A Convergent–Divergent Approach to Context Processing, General Intellectual Functioning, and the Genetic Liability to Schizophrenia

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Convergent and divergent validity are critically important in developing psychological measures that reveal interpretable deficits in disordered populations. This article reports on 2 studies that evaluated the validity of context processing measures. In Experiment 1, a confirmatory factor analysis of data from 481 healthy adults established the convergent validity of 2 context processing measures and showed that context processing accounted for significant amounts of variance in standard IQ and working memory measures. In Experiment 2, 20 schizophrenia patients, 16 of their healthy siblings, and 28 controls were evaluated using a novel, short context processing measure, the dot pattern expectancy (DPX) task. The DPX was sensitive to specific deficits in schizophrenia patients and their healthy siblings. These findings support the construct validity of context processing measures, suggest context processing is a component of intellectual functioning, and demonstrate that brief context processing measures remain sensitive to psychopathological deficits.

Keywords: context processing, schizophrenia, intelligence, endophenotype

The two studies reported in this article contribute to the ongoing expansion of the neuropsychologist’s toolbox to include more measures of molecular, explanatory cognitive mechanisms such as those developed in experimental cognitive psychology (MacDonald & Carter, 2002). The focus of these studies is context processing, a construct that has been generative in both experimental psychology and psychopathology. Here we evaluate several aspects of the validity of context processing measures and the sensitivity of a novel measure to specific deficits in context processing among schizophrenia patients and their healthy siblings.

Context processing is conceptualized as the component of cognitive control that represents and actively maintains task-relevant information despite subsequent noise (Cohen & Servan-Schreiber, 1992; E. K. Miller, 2000). Task-relevant information includes the environmental stimuli, instructions, or goals that must be integrated to guide behavior. Such guidance is particularly needed to make novel or secondary responses. For example, on your way to work, the context of having to pick up doughnuts allows you to change your usual route accordingly. Failure to maintain this context can lead to very disappointed colleagues. Changing a habitual route requires more than simply storing this errand in short-term memory as one might a letter string; the stored information must be actively maintained despite environmental distractions and transformed into support for a novel response (e.g., turning at the stoplight). This hallmark of context processing is related to earlier cognitive constructs such as selective attention (Norman & Shallice, 1986), distractibility (Oltmanns & Neale, 1975), and working memory’s central executive (Baddeley & Hitch, 1974), all of which speak to the need for manipulating incoming information to control responses on the basis of abstract task demands.

This kind of context processing has been the focus of a number of connectionist models. That is, unlike many other executive functions, mathematical simulations of parallel units performing simple computations have been able to account for experimental findings across a number of (primarily verbal) context processing tasks (e.g., Braver, Barch, & Cohen, 1999; Cohen, Dunbar, & McClelland, 1990). Furthermore, functional MRI and electrophysiological experiments suggest that two aspects of context processing—context representation and context maintenance—are associated with activity in middle frontal gyrus (Barch et al., 1997; Dias, Foxe, & Javitt, 2003; MacDonald, Cohen, Stenger, & Carter, 2000; Perlstein, Dixit, Carter, Noll, & Cohen, 2003).

Validity of Context Processing Measures

Although formal and neurobiological components of context processing are well documented in the literature, there is little...
known about the convergent and divergent validity (Campbell & Fiske, 1959) of context processing measures. Nor is there published data on the relationship between context processing and higher order cognitive processes such as intellectual functioning. Thus, Experiment 1 was designed to address whether context processing measures converge, or correlate, with each other and whether they measure something different, or diverge, from measures of other constructs.

