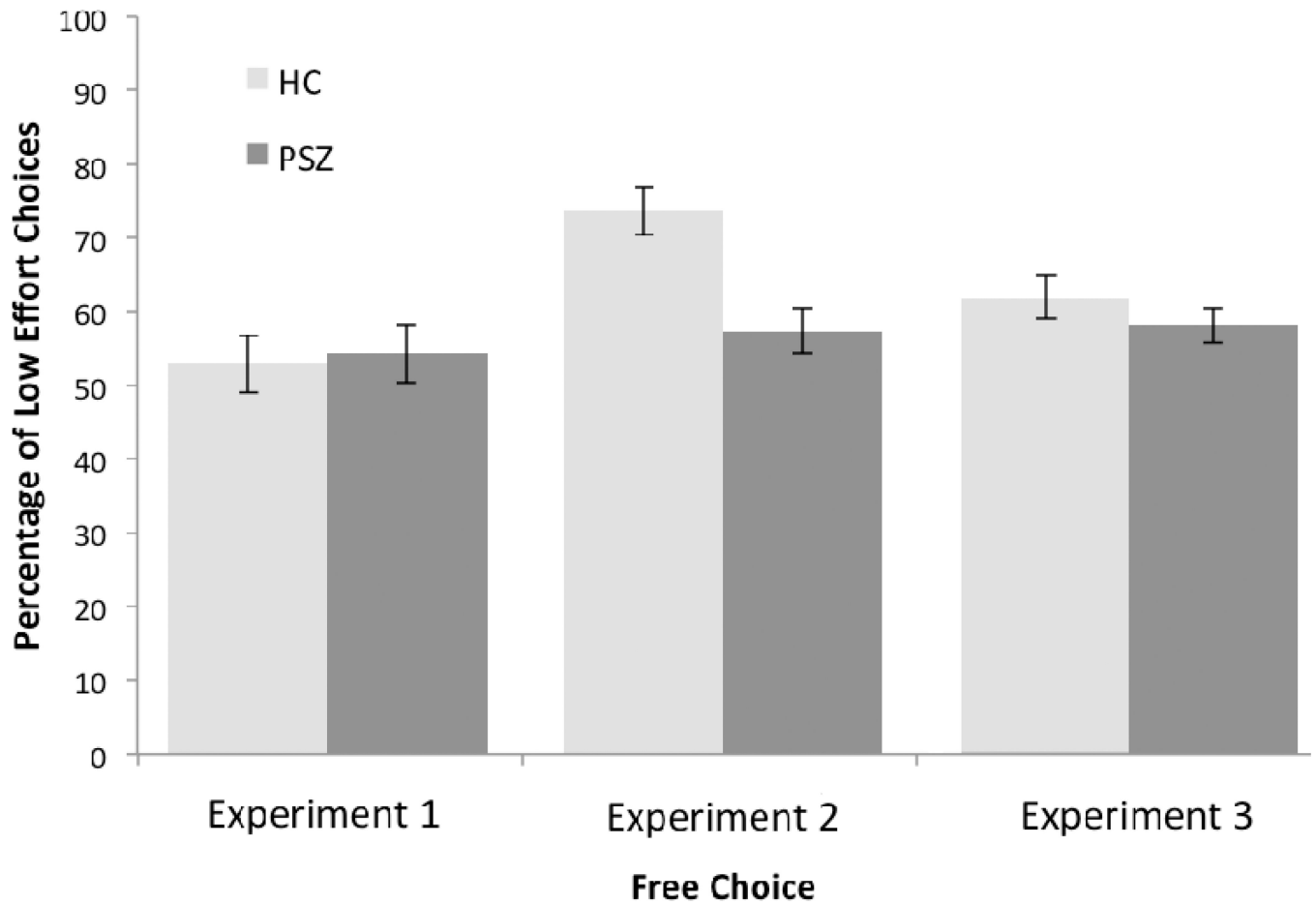
## References

- American-Psychiatric-Association. Diagnostic and Statistical Manual of Mental Disorders (Fourth, Text Revision Ed.). Washington, DC: American Psychiatric Association; 2000.
- Andreasen, NC. The Scale for the Assessment of Negative Symptoms (SANS) Technical Report. University of Iowa; 1983.
- Barch DM, Dowd EC. Goal representations and motivational drive in Schizophrenia: The role of prefrontal-striatal interactions. *Schizophrenia Bulletin*. 2010; 36:919–934. [PubMed: 20566491]
- Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research – Conceptual, strategic and statistical considerations. *Journal of Personality and Social Psychology*. 1986; 51(6):1173–1182. [PubMed: 3806354]
- Cohen AS, Minor KS. Emotional experience in patients with schizophrenia revisited: Meta-analysis of laboratory studies. *Schizophrenia Bulletin*. 2010; 36:143–150. [PubMed: 18562345]
- Crosson PL, Walton ME, O'Reilly JX, Behrens TE, Rushworth MF. Effort-based cost-benefit valuation and the human brain. *Journal of Neuroscience*. 2009; 29:4531–4541. [PubMed: 19357278]
- First, MB.; Spitzer, RL.; Gibbon, M.; Williams, JBW. Structured Clinical Interview for DSM-IV- Axis I Disorders (SCID-I). Washington, DC: American Psychiatric Press; 1997.
- Frith CD, Blakemore S, Wolpert DM. Explaining the symptoms of schizophrenia: Abnormalities in the awareness of action. *Brain Research Reviews*. 2000; 31:357–363. [PubMed: 10719163]
