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Sensory processing, neurocognition, and social cognition in schizophrenia: Towards a cohesive cognitive model

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ABSTRACT

Schizophrenia research has identified deficits in neurocognition, social cognition, and sensory processing. Because a cohesive model of "disturbed cognitive machinery" is currently lacking, we built a conceptual model to integrate neurocognition, social cognition, and sensory processing.

In a cross-sectional study, the cognitive performance of participants was measured. In accordance with the Schedules for Clinical Assessment in Neuropsychiatry, the participants were assigned to either the schizophrenia group or the non-schizophrenic psychosis group. Exclusion criteria included substance abuse, serious somatic/neurological illness, and perceptual handicap. The male/female ratio, educational level, and handedness did not differ significantly between the groups.

The data were analyzed using structural equation modeling. Based upon the results of all possible pairwise models correlating neurocognition, social cognition, and sensory processing, three omnibus models were analyzed. A statistical analysis of a pairwise model-fit (χ^2, CFI, and RMSEA statistics) revealed poor interrelatedness between sensory processing and neurocognition in schizophrenia patients compared with healthy control participants. The omnibus model that predicted disintegration between sensory processing and neurocognition was statistically confirmed as superior for the schizophrenia group ($\chi^2(53)$ of 56.62, $p = 0.341$, RMSEA = 0.04, CFI = 0.95). In healthy participants, the model predicting maximal interrelatedness between sensory processing/neurocognition and neurocognition/social cognition gave the best fit ($\chi^2(52)$ of 53.74, $p = 0.408$, RMSEA = 0.03, CFI = 0.97). The performance of the patients with non-schizophrenic psychosis fell between the schizophrenia patients and control participants.

These findings suggest increasing separation between sensory processing and neurocognition along the continuum from mental health to schizophrenia. Our results support a conceptual model that posits disintegration between sensory processing of social stimuli and neurocognitive processing.

1. Introduction

A proper characterization of the various sensory, neurocognitive (NC), and social cognitive (SC) deficits associated with schizophrenia has remained elusive. Nevertheless, studies have indicated that both NC and SC factors can predict social functioning (Green et al., 2000; Fett et al., 2011). Moreover, recent findings in the field of sensory perception have revealed clear differences between healthy individuals and schizophrenia patients with respect to how sensory information is processed (Javitt, 2009a).

The current classification of "impaired cognitive machinery" reflects historical notions from visionaries such as Kraepelin (*dementia praecox*, an NC factor) (Kraepelin, 1919), Jaspers (*empathic communication*, an SC factor) (Jaspers, 1946), and Bleuler (*disintegration* between thinking, memory, and perception, a sensory processing (SP) factor) (Bleuler, 1911). Each of these founding fathers in their respective fields contributed a necessary—albeit insufficient—explanation in their attempt to unravel the mysteries of schizophrenia. Here, we explored how NC, SC, and SP factors can be combined to build a conceptual model of disturbed cognition in schizophrenia.

NC impairments have typically included attention-controlled functions such as executive functioning and memory (Green et al., 2000; Fett et al., 2011). For example, Fett et al. (2011) analyzed 52 studies and reported that NC factors account for 15% of the variance among different social outcome areas.

SC encompasses one's ability to comprehend the feelings of others. Subdomains of this field include emotion perception and theory of

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mind. As with NC, these functions have traditionally been measured as attention-controlled capacities. SC factors have explained more variance in functional outcome (23%) than NC factors (Fett et al., 2011), underscoring the current view that SC adds unique variance to outcome (Pinkham et al., 2003; Allen et al., 2007).

SP is defined by its pre-attentive nature; SP occurs prior to NC and SC, and it permits stimuli to be filtered in and/or out (Javitt, 2009a). Several studies of schizophrenia have reported impaired performance in various visual (Doniger et al., 2002; Kim et al., 2006; Revheim et al., 2006) and auditory (Umbricht and Krljes, 2005; Turetsky et al., 2009) tasks. In addition to visual-only and auditory-only deficits, deficits in multisensory processing have recently been reported (de Jong et al., 2009, 2010; Williams et al., 2010; Van den Stock et al., 2011). Normally, behavioral and neural performance is enhanced by processing information received from multiple sensory channels (Calvert et al., 2000; de Gelder, 2000; Calvert, 2001). Common examples of multisensory events are plentiful and include the ability to process emotions that occur simultaneously in faces and voices, which is crucial for adapting to social environments. We previously reported impaired multisensory integration of emotional faces and voices in schizophrenic and—to a lesser extent—non-schizophrenic psychosis patients (de Jong et al., 2009). Recently, these findings were expanded by a report stating that schizophrenic patients have abnormal multisensory integration of bodily and vocal expressions (Van den Stock et al., 2011).

