Sensory Contributions to Impaired Prosodic Processing in Schizophrenia

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Background: *Deficits in affect recognition are prominent features of schizophrenia. Within the auditory domain, patients show difficulty in interpreting vocal emotional cues based on intonation (prosody). The relationship of these symptoms to deficits in basic sensory processing has not been previously evaluated.*

Methods: *Forty-three patients and 34 healthy comparison subjects were tested on two affective prosody measures: voice emotion identification and voice emotion discrimination. Basic auditory sensory processing was measured using a tone-matching paradigm and the Distorted Tunes Test (DTT). A subset of subjects was also tested on facial affect identification and discrimination tasks.*

Results: *Patients showed significantly impaired performance on all emotion processing tasks. Within the patient group, a principal components analysis demonstrated significant intercorrelations between basic pitch perception and affective prosodic performance. In contrast, facial affect recognition deficits represented a distinct second component. Prosodic affect measures correlated significantly with severity of negative symptoms and impaired global outcome.*

Conclusions: *These results demonstrate significant relationships between basic auditory processing deficits and impaired receptive prosody in schizophrenia. The separate loading of auditory and visual affective recognition measures suggests that within-modality factors may be more significant than cross-modality factors in the etiology of affect recognition deficits in schizophrenia.*

Key Words: Schizophrenia, auditory, visual, prosody, emotion, face recognition

Schizophrenia is associated with deficits in both higher order cognition (e.g., Braus et al 2002) and early sensory processing (Butler et al 2001; Foxe et al 2001; Javitt et al 2000). Although these two types of deficit are most often studied in isolation, the possibility exists that deficits in early sensory processing may contribute greatly to deficits in higher order cognition. In schizophrenia, one of the most significantly impaired functions is in the ability to decode emotion based on either facial expression or speech intonation (e.g., Alpert et al 2000; Edwards et al 2001, 2002; Gur et al 2002; Haskins et al 1995; Kerr and Neale 1993; Ross et al 2001). These deficits have been attributed to deficits in emotion processing brain regions (Edwards et al 2001; Gur et al 2002), although the basis for the dysfunction remains to be determined. The present study evaluates the degree to which deficits in ability to decode emotion, especially in the auditory modality, depend on more basic deficits in early sensory processing.

Prosody refers to our ability to recognize, comprehend, and produce affect as well as semantic meaning based on the intonation, stress, and rhythm patterns of vocal utterances. Emotional prosody refers to the ability to detect affect and infer emotion based on prosodic information, while semantic prosody refers to the ability to differentiate meaning, for example, differentiating questions from answers. Receptive prosody refers to the ability to decode prosodic information in statements made by others, while expressive prosody refers to the ability to express emotion or other prosodic information in our own utterances. Deficits in receptive emotional prosody in schizophrenia were first demonstrated in 1973 (Jonsson and Sjostedt 1973). Subsequent studies demonstrated deficits in semantic, as well as emotional, prosody (e.g., Kerr and Neale 1993), and in expressive, as well as receptive, prosody (Alpert and Anderson 1977; Fricchione and Howanitz 1985). Deficits in receptive prosody are seen in both chronic and first episode patients (Edwards et al 2001; Haskins et al 1995), as well as children with schizophrenia (Baltaxe and Simmons 1995), and occur independent of medication (Kerr and Neale 1993; Ross et al 2001), suggesting that these deficits represent a trait aspect of the illness (Edwards et al 2002).

Within the realm of sensory perception, multiple studies have shown basic pitch perception and auditory sensory memory (i.e., tone matching) deficits in individuals with schizophrenia. These sensory deficits may have an important influence on higher-order processes such as prosodic comprehension, since, much like music, speech relies on the production and recognition of structured patterns of pitch, duration, and intensity. Further, much like elemental pitch processing, prosodic functioning relies substantially on right hemispheric function (Patel et al 1998). We hypothesize that the presence of elemental pitch deficits in schizophrenia, which we have demonstrated previously (e.g., Strous et al 1995; Javitt et al 1999; Rabinowicz et al 2000), may significantly contribute to the deficits in affective prosodic functioning that are seen in patients with schizophrenia.

