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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.

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 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

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).

Sorting Test (WCST) (Heaton et al., 1993) was used to measure executive functioning, and the number of categories completed was used to quantify performance. An original version of the Stroop color-word test (Hammes, 1973) was used to measure selective-attention performance; difference scores between the time to complete cards II and III were computed. Finally, verbal working memory was measured using the Letter Number Sequencing subtest of the Wechsler Adult Intelligence Scale—III (WAIS-III) (Wechsler, 1997); raw test scores were used to quantify performance.

2.2.3. Social cognition

Two visual and two auditory emotion perception tasks were performed. First, 20 faces from the Ekman and Friesen series were presented randomly and serially via a computer screen. Each face displayed one of the following five emotions: happy, angry, sad, fear, or disgust. The subject pressed one of five buttons on a response box as quickly as possible to indicate which facial emotion was being portrayed on the screen. In the second visual task, three emotional faces from the Ekman and Friesen series were presented simultaneously on the computer screen; one face was positioned at the top of the screen, and two faces were positioned at the bottom. The subject pressed one of two response keys to indicate which of the two faces displayed below portrayed the same emotion as the face displayed at the top of the screen. The emotions included the same five emotions used in the first visual task plus the emotions surprise and neutrality. The three faces were from three different people and were all of the same gender within a trial. This task included 28 trials.

The third task was a voice emotion recognition task in which 80 emotional sentences were presented in random order. The subject was instructed to indicate which of the following five emotions they heard: happiness, sadness, anger, fear, or disgust. The fourth task was a voice emotion-matching task. Three voice utterances that were spoken with emotion were presented in serial order. Within each trial, the first utterance indicated the target emotion, which was happiness, sadness, fear or anger. Either the second or the third utterance was spoken with the same emotion as the target emotion, and the subject was asked to indicate which of the two utterances matched the target emotion. This task included 48 trials. In all four visual and auditory tasks, emotion perception was measured as the proportion of correct responses.

3. Results

Table 3 shows the means, standard deviations, and the ANOVA test results across the three groups for each cognitive performance variable. The three groups differed significantly with respect to several tasks. Subsequent post-hoc testing revealed that the *Sch* group performed worse than the *Ctrl* group in most of the tests.

Structural equation modeling (SEM) (Ullman, 2001; Tomarken and Waller, 2005) was used to examine the relationships between SP, NC, and SC. SEM combines confirmatory factor analysis with multiple regression to analyze relationships between constructs. The relationships were first analyzed by modeling pairs of cognitive domains. Fig. 1 shows the various models for each of the three possible pairs. Thus, the pairs of cognitive domains were estimated both as separate constructs and as interrelated factors. The model that yielded the best fit determined whether the cognitive domains were functionally integrated or disintegrated. If the distinct construct model yielded the best fit, the cognitive domains were considered to be disintegrated; on the other hand, if the interrelated construct model yielded the best fit, the cognitive domains were considered to be functionally integrated. Based upon the pairwise analyses, we generated three omnibus models to describe the functional relationships between all three cognitive domains (Fig. 2).

3.1. Pairwise models

Table 4 summarizes the principal results for all groups; the integration and disintegration model chi-squared (χ^2) results are reported as well as the statistics for testing the differences between the groups. Additionally, the root mean square error of approximation (RMSEA) and the comparative fit index (CFI) were determined. An RMSEA values of <0.05 and a CFI values of >0.95 indicate a good fit with the data.

3.1.1. Sensory processing/neurocognition

In the *Sch* group, the difference between the χ^2 results of both models was not significant, but the RMSEA and CFI values revealed that the performance data were better fit by the disintegration model (0.04, and 0.93 respectively) than by the integration model (0.05, and 0.89 respectively). This finding suggests that the pre-attentive SP of social stimuli and attention-controlled NC are discrete—and perhaps separate—processes. In the *N-Sch-Psy* group, neither model had a better fit than the other. In the *Ctrl* group, however, the integration model had the better fit (between-models χ^2-difference $p = 0.028$, with maximum RMSEA and CFI values for the integration-solution only), indicating that the performance data were best modeled as interrelated constructs in this group. These contrasting findings were underscored by a lack of correlation between SP and NC in the *Sch* group ($r = 0.06$) compared to the *Ctrl* group ($r = 0.23$). Apparently, the extent to which

Table 3
Results of tasks administered to measure sensory processing, neurocognition, and social cognition. All summary values represent mean ± SD.