The task that has been most commonly used in context processing experiments is the expectancy AX task, originally modified by Cohen and colleagues (Servan-Schreiber, Cohen, & Steingard, 1996) from the original AX Continuous Performance Test (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956). In the expectancy AX task, participants view a series of letters one at a time on a computer screen and are asked to identify each letter as a “target” or “nontarget” by pressing one of two keys on a computer keyboard. A target is defined as the letter X, but only if the preceding letter was an A. All other letters are nontargets. The cue, whether an A or some other letter (hereafter B), provides the context for preparing a response. On AX\textsubscript{exAX} trials (the subscript indicates the expectancy AX task), the context of the A is important for deciding whether the subsequent X is a valid probe. Likewise, for the occasional BX\textsubscript{exAX} trials, the B provides the context that the subsequent X is not a target, even though X’s are generally valid targets. Individuals who cannot represent or maintain this context, such as schizophrenia patients, are thought to be more likely to be lured into mistaking this invalid X for a target. Because it requires overcoming a habitual response pattern, the BX\textsubscript{exAX} condition is thought to be even more sensitive than the AX\textsubscript{exAX} condition to individual differences in context processing. On the occasional AY\textsubscript{exAX} trials, the A cue supports the expectation of a valid X target. When a non-X probe occurs (hereafter Y), individuals whose strong representation of context leads them to prepare a target response then must overcome that prepared response. According to some models, performance in this condition should be inversely correlated with context processing; that is, individuals with poor context processing should perform better in this condition (Braver, 1997; Braver & Cohen, 2001). Because both BX\textsubscript{exAX} and AY\textsubscript{exAX} trials need to be relatively rare, this task requires at least 20 min to complete.

Despite its usefulness in experimental, neuroimaging, and psychopathology studies, the expectancy AX task has rarely been included as part of standard neuropsychological assessment, perhaps because the time required seems inefficient. If, as context processing theory suggests, task-relevant information is represented and maintained in modality-neutral integrative cortices such as dorsolateral prefrontal cortex (E. K. Miller & Cohen, 2001), there may be ways to measure context processing more efficiently. One possibility is to use visuospatial stimuli, such as dot patterns, that can be parametrically manipulated to show invalid cues that are similar to the valid cues, and invalid probes that are distinct from the valid probes (see Figure 1). We believed this would (a) increase AY errors; (b) allow more frequent interleaving of critical (BX and AY) trials; and (c) allow a shorter delay between the cue and probe, because novel, visuospatial stimuli degrade faster than overlearned stimuli such as letters or words. Thus, the current study evaluated a novel, visuospatial variant of the expectancy AX task, the dot pattern expectancy (DPX) task. To investigate the modality neutrality of individual differences in context processing, we tested the hypothesis that the DPX would show convergent validity with the corresponding AX and BX conditions of the expectancy AX task. Next, we tested the hypothesis, derived from formal models, that errors on AY trials measure better context processing and should therefore be negatively correlated with AX and BX performance across modalities.

The brain regions involved in context processing have also been implicated in general intellectual functioning (Duncan & Owen, 2000; Gray & Thompson, 2004) and in working memory tasks with large demands on executive processes (D’Esposito et al., 1995; Sakai, Rowe, & Passingham, 2002). There is a great deal of debate about the cognitive components of these higher level processes (e.g., Ackerman, Beier, & Boyle, 2005; Oberauer, Schulze, Wilhelm, & S ü b, 2005). Thus, Experiment 1 provided an opportunity to evaluate whether strategically simple context processing tasks could account for variance in these more abstract functions. Such a finding would be supportive of the position that the prefrontal mechanisms that represent and maintain abstract task-relevant information are an important, explanatory component of human intellectual abilities (Kane & Engle, 2002).

Specific Deficits in Context Processing and the Genetic Liability to Schizophrenia

Although the convergence of the BX measures of context processing in the established expectancy AX and the novel DPX tasks addressed task validity, this would not indicate whether the DPX might be useful for studying deficits in impaired groups. Thus, in Experiment 2 we examined whether a shorter measure of context processing could detect a specific deficit in two impaired populations, namely, schizophrenia patients and their healthy relatives.

The expectancy AX task has previously been useful for studying context processing deficits in schizophrenia. Deficits in context processing are prominent and persistent in chronic and first-episode schizophrenia patients (Barch, Carter, MacDonald, Braver, & Cohen, 2003; Cohen, Brarch, Carter, & Servan-Schreiber, 1999; Javitt, Shelley, Silipo, & Lieberman, 2000) and have been observed in their healthy siblings (MacDonald, Pogue-Geile, Johnson, & Carter, 2003). Furthermore, these deficits appear to be process-specific, or differential, deficits. A specific deficit is an impairment in a particular domain over and above a generalized impairment (Chapman & Chapman, 1973; Knight, 1984). A generalized impairment is a pattern of poor performance across a variety of different tests, which is frequently observed in schizophrenia (see Heinrichs & Zakzanis, 1998). Thus, evidence of a process-specific deficit might provide additional interpretative leverage to relate cognitive dysfunctions to abnormalities in neural and genetic mechanisms (MacDonald & Carter, 2002). In the expectancy AX task, the interpretation of a specific deficit has relied on a dissociation between a context processing condition and a control condition. To explore the sensitivity of the DPX to specific

![Figure 1](dot_pattern_stimuli_braille_font_used_in_dot_pattern_expectancy_task.png)

**Figure 1.** Dot pattern stimuli (Braille font) used in dot pattern expectancy task.
deficits in context processing, in Experiment 2 we examined whether this pattern of impairments would be observed in schizophrenia patients and their healthy siblings.

