The panmodal sensory imprecision hypothesis of schizophrenia: reduced auditory precision in schizotypy

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Abstract

Research on tasks such as pitch discrimination suggests the presence of a panmodal sensory imprecision in schizophrenia: a global deficit in the fidelity of representations. In order to better understand the basis of this deficit, auditory precision was examined in a normal sample varying in schizotypal personality disorder (SPD) symptoms. Experiment 1 reports a significant linear relationship between auditory imprecision and SPD scores. A second experiment on the effects of delay revealed that, as in schizophrenia, this deficit did not reflect an increased rate of decay of the representation. A third experiment used an auditory inspection time task to examine speed of processing using a backward mask to limit exposure duration. No differences in processing speed were found. These results mirror findings in schizophrenia and suggest that the rate of information accumulation into the sensory store is normal, as is the rate of decay of this representation, but that the ultimate fidelity of primary sensory representations is reduced. It is suggested that deficits in the fine structure of representations may be a basic element of vulnerability for schizophrenia.

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1. Introduction

People with schizophrenia show deficits on simple sensory judgment tasks such as pitch discrimination (Strous, Cowan, Ritter, & Javitt, 1995), supporting what Javitt has called “panmodal sensory imprecision” as a basic deficit in schizophrenia (Javitt, Liederman, Cienfuegos, & Shelley,
While pitch discrimination deficits in schizophrenia are reliable and large, especially in chronic schizophrenia (Rabinowicz, Silipo, Goldman, & Javitt, 2000), pitch discrimination has not previously been examined in normal subjects differing in schizotypal personality disorder scores (SPQ: Raine, 1991). Such an analysis has several advantages in examining the role of panmodal sensory imprecision as a basic vulnerability trait for schizophrenia. In particular, this group is not medicated nor are they acutely agitated, and any differences found are not confounded by side effects of chronicity or treatment.

If sensory discrimination deficits mark vulnerability to schizophrenia, then they should be present even in a-symptomatic samples at risk for schizophrenia and should covary with schizotypal personality disorder scores (i.e., show “dose dependence”). In this paper, three experiments are reported: the first examined the relationship of schizotypal symptoms to pitch discrimination in 74 normal subjects, concluding that schizotypy is associated with decreased sensory precision. Experiments 2 and 3 critically examined possible confounds of sensory imprecision with alternative explanations based on slowing of initial information acquisition and rapid decay of stored memory.

The physiology of sensory representation and previous findings in schizophrenia are next briefly reviewed. Behaviorally, average subjects can reliably detect differences in pitch ($\Delta f$) of only 1–3% between comparison tones presented at an ISI of 1 s or less, even when they are not attending to the tone source (Cowan, Lichty, & Grove, 1990; Norman, 1969). Physiologically, the functions supporting this precision pitch behavior are localizable to bilateral primary auditory cortex (PAC: Zatorre, Belin, & Penhune, 2002). Bilateral lesions to the PAC substantially raise the pitch difference required for tones to be discriminated (Colombo, Rodman, & Gross, 1996; Iversen & Mishkin, 1973), and recent data on fine pitch discrimination in brain injury patients (Tramo, Shah, & Braida, 2002) indicate that frequency-selective neurons in PAC are essential for precise pitch discrimination: with bilateral PAC lesions causing up to an eightfold decrement in frequency discrimination. By contrast, unilateral PAC lesions, lesions to the auditory midbrain, and dorsolateral pre-frontal lesions resulted in no observable deficit in precision. Electrophysiologically the presentation of discriminable tones evokes a mismatch negativity (MMN), generated in PAC and measurable at the scalp (Lu, Williamson, & Kaufman, 1992, pp. 1668–1670; see also Cowan, Winkler, Teder, & Naatanen, 1993; Javitt, 2000).

Despite this basic role of PAC in discrimination it is true that a diverse set of brain systems are involved in even simple auditory comparisons. In monkeys, Gross has demonstrated that lesioning auditory association cortex in the superior temporal gyrus impairs delayed matching, while preserving immediate auditory comparison performance and delayed matching in the visual modality (Colombo, Rodman, & Gross, 1990). Lesions to frontal cortex do not produce specific deficits in the precision of auditory comparisons but do increase the effects of interference on tasks where distracter stimuli compete for attention (Chao & Knight, 1995, 1998). Together, these data suggest that sensory precision, delayed matching, and vulnerability to distraction are triply dissociable to PAC, auditory association cortex, and prefrontal cortex respectively, and that, therefore, lesions in any of these regions could potentially explain reduced pitch discrimination performance under specific circumstances (Alain, Woods, & Knight, 1998).