	Schizophrenia	Non-schizophrenic psychosis	Healthy controls	*p*-value
Number of participants	55	46	50	
Sensory processing				
Multisensory integr. happy/fear, %[a]	10.25 (11.56)	17.00 (10.51)	15.76 (14.53)	$p = 0.021$[c]
Multisensory integr. happy/sad, %[a]	4.69 (6.82)	6.25 (9.99)	6.51 (8.24)	$p = 0.500$
Neurocognition				
CPT, d'[a]	3.349 (0.763)	3.061 (0.894)	3.749 (0.631)	$p < 0.001$[d]
WCST-categories, N[b]	4.500 (2.196)	4.689 (1.743)	5.357 (1.428)	$p = 0.071$
Stroop-interference, sec.[a]	34.70 (16.09)	38.88 (25.84)	27.50 (10.35)	$p = 0.018$[e]
WAIS numbers and digits, raw score[a]	10.02 (2.74)	10.09 (2.67)	11.79 (2.85)	$p = 0.003$[d]
Social cognition				
Facial emotion recognition, %[a]	78.09 (11.84)	80.98 (10.57)	82.30 (9.49)	$p = 0.123$
Facial emotion matching, %[a]	89.02 (6.41)	88.98 (4.69)	91.93 (4.67)	$p = 0.008$[d]
Vocal emotion recognition, %[a]	61.83 (11.77)	63.61 (8.41)	68.85 (10.49)	$p = 0.002$[d]
Vocal emotion matching, %[a]	61.46 (8.53)	61.55 (7.49)	64.00 (7.94)	$p = 0.201$

[a] ANOVA.
[b] Chi-square.
[c] The schizophrenia group differed significantly from both the non-schizophrenic psychosis and control groups after post-hoc Fisher's LSD.
[d] Both schizophrenia and non-schizophrenic psychosis groups differed significantly from the control group after post-hoc Fisher's LSD.
[e] The non-schizophrenic psychosis differed significantly from the control group after post-hoc Fisher's LSD.