Experiment 1: Convergent and Divergent Validity of Context Processing Measures

Method

Participants. As part of the University of Pittsburgh’s ongoing Adult Health and Behavior Study, 502 volunteers age 30–54 were recruited through direct mail solicitation. Participants were either Caucasian or African American and were ruled out for a positive history of myocardial infarction or coronary revascularization, chronic kidney or liver disease, cancer, history of neurological disorder or psychosis as measured by the Structured Clinical Interview for DSM–IV—Non-Patient Edition (First, Spitzer, Gibbon, & Williams, 2002), or current use of psychotropic, glucocorticoid, or antihypertensive medications. No information was obtained regarding first-degree relatives’ psychiatric status.

Tasks. There were two measures of context processing: the expectancy AX task and the DPX. The expectancy AX task was presented in four blocks of 38 letter pairs, of which 30 (79%) were AXexAX trials, 3 (8%) were BYexAX trials, and 2 (5%) were BYexAX trials (which were included as a general manipulation check). The cue (A or B) appeared for 1,000 ms, there was a 5,000-ms delay, and then the probe (X or Y) appeared for 500 ms followed by a 1,000-ms intertrial interval. This task lasted about 20 min plus breaks and training time. The DPX differed from the expectancy AX task in the following ways: (a) The stimuli were selected from Braille font dot patterns as depicted in Figure 1, and participants were instructed to consider them as visual patterns (rather than relabeling them); (b) each block consisted of 40 trials: 28 (70%) were AXDPX trials, 5 (12.5%) were AYDPX trials, 5 (12.5%) were BXDPX trials, and 2 (5%) were BYDPX trials; lastly, (c) the delay between the cue and the probe was shortened to 4,000 ms. This task lasted 13 min plus breaks and training time. Although the computer provided feedback on each trial, performance was unsupervised after initial training. Participants who made more than 90% AX errors or 20% BY errors on either task were removed from analyses, because it was unclear whether they had understood the task instructions.

Intellectual functioning was evaluated using the total scores from the Vocabulary and Matrix Reasoning subtests of the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999). Executive functions in working memory were measured using the d' sensitivity score from letter and spatial versions of the N-back (Gevins & Cutillo, 1993). The letter N-back used upper- and lowercase letters, and targets were 3-back repeats (case neutral). The spatial N-back tasks used dot patterns similar to those from the DPX, and targets were 2-back repeats. Both tasks consisted of 56 trials (50% targets) using a common stimulus duration of 500 ms and a 2,000-ms intertrial interval.

Analyses. The convergent and divergent validity of the normal Blom transform of accuracy data from the context processing measures were evaluated using a confirmatory factor analysis implemented in LISREL (Jöreskog & Sörbom, 2001). The correlations between the latent factors in this model were then compared with latent working memory and general intellectual functioning factors using a measurement model. In both cases, the model reduction strategy was to begin with an unnecessarily complex (overfit) model and then gradually simplify it until further simplification drastically reduced its ability to predict the observed data (see Appendix table). Successive models were reduced according to Bayes’s information criterion (Raftery, 1995). A regression-based structural model was then used to test whether context processing and working memory sensitivity measures accounted for overlapping variance in intellectual functioning.

Results and Discussion

Of the initial sample of 502, 21 participants (4%) were excluded owing to poor performance on context processing measures. Excluded participants were significantly more likely to be African American and have lower education (ps < .001) but did not differ on other demographic variables. Demographic data from the final general population sample of 481 are summarized in Table 1.