Initial reports of a deficit in sensory comparison in schizophrenia were based on greatly increased thresholds for identifying two brief tones as either being the same or different in pitch.
when presented at an ISI of 300-ms (Strous et al., 1995). Javitt’s group subsequently replicated this finding showing effect sizes between 0.48 and 1.96 (Javitt et al., 1999; Javitt, Strous, Grochowski, Ritter, & Cowan, 1997; March et al., 1999; Rabinowicz et al., 2000) and extending the finding to other modalities, such as weight discrimination (Javitt et al., 1999). Cognizant of the possible role for frontal cortical systems in modulating sensory areas, this group also examined the effects of delay, of distraction, and of masking on pitch discrimination in schizophrenia.

Compatible with the sensory imprecision hypothesis, the schizophrenic deficit in comparison performance is present at zero-delay (March et al., 1999). Moreover, there was no differential impact of delay in schizophrenic subjects over and above that to be expected from their initial sensory deficit (Javitt et al., 1997). Likewise while simultaneous distraction tasks increase thresholds, this effect is equal in normals and schizophrenics (Rabinowicz et al., 2000). While these findings suggest that the effective fidelity of the auditory store is reduced in schizophrenia, it remains possible that the ultimate fidelity of the store might be normal but that, because of slowed rates of information acquisition, the schizophrenic group was working with what was effectively a shorter, and therefore less informative, sample of the stimulus. Relatedly, the short-term store might be normal but have increased vulnerability to masking interference from subsequent auditory stimuli. These possibilities seem unlikely as following the trial stimuli by an auditory mask does not differentially affect patients. This research suggests that rates of extraction of information into the sensory buffer are normal, but that the fidelity of the buffer is impaired in schizophrenia (March et al., 1999).

In the three experiments presented below, the basic finding of pitch discrimination rates is replicated in a normal population varying on schizotypal personality rather than schizophrenia (Experiment 1), and the effects of delay and processing speed under masked conditions are examined (Experiments 2 and 3).

2. Experiment 1: Auditory sensory imprecision and schizotypy

This experiment aimed to replicate the reduced sensory precision finding, but in an asymptomatic normal population. A method for assessing auditory precision was chosen which is capable of testing for small differences and which maximized the precision of threshold estimates. Asking subjects to report the relative pitch of two tones, i.e., asking subjects to report which of two successive tones is the higher, provides a significantly more sensitive measure of bilateral PAC lesions than is gained from same–different pitch judgments (Tramo et al., 2002). For this reason the present experiment adopted a relative pitch response rather than the same–different judgment used previously. In addition, computerized algorithms and online stimulus generation enable arbitrary stimuli to be created in real time and thus support very efficient adaptive testing paradigms that rely on having a full range of stimuli available for presentation. For this reason, an asymmetric staircase testing method (Garcia-Perez, 1998) was used to estimate thresholds, rather than a conventional method of adjustment or simpler staircase design. This is described in detail below, but in general provides a more efficient and accurate estimate of discrimination than conventional staircases.
2.1. Method

2.1.1. Subjects

Seventy-three people participated (37 male and 36 female; mean age 29 years, SD = 14). The sample was drawn from Macquarie University students, and community volunteers drawn from the friends and family of the students. Students received course credit for their participation.

2.1.2. Materials

Schizotypal personality disorder was assessed using the 22-item brief schizotypal personality questionnaire (SPQ: Raine, 1991). In order to mask the content of this questionnaire and encourage honest responding, the SPQ items were intermingled with items from the 240-item NEO PI-R measure of normal personality (Costa & McCrae, 1992) and were scored on a Likert 0–4 scale rather than the binary “yes/no” format.