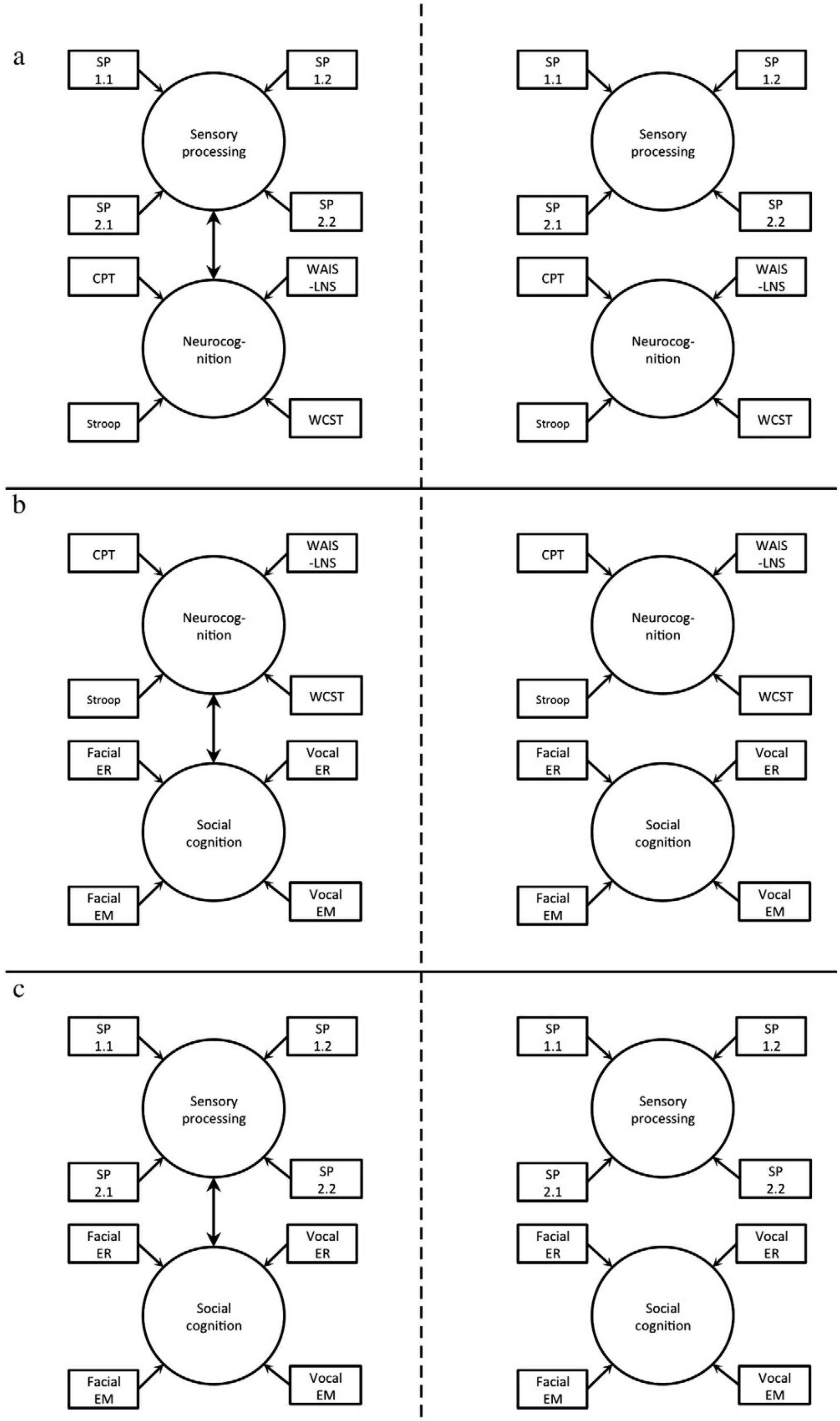

Fig. 1. Schematic depicting the pairwise relationships between the three cognitive domains. Panels a, b, and c represent the relationship between sensory processing and neurocognition (a), neurocognition and social cognition (b), and sensory processing and social cognition (c). For each pair of domains, the left panels depict the integration model (indicated by the vertical two-directional arrows), and the right panels depict the disintegration model. SP = sensory processing task; CPT = continuous performance Task; WAIS = Wechsler Adult Intelligence Scale; WAIS-LNS = WAIS-Letter-Number-Sequencing; WCST = Wisconsin Card Sorting Test; ER = emotion recognition; EM = emotion matching.