- Gold JM, Waltz JA, Matveeva TM, Kasanova Z, Strauss GP, Herbener ES, Collins AG, Frank MJ. Negative symptoms and the failure to represent the expected reward value of actions: behavioral and computational modeling evidence. *Archives of General Psychiatry*. 2012; 69(2):129–138. [PubMed: 22310503]
- Gold JM, Hahn B, Strauss GP, Waltz JA. Turning it upside down: Areas of preserved cognitive function in schizophrenia. *Neuropsychology Review*. 2009; 19(3):294–311. [PubMed: 19452280]
- Gold JM, Strauss GP, Waltz JA, Robinson BM, Brown JK, Frank MJ. Negative symptoms of schizophrenia are associated with abnormal effort-cost computations. *Biological Psychiatry*. 2013; 74:130–136. [PubMed: 23394903]
- Greenzang C, Manoach DS, Goff DC, Barton JJ. Task-switching in schizophrenia: Active switching costs and passive carry-over effects in an antisaccade paradigm. *Experimental Brain Research*. 2007; 181:493–502. [PubMed: 17486327]
- Heerey EA, Robinson BM, McMahon RP, Gold JM. Delay discounting in schizophrenia. *Cognitive Neuropsychiatry*. 2007; 12:213–221. [PubMed: 17453902]
- Heerey EA, Gold JM. Patients with schizophrenia demonstrate dissociation between affective experience and motivated behavior. *Journal of Abnormal Psychology*. 2007; 116:268–278. [PubMed: 17516760]
- Heerey EA, Matveeva TM, Gold JM. Imaging the future: Degraded representations of future rewards and events in schizophrenia. *Journal of Abnormal Psychology*. 2011; 120:483–489. [PubMed: 21171727]
- Kirkpatrick B, Strauss GP, Nguyen L, Fischer BA, Daniel DG, Cienfuegos A, et al. The Brief Negative Symptom Scale: Psychometric properties. *Schizophrenia Bulletin*. 2001; 37:300–305. [PubMed: 20558531]