To test this hypothesis, we collected behavioral measures of affective prosodic comprehension in patients and comparison subjects. Within the patient group, we collected psychophysical measures of pitch perception to both music and pure tones. To further illustrate the specific contribution of pitch perception to affective prosodic comprehension, measures of affective facial comprehension were also collected as a control condition.

Methods and Materials

Participants

Forty-three stable patients meeting DSM-IV criteria for either schizophrenia or schizoaffective disorder and 34 healthy control subjects volunteered to serve in this experiment. The Institutional

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Table 1. Demographic and Clinical Characteristics of Healthy Control and Patient Populations

Demographic/Clinical Criteria	Control (*n* = 34)	Schizophrenia (*n* = 43)
Age	36 ± 9	39 ± 12
Gender (M/F)	14/20	33/10
Handedness R/L	30/4	40/3
Education	15.6 ± 2.3	10.6 ± 3.2
BPRS Total (*n* = 39)	N/A	34.3 ± 8.4
BPRS Conceptual Disorganization	N/A	2.1 ± 1.3
BPRS Anxiety/Depression	N/A	6.8 ± 3.1
BPRS Positive Symptoms	N/A	8.6 ± 4.4
SANS Total (*n* = 39)	N/A	29.2 ± 12.5
ILS-PB (*n* = 38)	N/A	32.8 ± 13

Values are mean ± SD.
M, male; F, female; R, right; L, left; BPRS, Brief Psychiatric Rating Scale; SANS, Schedule for Assessment of Negative Symptoms; ILS-PB, Independent Living Scales-Problem Solving Subscale.

Review Board of the Nathan Kline Institute for Psychiatric Research approved all experimental procedures, and all patients were recruited from facilities associated with the Institute. Written, informed consent was provided by all subjects after the procedures of the experiment were fully explained. Both patients and healthy comparison subjects received $10/hour for participation.

Diagnoses were obtained by Structured Clinical Interview for DSM-IV (SCID) performed by masters or doctoral level psychologists, psychiatrists, or trained diagnostic technicians using all available clinical information. Thirty-four patients met criteria for schizophrenia and 10 met criteria for schizoaffective disorder. Twenty-four patients were receiving only second-generation antipsychotics (primarily risperidone or olanzapine), 3 patients were receiving only traditional antipsychotics (haloperidol), and 16 patients were receiving combinations. Mean daily antipsychotic dose was 1068.3 ± 423.4 chlorpromazine equivalents, using Hyman and Arana (1987) and "best estimate" conversion factors for new antipsychotic medications. Mean illness duration was 17.4 ± 9.6 years. The healthy control group consisted of staff volunteers as well as individuals who responded to local advertisements. Handedness of all subjects was assessed using the Edinburgh handedness inventory (see Table 1 for further demographic information) (Oldfield 1971).

Auditory Sensory Processing

Two tests of auditory sensory processing were employed: a tone matching task, which reflects processing within primary auditory regions (Liegeois-Chauvel et al 2001; Zatorre and Samson 1991), and the distorted tunes task (Drayna et al 2001), which reflects processing within unimodal sensory association cortex, especially in the right hemisphere (Zatorre 1985; Zatorre et al 2002). These measures were obtained for patients only.

Tone Matching Task (TMT). A simple tone-matching paradigm was employed, as described previously (Strous et al 1995). Tones were generated on a Pentium personal computer (PC; Winbook, Hilliard, Ohio) with SoundBlaster Pro audio card (Creative Sound Systems, Milipitas, California) using the Neuroscan Stim (Neurosoft; Compumedics USA, El Paso, Texas) software and were presented binaurally through headphones at nominal intensity level of 70 dB sound pressure level (SPL). Subjects were presented with pairs of 100-millisecond tones in series, with 500 milliseconds intertone interval. Within each pair, tones were either identical or differed in frequency by specified amounts in each block (2.5%, 5%, 10%, 20%, or 50%). In each block, half the tones were identical and half were dissimilar. Subjects responded by pressing one of two keys to answer whether the pitch was the same or different. Tones were derived from three reference base frequencies (500, 1000, and 2000 Hz) to avoid learning effects. In all, the test consisted of five sets of 26 pairs of tones and took approximately 20 minutes to complete. Participant performance across these five levels was averaged and this score was used for analysis.