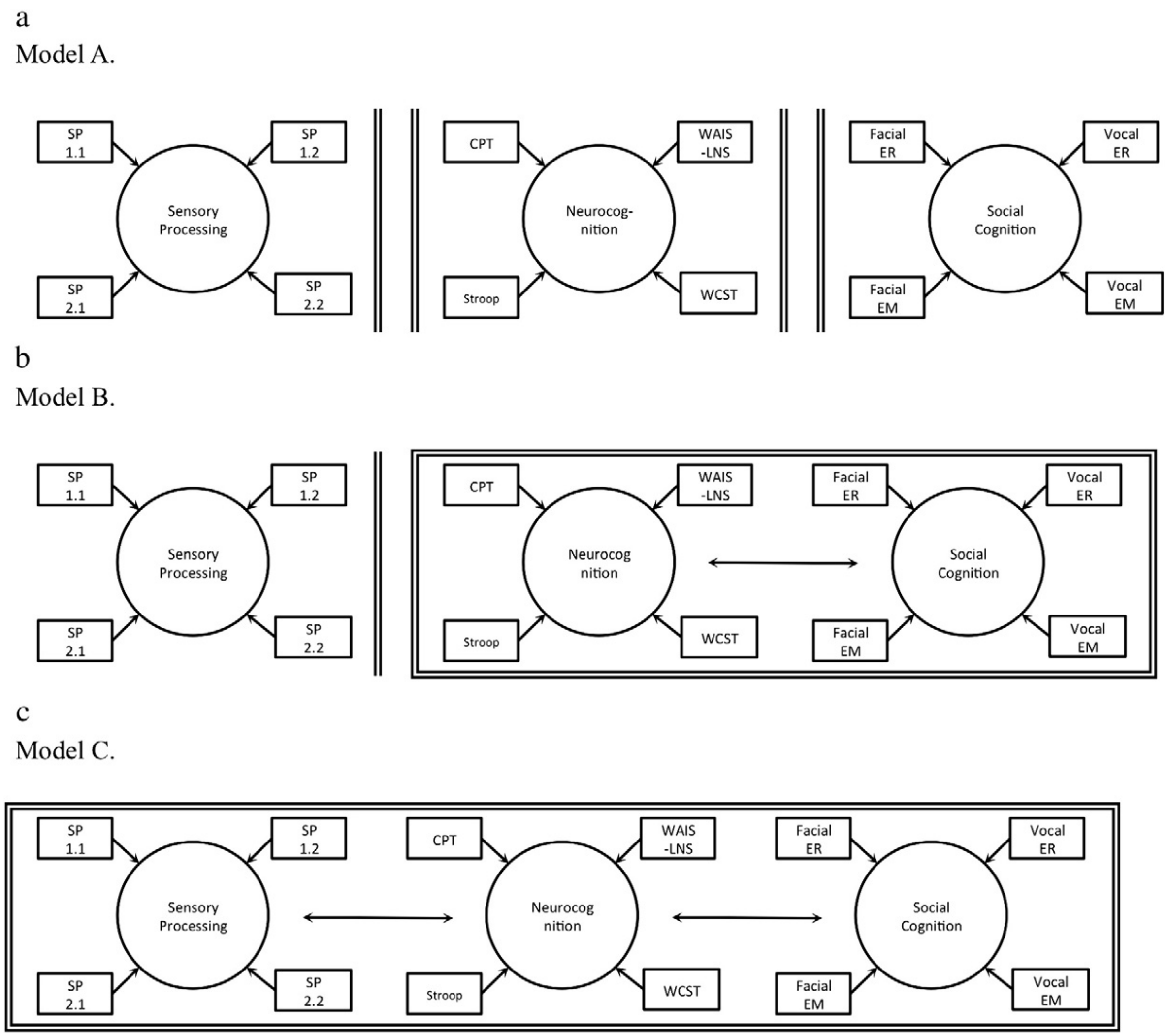

Fig. 2. Omnibus models that include all three cognitive domains with differently defined interrelationships. The double vertical lines indicate disintegration between the domains on either side. The boxes indicate integration between the domains contained within the box. For details, see the text. For abbreviations, see Fig. 1.

SP and NC can be estimated as a single integrated construct decreases as one progresses along the continuum from mentally healthy subjects to non-schizophrenic psychosis to schizophrenia.

3.1.2. Neurocognition/social cognition

In all groups, the performance data with respect to the NC and SC tasks were best modeled as interrelated constructs. In both the *Sch* and *Ctrl* groups, the χ^2-difference reached significance in favor of the integration model (with $p = 0.003$ and <0.001 for the *Sch* and *Ctrl* groups, respectively). In the *N-Sch-Psy* group, the χ^2-difference did not quite reach significance ($p = 0.085$), and the RMSEA and CFI values also indicated a better fit for the integration model (0.95 and 0.05, respectively) than the disintegration model (0.90 and 0.07, respectively). Within the integration models, the correlations between NC and SC were low-to-moderate in strength ($r = 0.54$, 0.37, and 0.60 for the *Sch*, *N-Sch-Psy* and *Ctrl* groups, respectively).

Table 4
χ^2 values for all groups and, within each pair of two cognitive domains, for both the integration (χ^2_1) and disintegration (χ^2_2) models (see Fig. 1). The *p*-value of the difference ($\chi^2_1 - \chi^2_2$) and RMSEA/CFI values indicate whether performance data are better fit by either of the two models (superior model values are in bold type).