The task developed in earlier reports (Javitt et al., 1997; Rabinowicz et al., 2000) was modified in the present experiment and computerized using Macintosh iMac computers running custom National Instruments LabVIEW software. Following previous research, the stimuli were sine waveforms of 100 ms duration, windowed through a cosine filter to avoid abrupt onset and offset impulses that might allow stimulus identification on the basis of audio artifacts rather than pitch comparison. Stimuli were presented at a nominal 75 dB and with an onset-to-onset interval of 1 s between comparison targets, and with a 2 s inter-trial-interval timed from the last response. On each trial a base tone was selected at random from one of three possible values: 500, 1000 or 2000 Hz. A second stimulus was then synthesized to differ in frequency from this base tone (up or down at random) by an amount determined from the current stair case location. The order of the tones (high or low tone first) was selected at random on each trial, with the proviso that each order occurred equally over the course of each successive sequence of six trials. Significant differences in the current method compared to that of earlier studies were as follows. Firstly, the two tones within each trial always differed from each other, and the subject's task was to report the stimulus order (hi-first or hi-second, rather than whether the tones were the same or different). Second, instead of drawing the difference tones from a fixed set of percentage frequency-difference levels (\(\Delta f\)) and presenting these in blocks, a Garcia-Perez (1998) staircase was used to estimate the 83.15%-correct value for each subject. This staircase gains efficiency by using a single large, asymmetric, step size (the step-up size was 0.3 log units and the step-down size was 0.2218 log units, i.e., 0.7393 * the step-up size). A large step generates reversals rapidly, thus increasing the data for threshold estimation and ensuring that most reversals do in fact bracket the target threshold. In addition, the large step allows the algorithm to recover from a sequence of lucky guesses by the subject, and subjects don't experience prolonged exposure to stimuli below their discrimination threshold. As recommended by Garcia-Perez, the staircase algorithm could request pitch differences of any value. However, the physical pitch difference was limited to an upper boundary of 100% \(\Delta f\).

In estimating pitch thresholds, the following rules were used: Trials started with a \(\Delta f\) of 100%—well above threshold for all subjects—ensuring that subjects had a clear understanding of the task (Green, Richards, & Forrest, 1989). Reversals were determined using a conventional 3-up, 1-down rule, and testing finished after 17 reversals (typical total numbers of trials were between 80 and 115 with no subject receiving more than 150 trials).
2.2. Procedure

All testing was conducted after informed consent was provided. The psychometric testing was completed in a session scheduled prior (sometimes immediately prior) to the experimental test session. In the experimental session subjects sat at the computer and were fitted with high quality headphones (Sony MDR 7502 Professional series). Initial screen prompts allowed the experimenter to ensure that the stimulus intensity was correct and that the headphones were oriented for correct stereo lateralization. The subject then saw on screen and was read aloud the instruction “In this next task, you will hear pairs of tones one after the other. The tones differ in pitch, and one will be higher than the other. Your task is to report whether the highest-pitch tone was presented first or second.” On each experimental trial, subjects could respond at any time after the second tone began to play, and pressed the “F8” or “F9” keyboard keys to indicate whether the higher of the two tones was first or second respectively. Practice trials with a 100% $\Delta f$ followed, accompanied by feedback in the form of an onscreen display indicating whether or not the previous response was correct. The real trials did not begin until four-trials in a row were completed correctly: this never took more than seven trials. If the subject had not responded 500 ms after the second tone was completed, a prompt appeared within the response dialog (which was on screen continuously) reminding the subject of the task and the response keys. Testing took around 15 min.

2.3. Results

In readying the data for analysis, each subject’s pitch discrimination threshold was computed individually by taking the mean of the log($\Delta f$) values at each of the 17 staircase-reversals. The SPQ was scored for its three components, and the total score was also computed giving four measures: cognitive–perceptual symptoms, interpersonal, and disorganization, and total SPQ score.

Because both the pitch discrimination task and the SPQ are continuous measures, regression statistics were used to quantify the relationship between the two variables, rather than making arbitrary diagnostic cut-off decisions. As shown in Fig. 1, the pitch-precision measure covaried significantly with total schizotypal symptoms (adjusted $R^2 = 0.21$, $F(1,72) = 20.55$, $p < 0.0001$). For some subjects, the staircase targeted stimulus differences of greater than the maximum physical difference presented 100% (0.3 on the log scale). Constraining the estimate to a maximum of 100% left the relationship largely intact, at $R^2 = 0.201$. Analyzing the pitch data separately for male and female participants gave $R^2$ values of 0.19 in females ($F(1,34) = 7.95$, $p = 0.0079$) compared to 0.272 in males ($F(1,35) = 13.1$, $p = 0.0009$). The relationship of pitch to SPQ, then, was not specific for one gender, but did tend to be stronger in males than females in this young sample.