Distorted Tunes Task. The Distorted Tunes Task (DTT) (Drayna et al 2001) consists of 26 familiar tunes ranging in length from 12 to 26 notes. Seventeen of the tunes are rendered melodically incorrect by changing the pitch of two to nine notes within the tune. Subjects respond "yes" or "no" as to whether the melody is correct. Subject scores are calculated based on the percentage of correctly categorized melodies.

Affective Prosody

Two basic tests of affective prosodic processing were employed: 1) the Voice Emotion Identification Test (VOICE-ID), and 2) the Voice Emotion Discrimination Test (VOICE-DISCRIM) (Kerr and Neale 1993).

Voice Emotion Identification Test. This test consists of 21 sentences of neutral content on audiotape (e.g., "He tossed the bread to the pigeons," "The boy went to the store"). The sentences are spoken aloud by male and female speakers to convey one of six different emotions (happiness, anger, fear, sadness, surprise, or shame). Participants are given a piece of paper with the six emotions listed. They are asked to listen to each sentence and to tell the experimenter which of the six emotions best describes the speaker's tone of voice. Participants are asked to guess if unsure.

Voice Emotion Discrimination Test. This test contains 35 separate pairs of sentences. Each pair contains sentences that consist of the same words (i.e., "The game ended at 4 o'clock," "The game ended at 4 o'clock") or different words (i.e., "The boy went to the store," "He tossed the bread to the pigeons") and in which the second sentence is read with the same or different prosody (emotion) as the first. Participants are asked to focus on the mood rather than the content of the sentences and to tell the experimenter whether the sentences are said in the same or in a different emotion. Participants are asked to guess if unsure.

Visual Affective Processing

Two basic tests of face emotion processing were employed: 1) the Face Emotion Identification Test (FACE-ID), and 2) the Face Emotion Discrimination Test (FACE-DISCRIM) (Kerr and Neale 1993). These measures, which were added partway through the study and were available for only a subset of participants, use black and white photographs of faces displaying different emotions created by Izard (1971) and Ekman (1976).

Face Emotion Identification Test. This test consists of 19 photographs of facial emotions presented on videotape for approximately 15 seconds with a blank screen of approximately 10 seconds between pictures. Participants are asked to look at each face and tell the experimenter which of six emotions best describes the emotion in the photograph. The same six emotions are used as in the VOICE-ID test, and participants are again given a list of the emotions. Participants are asked to guess if unsure.

Face Emotion Discrimination Test. This test consists of 30 pairs of photographs. Each pair of photographs is presented simultaneously. Participants are asked to tell the experimenter whether the two people in each pair are displaying the same or

Table 2. Tone Matching Test Performance in Patients with Schizophrenia

Level (% ΔF)	Performance (% Correct)	SD
50	92	10
20	85	14
10	76	18
5	71	20
2.5	61	15
Average Across All Levels	77	14

different emotions on their faces. Participants are asked to guess if unsure.

Clinical Measures

Clinical measures included the Brief Psychiatric Rating Scale (BPRS), including the anxiety/depression (items: somatic concern, anxiety, guilt feelings, depression) and positive symptom (items: disorganization, suspiciousness, hallucinatory behavior, unusual thought content) subscales (Overall 1961), and the Scale for the Assessment of Negative Symptoms (SANS), using total score without globals as a summary measure (Andreasen 1982). In addition, the Independent Living Scales problem-solving factor subscale (ILS-PB) (Loeb 1996) was employed as a measure of the patients' global functioning. The ILS-PB is comprised of 33 items related to money management, home/transportation, and social adjustment. Questions such as, "Tell me two reasons why it is important to pay your bills," "What might you do if both your lights and your TV went off at the same time," and "Why is it important to know about the side effects of the medicine you are taking" are used to elucidate effective strategies and ways to negotiate life on a day-to-day basis. The ILS-PB scores have been shown to predict living status (inpatient vs. outpatient) more strongly than verbal memory or other measures (Revheim and Medalia 2004). Raw scores on the ILS-PB were converted into standard scores as per the instructions found in the manual, which were then used as variables in the present study.