Model	Schizophrenia (N = 55)					Non-schizophrenic psychosis (N = 46)					Model	Controls (N = 50)				
	Integration		Disintegration			Integration		Disintegration				Integration		Disintegration		
	χ^2_1 (corr.)	RMSEA/ CFI	χ^2_2	RMSEA/ CFI	$p(\chi^2_1 - \chi^2_2)$	χ^2_1 (corr.)	RMSEA/ CFI	χ^2_2	RMSEA/ CFI	$p(\chi^2_1 - \chi^2_2)$		χ^2_1 (corr.)	RMSEA/ CFI	χ^2_2	RMSEA/ CFI	$p(\chi^2_1 - \chi^2_2)$
SP-NC[b]	21.59 (.06)	0.89/ 0.05	**21.66**	**0.93/ 0.04**	$p = 0.791$	13.94 (.02)	1.0/ 0.00	14.55	1.0/ 0.00	$p = 0.435$	SP-NC[#]	**16.17 (0.23)**	**1.0/ 0.00**	21.02	0.95/ 0.03	$\mathbf{p = 0.028}$
NC-SC[b]	**26.86 (.54)**	**0.90/ 0.09**	35.85	0.79/ 0.12	$\mathbf{p = 0.003}$	**20.94 (.37)**	**0.95/ 0.05**	23.90	0.90/ 0.07	$p = 0.085$	NC-SC[#]	**21.31 (0.60)**	**0.95/ 0.05**	36.70	0.61/ 0.13	$\mathbf{p < 0.001}$
SP-SC[b]	11.55 (.06)	1.0/ 0.00	12.82	1.0/ 0.00	$p = 0.260$	[a]	[a]	[a]	[a]	[a]	SP-SC[#]	15.99 (0.26)	1.0/ 0.00	16.24	1.0/ 0.00	$p = 0.617$

[a] Estimates cannot be reported because the independence model is superior to the default model.
[b] Each model included 19 degrees of freedom; NC = neurocognition; SC = social cognition; SP = sensory processing.

Thus, with respect to NC and SC, all three subject groups showed clear integration between these two attention-controlled cognition domains.

3.1.3. Sensory processing/social cognition

Similar results were obtained for the *Sch* and *Ctrl* groups; specifically, no clear pattern was observed, and neither the integration model nor the disintegration model had a better fit. In the *N-Sch-Psy* group, the disintegration model appeared to be methodologically insufficient, as the "independence model" (which presumes a lack of relationships between the data) had a higher likelihood ($p = 0.023$) than the associations estimated by the "default" model ($p = 0.015$).

3.2. Omnibus models: sensory processing/neurocognition/social cognition

Based upon the results of our pairwise analysis, three omnibus models (termed Models A, B, and C) were generated (Fig. 2). Model A depicts SP, NC and SC as distinct constructs. Model B assumes distinctness between SP and NC, and interrelatedness between NC and SC. Model C represents all of the pairwise results in the *Ctrl* group; in this model, SP/NC and NC/SC are both modeled as interrelated constructs.

Table 5 displays the results of these three omnibus models. With respect to the *Sch* group, Model B best fitted the data relationships. A non-significant $\chi^2(53)$ of 56.62 ($p = 0.341$) with superior RMSEA (0.04) and CFI (0.95) values indicates that the performance data were estimated best when SP was modeled separately from NC and SC. The correlation coefficient between NC and SC was moderate (0.54). Model C, which assumes full interrelatedness, also yielded a not-significant result, but the correlation between SP and NC was negligible (0.03). These results in the *Sch* group suggest that whereas attention-controlled NC and SC capacities are interrelated, pre-attentive SP is disintegrated from attention-controlled performance. With respect to the *N-Sch-Psy* group, both Model A and Model C revealed no measurable relationship patterns within the performance data, given their respective *p*-values of 0.038 and 0.044. Only model B—which assumes distinctness between SP and NC—was found to be appropriate for this group, although the relationship was only slightly above the level of significance ($p = 0.052$), with poor RMSEA and CFI values (0.09 and 0.65). Finally, with respect to the *Ctrl* group, Model C was the superior model, with a non-significant $\chi^2(52)$ of 53.74, $p = 0.408$, and weak-to-moderate correlation coefficients of 0.33 and 0.60 between SP/NC and NC/SC, respectively.