While the brief SPQ is better suited to analyses of the total score than of subscales, the relationship of pitch precision to the disorganization, interpersonal, and cognitive–perceptual subscales was examined and each showed a significant relationship to pitch precision ($R^2 = 0.149$, 0.127, and 0.119 respectively, all $p$-values < 0.05). A stepwise multiple-regression examining the unique variance contributed by each subscale indicated that the cognitive–perceptual scale did not contribute unique variance (partial correlation = 0.093, $F$ to enter = 0.606).
These results suggest that pitch discrimination is impaired in normals with elevated schizotypal personality symptoms and that this is reflected in each of the schizotypal factors, but, at least in this brief assessment, showing stronger association to disorganization and withdrawal and without a unique contribution from cognitive and perceptual aberrations.

2.4. Discussion

The results of this experiment extend the finding of reduced auditory precision characteristic of schizophrenia to schizotypal personality in a non-clinical group (see Fig. 1). This has at least three initial implications. First, reduced precision in a pre-morbid population suggests that pitch discrimination deficits are not an artifact of illness or treatment, but may stand as a marker for risk or even act as a causal factor in the development of schizophrenia. Work is ongoing to examine how the magnitude of the deficit compares to that of chronic patients and if it covaries with state or is a trait marker. Secondly the linear relation across the range of SPQ scores suggests that biological vulnerability to schizophrenia may vary continuously in the normal population. This in turn lends support to the use of sensory precision measures in normal populations for studies aimed at the discovery of biological or genetic associations with schizophrenia, rather than relying solely on designs based on a diagnosis of schizophrenia. Finally, because sensory precision amongst normals is not random but correlates with behaviors related to schizophrenia implies that previous non-significant differences reported between controls and acute and outpatient groups (Rabinowicz et al., 2000) may have been hampered by schizophrenia-related variance within the “control” group.

This experiment, however, does not rule out alternative interpretations of the data in terms of distractability, rapid decay of memory traces, slower-than-normal accumulation of sensory information into the representational system, or increased backward masking effects from subsequent stimuli, rather than deficits in the ultimate fidelity or resolution of the schizotypal sub-
ject’s sensory representations. For this reason two further experiments were undertaken. In Experiment 2, the effect of increasing inter-stimulus delay was examined on a sub-sample of the participants of Experiment 1, and in Experiment 3 the rate of information accumulation and the effects of backward masking were examined.

3. Experiments 2 and 3: Auditory input speed and output decay in Schizotypy

The purpose of Experiments 2 and 3 was to test whether poor discrimination might be due to either early deficits in rate of information acquisition and/or vulnerability to backward masking, or to a rapid decay of the memory trace, preventing accurate reporting.

3.1. Stimulus input speed

Because stimulus report is impaired by a mask occurring immediately or within 200–300 ms of a brief stimulus (Cowan, 1984), the tone-comparison deficits in Experiment 1 might arise not from limits on the maximal precision of representation, but because of slowed information processing by schizotypals. Similarly increased vulnerability to backward masking might cause the stimulus 1 representation to be degraded by information from stimulus 2. Speed of processing and vulnerability to backward masking have been examined in only one previous report comparing masked and unmasked tone-matching in 14 medicated chronic schizophrenic patients and 16 controls (March et al., 1999). Using a method of adjustment, the pitch difference was adjusted for each subject so they achieved 80% correct with unmasked stimuli. Backward masking was introduced by following the second stimulus of each trial with a mask consisting of all seven possible test stimulus frequencies played simultaneously for 100 ms, and presented at offsets of 0, 20, 40, 80, 160, 250, or 500 ms from the offset of the second stimulus tone. As in previous studies, pitch perception was impaired even at zero-delay and without a mask. However, masking did not produce differential effects in schizophrenia: after controlling for non-masked performance, backward-masked matching, while poorer than in controls, was no worse in schizophrenics than would be predicted from their poor non-masked performance. This suggested that the rate of information processing from the short store was unimpaired, and that apparent vulnerability to backward masking in schizophrenia may reflect imprecision of stimulus representations, rather than increased efficacy of masking.