Statistics

Primary analyses were performed on all measures using analysis of variance (ANOVA) with factors of group (patient/control) and gender. In addition, the relative magnitude of deficits between tests was assessed using a task x group analysis. Effect sizes were expressed in SD units and interpreted according to criteria of Cohen (1988). Correlation between measures was assessed using Spearman correlations. In addition, within the patient group, principal components analysis (PCA) was used to investigate the interrelationship among sensory processing and prosodic measures. Principal components analysis was restricted by the following criteria: 1) using the Kaiser criterion, eigenvalues that were $\geq |1|$ were selected as components for rotation, and 2) component loading was considered significant only if it was $\geq .6$. All statistical analyses were performed using the JMP statistical software package (Academic Version 4.0.4; SAS Institute, Inc., Cary, North Carolina).

Two-tailed tests were used throughout with preset α level of significance of $p < .05$. Data in text reflect mean ± SD.

Results

Between-Group Analyses

Tone Matching Task and DTT performance were obtained for patients only. Tone Matching Task performance is shown in Table 2 and is similar to that obtained in previous studies with similar patients (Javitt et al 1999; Rabinowicz et al 2000; Strous et al 1995). Mean performance across all five levels was 77 ± 14%. In a prior study in which we tested performance on the three middle levels of the five used in the present study (5%, 10%, and 20%) (Strous et al 1995), patients scored a mean of 72% correct versus 93% correct for control subjects, with the between-group difference being highly significant and the effect size being on the order of 1.2 SD units. Mean performance on the DTT task was 69 ± 22% correct, with 66% of patients scoring below 88% correct, which is considered the threshold for "tune deafness" (Drayna et al 2001). In a prior study of healthy monozygotic and dizygotic twins, only 39.6% met this criterion ($z = 2.72$, $p = .006$ vs. present sample) (Drayna et al 2001). Affective prosodic processing and visual affective processing measures were obtained for both patients and control subjects. As expected, patients' performances were significantly poorer than that of control subjects on all four affect discrimination and identification measures (Table 3). Prosodic measures yielded the most substantial deficits, with VOICE-DISCRIM scores 23 percentage points lower and VOICE-ID scores 33 percentage points lower for patients than control subjects. Similar, but less pronounced, effects were observed in the visual modality, where FACE-DISCRIM and FACE-ID scores were reduced by 14 and 25 percentage points, respectively. There were also no significant main effects for gender (all $p > .05$)

To assess relative magnitude of auditory and facial affect recognition deficits in patients, a repeated measures ANOVA was conducted across visual and auditory measures. Significant differences between patients and control subjects were observed for both the VOICE-ID/FACE-ID ($F = 6.84$, $df = 1{,}42$ $p = .01$) and the VOICE-DISCRIM/FACE-DISCRIM ($F = 26.56$, $df = 1{,}43$,

Table 3. Auditory and Visual Affective Processing

Measure	Group	*n*	Mean	SD	F^a	*df*	*p*	E.S. (d)
VOICE-DISCRIM	Schizophrenia	43	64.4	14.0	36.0	1,73	<.0001	1.6
	Comparison	34	83.3	7.2				
VOICE-ID	Schizophrenia	43	44.5	15.4	37.3	1,73	<.0001	1.7
	Comparison	34	66.5	10.0				
FACE-DISCRIM	Schizophrenia	31	78.5	11.1	15.9	1,41	<.001	1.6
	Comparison	14	92.0	4.0				
FACE-ID	Schizophrenia	30	59.6	17.0	4.7	1,40	<.04	.8
	Comparison	14	72.9	16.6				

E.S., Effect size in standard deviation (d) units; VOICE-DISCRIM, Voice emotion discrimination task; VOICE-ID, Voice emotion identification task; FACE-DISCRIM, Face emotion discrimination task; FACE-ID, Face emotion identification task.

[a]Analysis of variance was performed with factors of group and gender. Values represent the main efect of group. There were no significant gender or gender by group findings.