Performance on the expectancy AX and DPX tasks for the final sample are summarized in Table 2. Initially, a mixed-model analysis of variance (ANOVA) compared 242 women with 239 men across all conditions on both context processing measures. Because there were no significant main effects of sex or any interactions between sex and performance on any variable (all Fs < 2.01, ps > .15), sex was not included in subsequent models. Confirmatory factor analyses tested the construct validity of context processing as measured by the expectancy AX task and the DPX (see Appendix table and Figure 2). This analysis demonstrated two latent factors measured by the expectancy AX and the DPX tasks. The first factor, Context Processing, was correlated

Table 1
Sample Characteristics: Selected Demographic and Symptom Expression Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Experiment 1: General population (n = 481)</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Patients (n = 20)</td>
<td>Siblings (n = 16)</td>
</tr>
<tr>
<td></td>
<td>Controls (n = 28)</td>
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</tr>
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<td>Demographic data</td>
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<td>43.6 (7.2)</td>
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<tr>
<td>Race (% African American)</td>
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<td>35</td>
</tr>
<tr>
<td>Education (years)</td>
<td>16.3 (3.2)</td>
<td>14.0 (2.2)</td>
</tr>
<tr>
<td>Parental education (years)</td>
<td>13.1 (3.0)</td>
<td>12.8 (2.6)</td>
</tr>
<tr>
<td>Symptom expression data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PANSS positive symptoms</td>
<td>6.4 (3.1)a,b</td>
<td>3.1 (0.3)a</td>
</tr>
<tr>
<td>PANSS negative symptoms</td>
<td>8.7 (3.6)a</td>
<td>6.7 (3.2)</td>
</tr>
<tr>
<td>PANSS disinhibition symptoms</td>
<td>8.1 (2.8)a,b</td>
<td>5.9 (2.1)a</td>
</tr>
<tr>
<td>BPRS</td>
<td>30.2 (7.6)a,b</td>
<td>20.1 (3.8)a</td>
</tr>
<tr>
<td>GAS score</td>
<td>65.9 (14.1)a,b</td>
<td>93.3 (4.6)a</td>
</tr>
</tbody>
</table>

Note. Data are means (and standard deviations) unless otherwise indicated. PANSS = Positive and Negative Syndrome Scale; BPRS = Brief Psychiatric Rating Scale; GAS = Global Assessment Rating Scale. Groups that share a subscript were different in post hoc tests (Tukey’s honestly significant difference test, ps < .05).
with AX and BX trials from both tasks to the same degree \((r = .67)\) for all). That is, these conditions showed convergent validity across tasks. The second factor, labeled the Preparatory factor, was defined by the AY condition and to a lesser extent the AX condition from both tasks. Contrary to our second hypothesis, the two latent factors were uncorrelated—that is, the factors were divergent.

Next, we examined the relationships between the Context Processing and Preparatory factors, working memory (as measured by the 3-back letter and 2-back dot pattern tasks), and intellectual functioning (as measured by Vocabulary and Matrix Reasoning). This model demonstrated significant correlations between Context Processing and both the Working Memory \((r = .50)\) and Intellectual Functioning \((r = .53)\) latent factors, suggesting a large proportion of overlapping variance between these three. The Preparatory factor was significantly correlated with the Working Memory factor \((r = .37)\) but not Intellectual Functioning. Parameter estimates for the best fitting model are provided in Figure 2. Finally, we fit a regression-based structural model with the latent Intellectual Functioning factor as the criterion and the Context Processing, Preparatory, and Working Memory factors as the predictors. Together, the three variables accounted for almost half of the variance of the Intellectual Functioning factor \((R^2 = .46)\). Both the Context Processing \((\beta = .25, SE = .08)\) and Working Memory \((\beta = .56, SE = .10)\) factors made significant, independent contributions to the prediction of intellectual functioning. The Preparatory factor did not \((\beta = .14, SE = .08)\).

Thus, it appeared that not one but two latent factors were tapped by the critical conditions of the expectancy AX and the DPX tasks. These factors were not significantly correlated. The model therefore provided convergent evidence for the two BX conditions as measures of context processing in a large, general population sample. This convergence was suggestive that a task such as the DPX might be useful for tapping context processing when testing time is constrained. These findings also showed that the relationship between the Context Processing factor and Intellectual Functioning was not secondary to spurious factors such as motivation or performance-related personality factors, which were likely to have been measured in all conditions of the expectancy AX and DPX tasks. Despite this evidence of convergent and divergent validity, this experiment was unable to address whether the DPX would

![Figure 2](#)

**Figure 2.** Confirmatory factor analysis of expectancy AX (exAX) and dot pattern expectancy (DPX) tasks (inside dotted line) and measurement model with Intellectual Functioning and Working Memory factors. All illustrated paths contribute significantly to fit. BX and AX loads on the Context Processing factor are equal, but the indicated AX loading is lowered owing to loadings on the Preparatory factor.
reveal specific deficits in context processing. Experiment 2 addressed this question directly in a sample of schizophrenia patients and their healthy siblings.