In the present study, information accumulation rate was assessed directly using an auditory inspection time task specifically developed to test for individual differences in the rate of processing information into a stage where it is protected from the effects of masking, as opposed to requiring precise discriminations, memory, or executive function (Vickers, Nettelbeck, & Willson, 1972). Typically a two-alternative forced choice method is used with one of two possible stimuli being presented on each trial, followed immediately by an efficient backward mask. Inspection time is determined using a staircase to estimate the minimum stimulus duration each subject requires to achieve a criterion accuracy (Deary, 2000).

The auditory inspection time task used here was adapted from Parker, Crawford, and Stephen (1998). The task involves reporting the spatial location of briefly presented tone stimuli similar to those used in Experiments 1 and 2, but presented 45° either to the left or the right of midline.
Subjects must report the location of the stimulus, which is masked by the immediate onset of a noise burst that disrupts processing. If the schizotypal pitch discrimination deficit is due to a reduced rate of information acquisition from auditory stimuli, or to increased vulnerability to interference from backward masking noise, then we should expect to find increased stimulus durations required for criterion accuracy on the auditory inspection time task.

3.2. Rapid decay

Because the pre-attentive store for high-precision acoustic information is vulnerable both to decay over time (Harris, 1952; Massaro, 1970) and to interference from concurrent auditory events (Deutsch, 1970; Keller, Cowan, & Saults, 1995; Pechmann & Mohr, 1992), the deficit reported in schizophrenia and, here, in schizotypals, may reflect interference and/or decay rather than reduced sensory precision. To address this possibility, pitch discrimination was examined across a longer delay of 4 s to see if pitch discrimination declined disproportionately during this delay, in which case the reduced precision in Experiment 1 might reflect decay over this initial interval.

Previous research has examined the effects of delay and distraction in schizophrenia (Javitt et al., 1997), comparing harder (5% Δf) and easier (20% Δf) frequency discrimination tasks in 18 chronic patients, and examining the time course of decreases in accuracy as ISI was increased from 0 to 20 s, with and without a concurrent distracter task (reading letters on screen). The data suggest that schizophrenic performance is normal with respect to vulnerability to both interference and decay over time, but shows reduced precision even at a zero-delay. Essentially, patients showed a normal time-course of discrimination for stimuli that they could readily discriminate initially. In the present experiment subjects from Experiment 1 were re-tested at a longer delay of 4 s using stimulus pairs set at the individually determined 85% correct frequency difference determined in the first experiment.

3.3. Method

3.3.1. Subjects

As many as possible of the subjects from Experiment 1 were brought back to the laboratory for a second testing session, during which they completed Experiments 2 and 3. Forty-seven of the subjects from Experiment 1 were available for re-test (25 female and 23 male; mean age 23.1 years, SD = 6.3).

3.3.2. Materials

The same iMac computers, Sony headphones, and LabVIEW software were used as in Experiments 1.

3.3.2.1. Auditory inspection time task. Inspection time stimuli consisted of a 441 Hz stereo sine waveform with one channel phase shifted by 40° resulting phenomenologically in a tone stimulus appearing clearly shifted to the left or to the right of the midline. This lateralized tone pulse was followed immediately by a backward mask consisting of a 500 ms square-wave stereo tone-burst appearing to the subject as a midline noise burst, to disrupt processing of the stimulus. As in
Experiments 1 and 2, the stimulus waveforms were synthesized at 44.1 kHz and 16 bit precision windowed through a cosine filter to avoid abrupt onset and offset artifacts which might allow stimulus identification on the basis of onset or offset artifacts. The laterality of the stimulus (left or right) was selected at random on each trial, with the proviso that each order occurred equally over the course of each successive sequence of six trials. The inspection time task was controlled by the same Garcia-Perez (1998) staircase and rules as in the previous experiment and stimuli were again presented at a nominal 75 dB with a 2 s inter-trial-interval timed from the last response.

3.3.2.2. Delayed presentation task. The effect of delay was examined by presenting trials identical to those used in the first experiment with the exception that the delay between the first and second stimulus of each trial was extended to 4 s (versus 1 s in the previous experiment), and a fixed $\Delta f$ was used, individually set to the threshold value determined in Experiment 1. This ensured that all subjects could accurately discriminate the stimuli at a short delay, and, therefore, that reductions in correct detection would reflect sensory decay and not a more basic difficulty in representing the stimuli.