- Kool W, McGuire JT, Rosen ZB, Botvinick MM. Decision making and the avoidance of cognitive demand. *Journal of Experimental Psychology. General.* 2010; 139:665–682. [PubMed: 20853993]
- Lesh TA, Niendam T, Minzenberg MJ, Carter CS. Cognitive control deficits in schizophrenia: Mechanisms and meaning. *Neuropsychopharmacology.* 2011; 36:316–338. [PubMed: 20844478]
- Mathalon DH, Fedor M, Faustman WO, Gray M, Askari N, Ford JM. Response-monitoring dysfunction in schizophrenia: An event-related brain potential study. *Journal of Abnormal Psychology.* 2002; 111(1):22–41. [PubMed: 11866176]
- Monsell S. Task switching. *Trends in Cognitive Sciences.* 2003; 7:134–140. [PubMed: 12639695]
- Morris SE, Holroyd CB, Mann-Wrobel MC, Gold JM. Dissociation of response and feedback negativity in schizophrenia: electrophysiological and computational evidence for a deficit in the representation of value. *Frontiers in Human Neuroscience.* 2011; 5:123. [PubMed: 22065618]
- Nuechterlein, KH.; Green, MF. *MATRICES Consensus Cognitive Battery Manual.* Los Angeles, CA: MATRICS Assessment, Inc.; 2006.
- Overall J, Gorham D. The Brief Psychiatric Rating Scale. *Psychological Reports.* 1962; 10:799–812.
- Pfohl, B.; Blum, N.; Zimmerman, M. *Structured Interview for DSM-IV Personality (SID-P).* Washington, DC: American Psychiatric Press; 1997.
- Ravizza SM, Moua KC, Long D, Carter CS. The impact of context processing deficits on task-switching performance in schizophrenia. *Schizophrenia Research.* 2010; 116:274–279. [PubMed: 19734013]
- Salamone JD, Correa M. The mysterious motivational functions of mesolimbic dopamine. *Neuron.* 2012; 76:470–485. [PubMed: 23141060]
- Schmidt L, Lebreton M, Clery-Melin ML, Daunizeau J, Pessiglione M. Neural mechanisms underlying motivation of mental versus physical effort. *PLoS Biology.* 2012 Feb.10(2):e1001266. [PubMed: 22363208]
- Strauss GP, Robinson BM, Waltz JA, Frank MJ, Kasanova Z, Herbener ES, Gold JM. Patients with schizophrenia demonstrate inconsistent preference judgments for affective and nonaffective stimuli. *Schizophrenia Bulletin.* 2011; 37(6):1295–1304. [PubMed: 20484522]
- Strauss GP, Gold JM. A new perspective on anhedonia in schizophrenia. *American Journal of Psychiatry.* 2012; 169:364–373. [PubMed: 22407079]
- Treadway MT, Buckholtz JW, Cowan RL, Woodward ND, Li R, Ansari MS, et al. Dopaminergic mechanisms of individual differences in human effort-based decisionmaking. *Journal of Neuroscience.* 2012; 32:6170–6176. [PubMed: 22553023]
- Wechsler, D. *Wechsler Abbreviated Scale of Intelligence (WASI).* San Antonio, TX: The Psychological Corporation; 1999.
- Wechsler, D. *Wechsler Test of Adult Reading (WTAR).* San Antonio, TX: The Psychological Corporation; 2001.
- Westbrook A, Kester D, Braver TS. What is the subjective cost of cognitive effort? Load, trait, and aging effects revealed by economic preference. *PLoS One.* 2013 Jul 22.8(7):e68210. [PubMed: 23894295]
- Wylie GR, Clark EA, Butler PD, Javitt DC. Schizophrenia patients show task switching deficits consistent with N-methyl-d-aspartate system dysfunction but not global executive deficits: Implications for pathophysiology of executive dysfunction in schizophrenia. *Schizophrenia Bulletin.* 2010; 36:585–594. [PubMed: 18835838]



**Figure 1.** Illustration of a trial sequence from the Demand Selection Task. The choice of a color patch reveals a number that appear in either yellow or blue. The number indicates the type of judgment, parity or magnitude, the subject must make on that trial:



**Figure 2.** Mean proportion of low-demand choices (+SE). Experiment 1 results shown in left panel, Experiment 2 results shown in middle panel, and Experiment 3 results are shown in the right panel.



	Experiment 1			Experiment 2			Experiment 3		
	SC	HC	N	SC	HC	N	SC	HC	N
N	18	13	36	25	2340	36	38.3(11)	39.6(10.2)	
Age	34.1(11)	37.8(13.6)	39.4(9.6)	38.2(12)	15.2(1.9)**	12.6(2.2)	15.1(2.0)**		
Education	13.6(2.4)	15.2(1.9)	13.0(2.1)	13.2(3.7)	14.4(2.8)	14.3(3.6)	14.8(3.1)		
Paternal Ed.	13.8(3.8)	14.3(3.7)	13.3(2.8)	14.6(1.9)	16.6,1	22,12,6	19,12,4		
Maternal Ed.	13.6(2.3)	14.3(2.5)	13.12,0	7,6	11,14	22,13	29,11		
#C/AA/O	10.6,2	5.7,1	109.6(14.5)	119(4.8)**	96.2(10.1)	117.3(10.2)**	99.7(14.6)	118.6(12)**	
#M/F	14,4	7,6	39.4(13.1)	53.4(6.5)*	29.9(11.1)	55.4(8.9)**	31.3(14.5)	54.1(10.4)**	
WASI IQ <sup>a</sup>			33.6(8.3)	34.2(8.4)					
MCCB Total <sup>b</sup>			21.7(9.8)	30(14.1)					
BPRS total			17.1(10.5)	25.6(15)					
SANS total									
BNSS total									

SC= People with Schizophrenia, HC= Healthy Controls, C= Caucasians, AA= African-Americans, O=Others, M=Males, F= Female.

\*  $p < 0.05$ ,

\*\*  $p < 0.01$  ;

<sup>a</sup>In Experiment 3, IQ data are missing for one patient, and 1 healthy control.

<sup>b</sup>Experiment 3 MCCB data are missing for 1 patient and 2 healthy controls.