Experiment 2: Specific Deficits in Schizophrenia Patients and Their Healthy Siblings

**Method**

**Sample.** A sample of 20 patients with schizophrenia or schizoaffective disorder, 16 of their healthy siblings, and 28 demographically similar control participants who were not part of Experiment 1 completed the DPX task. Participants, a subset of a larger sample described previously by MacDonald and colleagues (2003), were 18–45 years old and were either Caucasian or African American. All patients were chronic and taking medication as part of outpatient treatment at the time of the study. Siblings and controls had no history of psychosis as diagnosed using the Structured Clinical Interview for DSM-III-R—Non-Patient Edition (Spitzer, Williams, Gibbon, & First, 1990). Interviewers also rated participants on the Brief Psychiatric Rating Scale (Overall & Gorham, 1962) and the Positive and Negative Syndrome Scale (Kay, Opler, & Fiszbein, 1986), separated into three factors (Peralta & Cuesta, 1994).

**Tasks.** The DPX was identical to that used in Experiment 1, except that participants completed two rather than three blocks so that the task lasted 8 min 40 s. The test was given as part of a larger battery that included the expectancy AX task. Performance was supervised in this study: The experimenter was in the room and reminded participants approximately midway through to respond as quickly and accurately as possible. No participants needed to be removed from the analyses for extremely poor performance.

In reporting effect sizes, we have converted partial eta square statistics to Cohen’s $d$ to facilitate comparisons between omnibus and contrast analyses.

**Results and Discussion**

Demographic and symptom expression data from patients, siblings, and controls are summarized in Table 1. Note that the average age of the siblings was 36.3 years, largely past the prime risk period for developing schizophrenia.

Results from the DPX are illustrated in Figure 3. A 4 (condition) × 3 (group) mixed-model ANOVA of accuracy on the DPX indicated no significant effect of condition and a significant main effect of group, $F(2, 61) = 9.51, p < .001, d = 1.12$, with patients showing more errors on all conditions. Of importance, there was a significant interaction between condition and group, Greenhouse–Geisser adjusted $F(5.3, 161.4) = 3.51, p = .004, d = 0.68$. Examining within-group performance, controls made more $AY_{DPX}$ than $BX_{DPX}$ errors, $F(1, 27) = 21.75, p < .001$, Cohen’s $d_{BX-AY} = -1.79$. Other things being equal, larger impairments are found in more difficult conditions (Chapman & Chapman, 1973; M. B. Miller, Chapman, Chapman, & Collins, 1995); however, patients and siblings made nonsignificantly more $BX_{DPX}$ relative to $AY_{DPX}$ errors ($F_s < 0.05, p_s > .80$, Cohen’s $d_{BX-AY} = 0.09$ for both). Planned group contrasts showed that patients were worse than controls on $BX_{DPX}$ trials alone, $t(23.8) = 2.87, p = .008$, Cohen’s $d = 0.89$, whereas this effect was smaller when patients were compared with controls across both $BX_{DPX}$ and $AY_{DPX}$ conditions, $F(1, 61) = 3.94, p = .052$, Cohen’s $d_{BX-AY} = 0.53$.

The findings differed subtly when siblings were compared with controls. Although the siblings tended to make more errors than controls on $BX_{DPX}$ trials alone, $t(21.3) = 2.03, p = .054$, Cohen’s $d = 0.68$, this effect rose slightly when siblings were compared with controls across both $BX_{DPX}$ and $AY_{DPX}$ conditions, $F(1, 61) = 4.30, p = .052$, Cohen’s $d_{BX-AY} = 0.72$.

These findings suggest that because patients had a large generalized deficit, “correction” for $AY_{DPX}$ reduced the observed effect associated with the context processing deficit; because siblings had a negligible generalized deficit, this correction did not reduce the effect size. There were no significant differences between patients and siblings on either $BX_{DPX}$ alone or the interaction of $BX_{DPX}$ and $AY_{DPX}$. These data are supportive of a specific deficit in context processing associated with the genetic liability to schizophrenia.