3.4. Procedure

The delayed response task was completed first. Subjects were told that they would hear stimuli as in Experiment 1 and that they should simply respond to each trial by indicating whether the higher tone was presented first or second, as in Experiment 1. Forty trials were presented at 4-s delay, and the dependent variable calculated was % correct responses. The AIT was then completed. The subject was told that they would hear tones to either the left or the right of space, and that they should respond by indicating on which side they heard the tone, that the tone would be brief and would be followed by a masking noise, and that, if they were ever unsure of the lateralization, they should indicate which side seemed most likely. Subjects could respond at any time after the stimulus began to play, and pressed the “F8” or “F9” keyboard keys to indicate whether the tone was localized left or right respectively. Learning trials followed consisting of 300 ms duration stimuli presented with no mask and with on screen feedback about the correctness of each response. This introduced subjects to the task of identifying the stimulus location as being left or right and familiarized them with the response method. As soon as the subject demonstrated (by making four sequential correct responses) that they understood the task and could discriminate the stimuli, the mask was added to the stimulus. Practice continued as long as the subject wished, but no subject required more than eight trials. At this point it was explained that the duration of the stimulus would next be varied to see how short a tone they could localize. It was emphasized that correct responding was important and that response speed was irrelevant compared to accuracy. The experimental trials were then given. Testing lasted 15–20 min.

3.5. Results

In readying the data for analysis, percent correct was calculated as the dependent variable on the delay task, and, inspection time was calculated for each subject by taking the mean of the $\log(\Delta f)$ values at each of the 17 staircase-reversals.
3.5.1. Sensory input speed

The median inspection time was 73 ms (SD 63.2). A regression analysis of the relationship of SPQ to inspection time was non-significant ($R^2 = 0.023, p = 0.3$). To the extent that any trend was visible, in the data, higher schizotypy was associated with slightly better, rather than worse performance on the IT task. This suggests that both the rate of extraction of stimuli and protection of processed stimuli from masking are normal in schizotypy, and therefore not responsible for the observed decrement in sensory precision.

3.5.2. Delayed presentation effect

As expected, the mean % correct was below the level achieved at a short delay, (mean % correct at 4 s delay = 70.4, SD = 14.7). A regression of % correct across all 40 stimuli presented at a 4-s delay against total SPQ score was not significant ($R^2 = 0.001, p = 0.84$), suggesting that, when $\Delta f$ values are such that all subjects can discriminate the stimuli when presented with a short delay, there is no evidence for differential decay related to schizotypal personality.

3.6. Summary discussion

The final two experiments indicated that rates of accumulation of sensory information into auditory sensory memory are normal in schizotypes and that retention is normal at least over the interval from 1 to 4 s assessed in this experiment. Intact backward masking and input processing speed are compatible with data from schizophrenia. While schizophrenia has been associated with poor performance on backward-masked stimuli, more recent evidence suggests that schizophrenia is unrelated to backward masking effects, when the stimuli are readily discriminable (Knight, Elliott, & Freedman, 1985; March et al., 1999). Together with Experiment 1 it seems likely that schizotypy indexes a fundamental difficulty in constructing accurate sensory representations.

Acute schizophrenia has been shown to cause only a small deficit in sensory precision, translating into non-significant differences between controls and patients in the few small studies examining these populations (Rabinowicz et al., 2000). Moreover, MMN reductions have not been found in all populations, and it has been suggested that the deficit is not present in acute first-admission schizophrenia (Salisbury, Shenton, Griggs, Bonner-Jackson, & McCarley, 2002). The present finding of reduced precision in non-schizophrenic normals differing in schizotypal personality disorder score suggests that control-group variance on schizophrenia-related traits should be measured and controlled in future studies.