Table 4. Principal Components Analysis of Auditory and Visual Sensory and Affective Processing Measures

Rotated Factor Pattern	Factor 1 % of Total Variance	Factor 2 % of Total Variance
TMT	.82[a]	−.01
DTT	.83[a]	.12
VOICE-DISCRIM	.75[a]	.14
VOICE-ID	.60[a]	.31
FACE-DISCRIM	.09	.89[b]
FACE-ID	.15	.84[b]

TMT, Tone matching task; DTT, Distorted tunes task; VOICE-DISCRIM, Voice emotion discrimination task; VOICE-ID, Voice emotion identification task; FACE-DISCRIM, Face emotion discrimination task; FACE-ID, Face emotion identification task.
[a]Significant loading on Factor 1.
[b]Significant loading on Factor 2.

p = .001) pair of measures. However, there were no significant modality-by-group interactions for either the DISCRIM (F = .87, df = 1,43, p = .32) or ID (F = .99, df = 1,42, p = .38) measures, indicating that both modalities were affected to a similar degree. Effect sizes for both effects were large (d = .8–1.7) using Cohen's criteria (Cohen 1988).

Within-Group Analyses

Correlations Among Measures and Clinical Ratings. Correlation analyses were performed to analyze the relationship between auditory and visual affective processing measures and clinical symptoms. VOILE-ID performance correlated significantly with scores on the BPRS conceptual disorganization factor [$r_s(39) = .48$, $p < .01$], SANS total [$r_s(39) = .41$, $p < .01$], and ILS-PB [$r_s(38) = .43$ $p < .01$], with the latter correlation indicating likely significant contribution to global outcome in schizophrenia. In addition, both VOICE-DISCRIM [$r_s(39) = .53$, $p < .01$] and FACE-DISCRIM [$r_s(28) = .46$, $p < .01$] correlated significantly with BPRS conceptual disorganization scores, reflecting a significant relationship to overall cognitive symptom levels. Finally, only FACE-DISCRIM [$r_s(28) = .37$, $p < .05$] correlated significantly with BPRS positive symptom scores. No other significant correlations were found between TMT or DTT and ratings of clinical symptoms.

Principal Components Analysis. To evaluate interrelationships among prosody measures, a PCA was performed (Table 4). The PCA yielded only two components with eigenvalues ≥|1|. These two components accounted for 66% of the variance in the data and seemed to adequately describe the data based on screen plots and the rotation sums of squared loading. Selection of these two factors for rotation revealed the following pattern. Auditory sensory processing (TMT and DTT) and auditory affective measures (VOICE-DISCRIM and VOICE-ID) all loaded onto factor 1, which had an eigenvalue of 2.64 and explained 44% of the variance. Visual affective measures (FACE-ID and FACE-DISCRIM) loaded exclusively on factor 2, which had an eigenvalue of 1.30 and explained an additional 21.6% of the variance. There was no significant loading of auditory measures onto factor 2 of the PCA model, or reciprocally, of visual measures onto factor 1. No other factor explained more than 15% of the variance.

Correlational analyses were performed to further probe these relationships (Figure 1). A hierarchical pattern of results was observed, in which performance on the most basic measures of auditory discrimination (TMT) correlated significantly with performance on the DTT and VOICE-DISCRIM but not with VOICE-ID. In contrast, DTT performance correlated significantly with both VOICE-DISCRIM and VOICE-ID performance, both of which also correlated significantly with each other. Neither the TMT nor the DTT correlated significantly with either of the visual affective measures. Scores on the two visual affective measures, FACE-ID and FACE-DISCRIM, correlated with each other but not with corresponding auditory affective measures.

Discussion

The ability to decode other people's emotional states by analyzing either their vocal intonations or facial expression is an integral part of human existence, leading to significant recent interest in this process in schizophrenia (e.g., Edwards et al 2002; Gur et al 2002; Suslow et al 2003). The present study demonstrates that patients with schizophrenia show significant impairments in the ability to decode affect based on either auditory vocal or visual facial cues, replicating previous work in this population e.g. (e.g., Alpert et al 2000; Edwards et al 2001; Haskins et al 1995; Kerr and Neale 1993; Ross et al 2001). The main objective of the current study, however, was to assess whether affective (emotional) prosodic dysfunction in patients was related to more fundamental deficits in early auditory sensory processing. This hypothesis is based on recent work showing deficits in simple auditory processing in schizophrenia (Javitt et al 1997; Strous et al 1995; Rabinowicz et al 2000; Holcomb et al 1995; Wexler et al 1998), given that auditory affective recognition depends heavily on the ability to decode changes in pitch and intonation. However, to our knowledge, no studies have previously examined affective recognition ability relative to more basic components of sensory processing.