We also observed that the control groups in both Experiment 1 and Experiment 2 made more $AY_{DPX}$ than $BX_{DPX}$ errors. However, there was a significant performance difference between these two groups, with Experiment 1 participants making fewer $AY_{DPX}$ errors and more $BX_{DPX}$ errors than Experiment 2 controls, $F(1, 507) = 11.98, p = .001$, suggesting that experimental supervision contributed to increased $AY_{DPX}$ error rates.

**General Discussion**

To evaluate the convergent and divergent validity of context processing measures and the specificity of deficits in this process, we evaluated a large general population sample and a pilot sample of patients with schizophrenia and their siblings using both established and novel measures of context processing. We found that (a) both the AX and BX conditions of the established expectancy AX task and the novel DPX task measured context processing equally well, whereas AX and $AY$ conditions both measured an uncorrelated factor that may be associated with response preparation; (b) individual differences in context processing were closely related to variation in higher level working memory and general intellectual functions; and (c) the DPX was sensitive to specific context...
processing deficits in patients with schizophrenia and their healthy siblings. Additionally, we observed no sex differences in context processing.

Experiment 1 indicated that not one but two latent factors were tapped by the critical conditions of the expectancy AX and the DPX tasks. These factors were not significantly correlated. At its simplest level, this model provided convergent evidence for the two BX conditions as measures of context processing in a large, general population sample. This convergence is suggestive that a task such as the DPX might be useful for tapping context processing when testing time is constrained.

The confirmatory model of the expectancy AX and the DPX also provided two important theoretical insights into context processing. First, the equivalent ability of the two tasks to measure individual differences in this latent trait suggested that context processing is not sensitive to changes from phonemic (letter) to visuospatial (dot pattern) stimuli. The implication that cue information is not stored as a token (A or B) but is transformed into a representation associated with its significance (“likely to press target” or “must not press target, press nontarget instead”) is consistent with other observations that context processing is performed by modality-neutral, higher brain regions, such as the dorsolateral prefrontal cortex (bilateral BA 9 and 46; Barch et al., 1997; MacDonald et al., 2000; E. K. Miller & Cohen, 2001). Second, the AX condition was not significantly related to the Context Processing factor. According to formal models (Braver, 1997; Braver et al., 1999), AX errors should be more likely if the expectation of a valid probe is represented and maintained. However, in the current study, patients with schizophrenia made as many AX errors as controls, which has been previously observed (e.g., Barch et al., 2003; Cohen et al., 1999; MacDonald et al., 2003; for exceptions, see Stratta, Daneluzzo, Bustini, Casacchia, & Rossi, 1998); thus, this conjecture has been challenged. The AX condition may be more akin to a go/no-go task, in which a response must be overcome after it has been prepared and therefore draws strongly on response inhibition. These data also do not rule out the possibility that participants’ AX performance is affected by a number of heterogeneous factors. In either case, variance in the AX condition supports the divergent validity of context processing conditions.

The measurement model is also suggestive of the processes implemented by the prefrontal cortex in support of higher level cognitive functions, such as executive processing in working memory and intellectual ability. For much of the past century, psychologists and educators have struggled to explain the nature of general intellectual functioning, or g. Several recent studies have shown that tasks that efficiently tap the latent factor g involve prefrontal cortex (for a review, see Gray & Thompson, 2004). Executive processes in working memory also rely on this region (for a review, see Smith & Jonides, 1999). Because context processing has been well characterized and computationally modeled, and because measures such as the expectancy AX and DPX tasks have very simple task demands, this mechanism may be a useful way to conceptualize some aspects of the cognitive and neural basis of intellectual functioning. That is, these more complex processes may rely on the ability to flexibly represent and maintain context to control behavior. Neuroimaging could be used to confirm the common substrate of these functions in future studies. These data also show that in a highly educated sample, which might be expected to suffer from ceiling effects on such simple tasks, there is enough variance in performance to detect a strong link between context processing and other higher level functions.

Experiment 2 indicated that although patients with schizophrenia and their siblings did not perform significantly worse on BXDPx as compared with AYDPx trials, the BXDPx condition was significantly easier than the AYDPx condition (as demonstrated by controls). If context processing was spared, patients and their siblings should have performed better in the BXDPx condition, which they assuredly did not. The pattern, observed in both patients and siblings, indicates that the deficit in context processing is not primarily associated with disease state or chronicity, or even risk for developing schizophrenia (as the siblings were largely past the peak risk). Rather, context processing deficits mark the unexpressed genetic liability to the disorder.