Neuropsychological data suggest that fine-grained pitch discrimination is dependent on intact primary auditory cortex (Tramo et al., 2002). This strongly implies that the pitch discrimination deficits in the present study reflect bilateral dysfunction in primary auditory cortex. Schizotypal and schizophrenic subjects share abnormally low temporal lobe volumes (Dickey et al., 1999). This is at least compatible with the finding reported here of a shared temporal-cortex-based deficit in pitch discrimination. One interpretation of the link between schizotypal personality and schizophrenia would suggest that schizotypy arises when the schizotropic genome is expressed in the temporal lobes but spares the frontal lobe, while schizophrenia arises when both regions are affected. It is possible that there is a single disruptive influence which is present in a lower dose in schizotypes, and to which the temporal lobes are more sensitive, or that the temporal and frontal
disturbances are partly independent. Siever has recently proposed that schizotypes are protected from overt psychosis by normal or reduced sub-cortical dopaminergic activity (Siever et al., 2002).

It is possible and even likely, however, that representational infidelity extends beyond the pitch discrimination dimension and possibly beyond the temporal lobe cortex on which this task depends. Javitt et al. (1999) have shown difficulties in weight discrimination, but it would be valuable to assess the fidelity of other sensory systems, and of other dimensions within each domain: for instance pitch localization, and volume discrimination. This raises the question of the extent of the deficits in representation in schizophrenia and schizotypy. The lack of relation between auditory inspection time and SPQ scores suggests that rates of processing are normal in schizotypy. It does not rule out, however, that representations of localization are similarly imprecise, as has been found for pitch. The auditory localization task used very large differences in phenomenological location—much larger than the largest pitch difference examined. Further work might examine the minimum location difference resolvable by schizotypes. If this was found to be larger than normal it would suggest that the representation deficit extends more generally beyond PAC into wider temporal cortex (Tramo et al., 2002; Zatorre & Penhune, 2001).

A wider question is whether the representational deficit extends beyond the sensory domain into domains such as the representations supporting working memory. Sensory imprecision is in a position to act as a more basic cause for several of the deficits in information processing identified in schizophrenia. For instance, while people with schizophrenia show reduced amplitude of the P3, P3 itself is related to electrophysiological indices of fine pitch comparison such as MMN amplitude (Javitt, Doneshka, Grochowski, & Ritter, 1995). Likewise, Javitt et al. (1999) have reported that the deficit in context processing present in schizophrenics (Cohen, Barch, Carter, & Servan-Schreiber, 1999) and their normal relatives (MacDonald, Pogue-Geile, Johnson, & Carter, 2003) appears not to reflect an inability to maintain context online, but rather a deficit in forming an adequate initial representation of this context. Converging evidence for the linkage between basic sensory representations, “higher” cognitive tasks such as context processing, and thought disorder itself comes from work on the dissociative anesthetic drug ketamine which is able to induce schizophrenia-like thought disorder in normal volunteers (Lahti, Weiler, Michaelidis, Parwani, & Tamminga, 2001), reduces MMN, and impairs performance on context processing paradigms such as the A-X task (Umbricht et al., 2000).

One model for the linkage of sensory discrimination, working memory-type tasks, and thought disorder would suggest that the representation deficit is restricted to sensory representations, and that thought disorder is a consequence of poor input from these sensory regions, as has been proposed for non-psychotic disorders of awareness (Cooney & Gazzaniga, 2003). In this model, the integrity of sensory representations, upon which processes like expectation and contextual memory are computed, are seen as basic to the schizophrenic syndrome (Umbricht et al., 2000), either directly creating symptoms such as object misidentification (Doniger, Silipo, Rabinowicz, Snodgrass, & Javitt, 2001) or handicapping otherwise intact executive processes. Alternatively, it might be found that a disorder of the interpretive system itself is required for psychotic thought (Davies, Coltheart, Langdon, & Breen, 2001). A single-cause might still be true for schizophrenia: the schizophrenic genotype may lead to sparse or imprecise representations in frontal cortical systems (supporting reasoning and valence). If this is the case, rather than sensory imprecision deficit, one might more appropriately speak of a general “representational imprecision deficit” as characterizing the specific information processing limitation in schizophrenia. Alternatively,
Interprettive system disorders may have an independent etiology from that which degrades sensory representations. These theoretical predictions might be tested using highly discriminable stimuli in an A-X type task and varying the contextual load. Under the first view, performance on context-based tasks should be normal when the stimuli are highly discriminable, under the second, reasoning and sensory deficits should covary, and under the third model, deficits in working memory will be unexplained by sensory performance.

References