Although previous research has revealed that SC factors can mediate the effects of NC deficits on functional deficits (Brekke et al., 2007; Sergi et al., 2007; Schmidt et al., 2011), this study is the first to integrate NC, SC, and SP factors into a single cohesive model in an attempt to explain schizophrenia. Moreover, this study is unique in that healthy participants and non-schizophrenic psychosis patients were included in the study, allowing an analysis of cognitive patterns along a continuum of increasing vulnerability to schizophrenic psychosis.

2. Materials and methods

2.1. Participants

Outpatients (n = 101) at a regional psychiatric hospital were assessed using the Schedules of the Clinical Assessment in Neuropsychiatry (SCAN 2.1) (WHO, 1999). Fifty-five patients were diagnosed with schizophrenia (*Sch*), and 46 patients presented with a form of non-schizophrenic psychosis (*N-Sch-Psy*) (see Table 1 for the DSM-IV-classifications). Fifty neurologically and psychiatrically healthy subjects served as a control group (*Ctrl*). The study was approved by the regional Medical Ethics Committee, and the participants provided informed written consent and received financial compensation for their participation. For additional details of the procedures and patient cohort, see our previous reports (de Jong et al., 2009, 2010) and Table 2. Importantly, all of the patients lived independently or semi-independently with moderate support. PANSS scores revealed "moderate illness severity" with a Total Symptoms score of 75.5 (Leucht et al., 2005).

2.2. Tasks

2.2.1. Sensory processing (SP)

The performance data were identical to the dataset that was used in our previous study of impaired integration of facial and vocal emotions (de Jong et al., 2009). In brief, each subject listened to a short, semantically neutral vocalization spoken by professional actors while simultaneously viewing an image of a human face taken from the Ekman and Friesen series (Ekman and Friesen, 1976). Within each of two series of 64 trials (one trial with happy and fear as the target emotions and one trial with happy and sad), the facial and voice emotions were—in random order—matched in 32 trials and mismatched in the other 32 trials. The subjects were instructed to continue looking at the computer screen but to ignore the emotion depicted in the face. The subjects then pressed a button to indicate the emotion in the vocalization. Performance was measured as the proportion of correct responses in the mismatched trials subtracted from the proportion of correct responses in the matched trials. This difference score reflects the extent to which facial and vocal emotions are integrated.

Table 1
DSM-IV classifications within the two patient groups (schizophrenic patients and non-schizophrenic psychosis patients).

	Schizophrenic subjects	Non-schizophrenic psychosis subjects
295.30 Schizophrenia, paranoid type	53	
295.90 Schizophrenia, residual type	2	
295.40 Schizophreniform disorder		1
295.70 Schizoaffective disorder, bipolar type		3
295.70 Schizoaffective disorder, depressive type		5
297.1 Delusional disorder, persecutory type		3
298.8 Brief psychotic disorder		3
296.44 Bipolar I disorder, last episode manic, with psychosis		12
296.54 Bipolar I disorder, last episode depressed, with psychosis		1
296.24 Depressive disorder, single episode, with psychosis		3
296.34 Depressive disorder, recurrent, with psychosis		2
298.9 Psychosis not otherwise specified		13
Total	55	46

2.2.2. Neurocognition (NC)

NC was measured by testing sustained attention, executive functioning, selective-attention performance, and verbal working memory. A computerized continuous performance test (CPT) (CDLJava, version 7.01) was used to measure sustained attention (Lezak et al., 2004). We used the 3-7-target version of the text, and d' scores were used to quantify performance. A computerized version of the Wisconsin Card

Table 2
Demographic and clinical characteristics of the three groups (patients with schizophrenia, non-schizophrenic psychosis patients, and healthy controls).

	Schizophrenia	Non-schizophrenic psychosis	Healthy controls	p-value
Number of patients	55	46	50	
Age, years (mean ± SD)[a]	33.53 (8.80)[c]	35.22 (9.04)[c]	41.16 (12.94)	$p = 0.001$
Gender (% men)[b]	70.9	63.0	48.0	$p = 0.052$
Handedness (% right-handed)[b]	85.5	84.8	88.0	$p = 0.888$
Education (within-group %)[b]				$p = 0.079$
1[d]	7.3	2.2	0.0	
2	18.2	21.7	6.0	
3	40.0	37.0	56.0	
4	34.5	39.1	38.0	
PANSS[a]				
Positive	16.8	13.6		$p = 0.001$
Negative	20.6	16.2	NA	$p = 0.001$
General	38.1	35.0		$p = 0.058$
Total	75.5	64.8		$p = 0.001$

NA = not applicable.
[a] ANOVA.
[b] Chi-squared.
[c] Significantly different from controls but not from the other patient group.
[d] The highest completed educational level was noted according to standard conventions (Pichot et al., 1993) and using four categories that are suitable to the Dutch educational system (1 = elementary school; 2 = junior/secondary or vocational education; 3 = secondary education; 4 = post-secondary education or higher).

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