In addition to marking liability genes, evidence from other studies suggests that context processing deficits are diagnostically specific as well: The deficit is not prominent in nonpsychotic depressed (Servan-Schreiber et al., 1996) or bipolar patients (Brambilla et al., 2005), and it is transient in nonschizophrenic psychotic patients (Barch et al., 2003). The deficit also appears to be linked to the more characteristic symptoms of schizophrenia, including disorganization and formal thought disorder (Cohen et al., 1999; MacDonald et al., 2005).

Because participants from all three groups were drawn from a larger study (MacDonald et al., 2003), Experiment 2 was not an independent replication of a previous demonstration of this effect using the expectancy AX task. Instead, these data speak to the stability of this impairment across different stimulus modalities, suggesting that the increased efficiency of the DPX does not reduce sensitivity to deficits in patients with schizophrenia and their healthy siblings. Thus it may be a useful measure of an intermediate schizophrenia-related phenotype, or endophenotype (Gottesman & Gould, 2003), in larger epidemiological samples.

There are a number of limitations to these studies that bear comment. First, measurement models such as that tested in Experiment 1 are unable to speak directly to the causal relationship between context processing and general intellectual functioning. Thus, although these data support a parsimonious account of a mechanism that contributes to intellectual functioning, variance in context processing cannot be definitively interpreted as causing variance in intellectual functioning. Second, because family psychiatric histories were not available for Experiment 1 participants, we were unable to conduct a secondary analysis restricted to participants without any schizophrenic relatives. The results of Experiment 2 suggest that some of the variance in AXDPx and BXDPx trials was affected by liability genes. Thus, the final model probably incorporates variance associated with the genetic liability to schizophrenia as it occurs in the general population. Third, we found that controls differed between studies on the computer-administered task, which suggested that performance might be sensitive to experimenter supervision. Finally, the specific deficits reported in Experiment 2 were derived from a small sample and require replication (which is ongoing).

In summary, we used modern statistical procedures to demonstrate the convergent and divergent validity of two superficially
different context processing measures. This has practical implications for the measurement of endophenotypes associated with genetic risk to schizophrenia as well as perhaps other forms of psychopathology. The shorter DPX task facilitates the evaluation of this function, and the ability to “correct” for generalized deficits using the AYDPX condition can improve the interpretability of poor performance on the BXDPX condition. Furthermore, the large sample size allowed us to further refine current thinking about the molecular cognitive processes underlying higher level executive processing in working memory tasks and tests of general intelligence. Thus, these complementary studies illustrate some of the advantages of including more experimental measures in modern neuropsychological assessments.

References


Experiment 1 Confirmatory Factor Analysis Reduction Strategy: Convergent Validity and Measurement Model

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<th>No.</th>
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<th>df</th>
<th>RMSEA</th>
<th>BIC</th>
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<td>1</td>
<td>All measures load on latent Context Processing factor</td>
<td>82.11</td>
<td>9</td>
<td>.140</td>
<td>26.11</td>
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<tr>
<td>2</td>
<td>All measures also load on latent Preparatory factor, which correlates with Context Processing factor</td>
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<td>4</td>
<td>.071</td>
<td>−10.97</td>
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<tr>
<td>3</td>
<td>AY loadings on Context Processing factor and BX loadings on Preparatory factor removed</td>
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<td>6</td>
<td>.055</td>
<td>−21.85</td>
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<td>4</td>
<td>AX loadings on Preparatory factor equated</td>
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<td>AX and BX loadings on Context Processing factor equated</td>
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<td>14</td>
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<td>−57.55</td>
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</tbody>
</table>

Above model with Working Memory and Intellectual Functioning factors

<table>
<thead>
<tr>
<th>No.</th>
<th>Reduction</th>
<th>$\chi^2$</th>
<th>df</th>
<th>RMSEA</th>
<th>BIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Correlations between all latent factors</td>
<td>62.47</td>
<td>35</td>
<td>.038</td>
<td>−152.57</td>
</tr>
<tr>
<td>9</td>
<td>Correlation between Preparatory and Intellectual Functioning factors removed</td>
<td>64.67</td>
<td>36</td>
<td>.039</td>
<td>−156.52</td>
</tr>
</tbody>
</table>

Note. Boldface type indicates best-fitting models, illustrated in Figure 2. RMSEA = root-mean-square error of approximation; BIC = Bayesian information criterion (lower = improved fit); exAX = expectancy AX task; DPX = dot pattern expectancy task.

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