To assess potential relationships between sensory competence and affect discrimination, patients were evaluated on both their ability to perceive pitch changes of pure tones (TMT), as well as their ability to recognize complex pitch abnormalities

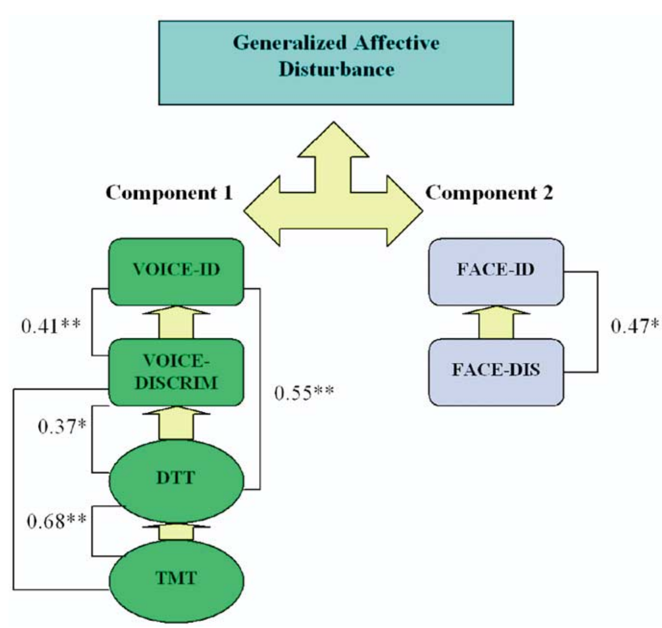

Figure 1. Schematic diagram of interrelationship between sensory and affective measures. Values shown represent Spearman correlation coefficients between indicated measures.*$p < .05$, **$p \leq .01$. TMT, Tone Matching Task; DTT, Distorted Tunes Task; VOICE-DISCRIM, Voice Emotion Discrimination Test; VOICE-ID, Voice Emotion Identification Test; FACE-DISCRIM, Face Emotion Discrimination Test; FACE-ID, Face Emotion Identification Test.

within short musical sequences (DTT). Two corresponding tasks were used for characterization of auditory and visual affective processing. In the discrimination tasks, subjects had to indicate whether two stimuli (sentences or faces), expressed the same or different emotions. In the corresponding identification tasks, subjects were required to name the emotion. A limitation of the present task is that TMT measures were obtained for patients only. However, deficits in TMT performance in schizophrenia have been repeatedly documented in schizophrenia (Holcomb et al 1995; Strous et al 1995; Javitt et al 1997; Wexler et al 1998). Control subjects, in general, show a threshold of 3% Δf for >90% correct performance versus 20% to 50% Δf observed in this and prior (Holcomb et al 1995; Javitt et al 1997; Rabinowicz et al 2000; Strous et al 1995; Wexler et al 1998) studies of schizophrenia.

Results of the experiment confirmed our a priori hypothesis. First, patients were equally impaired in auditory and visual affective judgments. We conducted a principal components analysis, which showed that auditory affective measures and auditory sensory measures loaded exclusively onto one component, whereas all the visual tasks loaded onto a second, independent component. Critically, and in line with our main hypothesis, we found robust correlations between tone-matching ability and affective prosodic discrimination. Further, in these correlation analyses, a hierarchical pattern was observed, with deficits in basic measures predicting deficits in affective processing measures. As such, our data, while showing only correlational relationships, suggest that prosodic processing deficits, ubiquitously seen in this population, may well be a consequence of more basic early sensory dysfunction in the auditory system. Thus, although schizophrenia is definitively associated with reduced limbic activation during affective processing (Gur et al 2002), our results suggest that the abnormal limbic activation may result, at least in part, from loss of normal, bottom-up input.

The hypothesis that bottom-up deficits drive impaired limbic function in prosodic tasks is consistent also with studies showing that schizophrenia patients do not have universal difficulty understanding the concept of emotion, only in detecting or expressing affect. For example, schizophrenia patients watching movies self-report levels of happiness and sadness similar to those reported by normal volunteers (Kring et al 1993). Similarly, when asked to categorize the emotional valence of words, schizophrenia patients and control subjects showed similar word valence patterns (Kring et al 2003). This disjunction between emotional self-experience and outward emotional perception and expression mirrors that of Bleuler's original 1911 conjecture (Bleuler 1950), in which he noted that while patients do not amplify their emotional responses in the same manner that healthy individuals do, they nevertheless show an intact conception of emotion.

In addition to showing relationships between early sensory processing dysfunction and higher order deficits in schizophrenia, the present study has implications for both the functional anatomy of schizophrenia and the nature of underlying emotional processing disturbances. On the level of functional anatomy, schizophrenia is frequently considered associated with predominant left hemispheric disturbance, particularly with regard to temporal lobe processing. An issue with this literature is that many tasks used in schizophrenia rely on phonetic analysis or other left-lateralized abilities and do not critically assess right hemisphere processing. When tasks are used that do stress right hemispheric function, such as emotional prosody tasks, right-sided deficits are observed as well (Mitchell et al 2004; Ross et al 2001). In the present study, a prosody task was selected that is known to depend heavily on right hemisphere processing (Lakshminarayanan et al 2003; Pell 1998; Zatorre et al 2002). Deficits were observed, consistent with prior literature documenting right-sided, as well as left-sided, temporal lobe dysfunction in schizophrenia.

On a functional level, patients showed equivalently severe deficits in affect discrimination, where they had to compare affect between stimuli but did not have to name the affect, as they did in affect identification. Thus, the present study argues against a specific deficit in the ability to name, rather than simply recognize, emotion. The fact that there were significant correlations between basic auditory processing measures and auditory affective processing measures and that there were not significant intercorrelations between auditory and visual affective processing measures argues against a generalized deficit in emotion processing and for separate sensory-driven deficits in decoding of emotion within both the auditory and visual systems. In the auditory system, the deficits reflect, in part, more basic limitations in decoding the pitch changes that encode affective prosody during normal conversation.

Although the present study concentrated primarily on the auditory system, deficits in basic sensory processing have also been demonstrated within the visual system as well (e.g., Butler et al 2001; Foxe et al 2001). Future studies therefore will have to determine the degree to which early sensory processing deficits contribute to visual, as well as auditory, affect discrimination in schizophrenia.

In the present study, deficits in prosodic processing correlated significantly with severity of conceptual disorganization and negative symptoms, as well as with problem-solving ability, as reflected in the ILS-PB. The ability to decode other people's emotions based on their tone of voice is a critical component of human interaction. Impaired emotion recognition ability, therefore, may be a significant mediating variable between basic disturbances in sensory processing on the one hand and poor global outcome on the other. It has also been observed that basic visual processing deficits contribute to poor global outcome in schizophrenia (Green et al 2000). Deficits in visual affect recognition, such as those observed here, therefore may also be a mediating variable between basic impairments in visual processing and poor global outcome in schizophrenia. Taken together, such results would fit nicely within frameworks such as Braff (1993), in which information processing deficits cascade upward into neuropsychological deficit symptoms, trait-related factors, and clinical outcome.

Finally, although the present study evaluated only affective prosody in schizophrenia, a prediction of the present study is that patients should have deficits in decoding nonaffective prosody as well. Whether or not patients have deficits in decoding nonaffective prosody, as well as affective prosody, has been studied to only a limited degree. Thus, for example, Kerr and Neale (1993) found that individuals with schizophrenia differed from comparison subjects on emotion perception tasks only to the same extent as they did on control tasks of basic speech perception. In contrast, for example, Murphy and Cutting (1990) reported that patients' performance on stress prosody tests was not significantly different from that of comparison subjects, whereas performance on emotional prosody tasks was significantly worse. We have previously observed decreased ability of patients to discriminate ambiguous speech sounds, suggesting at least that phonemic processing may be impaired at the sensory level (Cienfuegos et al 1999). Further studies, however, are required to fully resolve this issue.

In summary, our data suggest that deficiencies in elementary pitch perception, a fundamental building block in both melodic and prosodic comprehension, can significantly affect auditory affect recognition in schizophrenia. These findings further suggest that patients' inability to correctly infer other people's emotions from speech may be more related to deficits within sensory modality than to deficits in comprehending the concept of emotion per se. Future studies are required to further delineate the basis for the relationship between early auditory processing deficits and deficits in emotion recognition in schizophrenia and determine the degree to which similar relationships can be observed in other sensory domains.

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