4. Discussion

In this study, the participants were presented with a variety of tasks designed to assess their pre-attentive sensory processing, as well as neural cognition and social cognition (both of which are attention-controlled domains). In the *Sch* group, the performance data were modeled best when SP and NC were estimated to be discernible constructs. However, domains of cognition have been defined based on the notion that they reflect constructs that differ in their nature. Therefore, it is important to compare relationship patterns among all groups, including the *Ctrl* subjects as a reference group.

4.1. Sensory processing/neurocognition

A recently proposed sensory-perception theory described a complex web of interactions between pre-attentive and attention-controlled functions (Javitt, 2009a, b). Our sensory processing/neurocognition results in the *Ctrl* group satisfy the expectation of functional integration. These findings are reinforced by the notion that both domains were assessed using very different paradigms (pre-attentive tasks versus attention-controlled tasks) and materials (social stimuli versus non-social stimuli).

In contrast, the patients in the *Sch* group displayed a pattern of disintegration, and the performance of the patients in the *N-Sch-Psy* group was intermediate, falling between the schizophrenia patients and the control subjects. One possible explanation for this pattern builds upon well-documented deficits in both SP and NC that prevent their seamless integration. However, impaired interaction processes are likely additive, given our previous study that revealed reduced attention-controlled effects on the multisensory integration of emotions in schizophrenia patients, again with non-schizophrenic psychosis patients performing somewhere between schizophrenics and control subjects (de Jong et al., 2010). Accordingly, recent electrophysiological studies revealed associations between altered auditory parameters of early SP (e.g., mismatch negativity and P3a) and NC deficits (Hermens et al., 2010; Rissling et al., 2010).

4.2. Neurocognition/social cognition

Pair-wise modeling revealed the same pattern in each group—specifically, the integration-model was superior, thus indicating interrelatedness. Previous schizophrenia research yielded comparable results, including bivariate correlation scores between parameters of SC and NC of 0.23 to 0.67, respectively (Kohler et al., 2000; Sachs et al., 2004; Pinkham and Penn, 2006; Couture et al., 2011). Other studies have also revealed that SC and NC are interrelated constructs in schizophrenia (Addington et al., 2006; Allen et al., 2007; Sergi et al., 2007; Schmidt et al., 2011). Our similar result in non-schizophrenic psychosis patients extends this finding along the continuum of psychotic illnesses.

4.3. Sensory processing/social cognition

A similar pattern was revealed with respect to the *Sch* and *Ctrl* groups, indicating no clear bias towards either integration or disintegration between sensory processing and social cognition. Although no research has confirmed this finding, a possible explanation for the lack of a clear result is that the performance data for both domains were obtained by tasks that used highly similar—or even identical—social stimuli while also testing highly different (pre-attentive vs. attention-controlled) paradigms. In addition, the pre-attentive SP of

Table 5
χ^2 values and RMSEA- and CFI-fit indices for the three omnibus models (see Fig. 2). Within each group, the values of the superior model are in bold type.

Model[a]	Schizophrenia (N = 55) χ^2	RMSEA	CFI	Correlations	Non-schizophrenic. psychosis (N = 46) χ^2	RMSEA	CFI	Correlations	Controls (N = 50) χ^2	RMSEA	CFI	Correlations
A	65.61 ($p = 0.134$)	0.06	0.84	NA	No fit ($p = 0.038$)	–	–	NA	No fit ($p = 0.034$)	–	–	NA
B	**56.62 ($p = 0.341$)**	**0.04**	**0.95**	**0.54**[b]	**70.78 ($p = 0.052$)**	**0.09**	**0.65**	**0.37**[b]	59.12 ($p = 0.262$)	0.05	0.89	0.60[b]
C	56.60 ($p = 0.307$)	0.04	0.94	0.03/0.54[b]	No fit ($p = 0.044$)	–	–	–	**53.74 ($p = 0.408$)**	**0.03**	**0.97**	**0.33/0.60**[b]

NA = not applicable.
[a] Degrees of freedom for χ^2's of models A, B and C are 54, 53, and 52, respectively.
[b] Correlations represent associations between neurocognition/social cognition in Model B, and between sensory processing/neurocognition and neurocognition/social cognition in Model C.

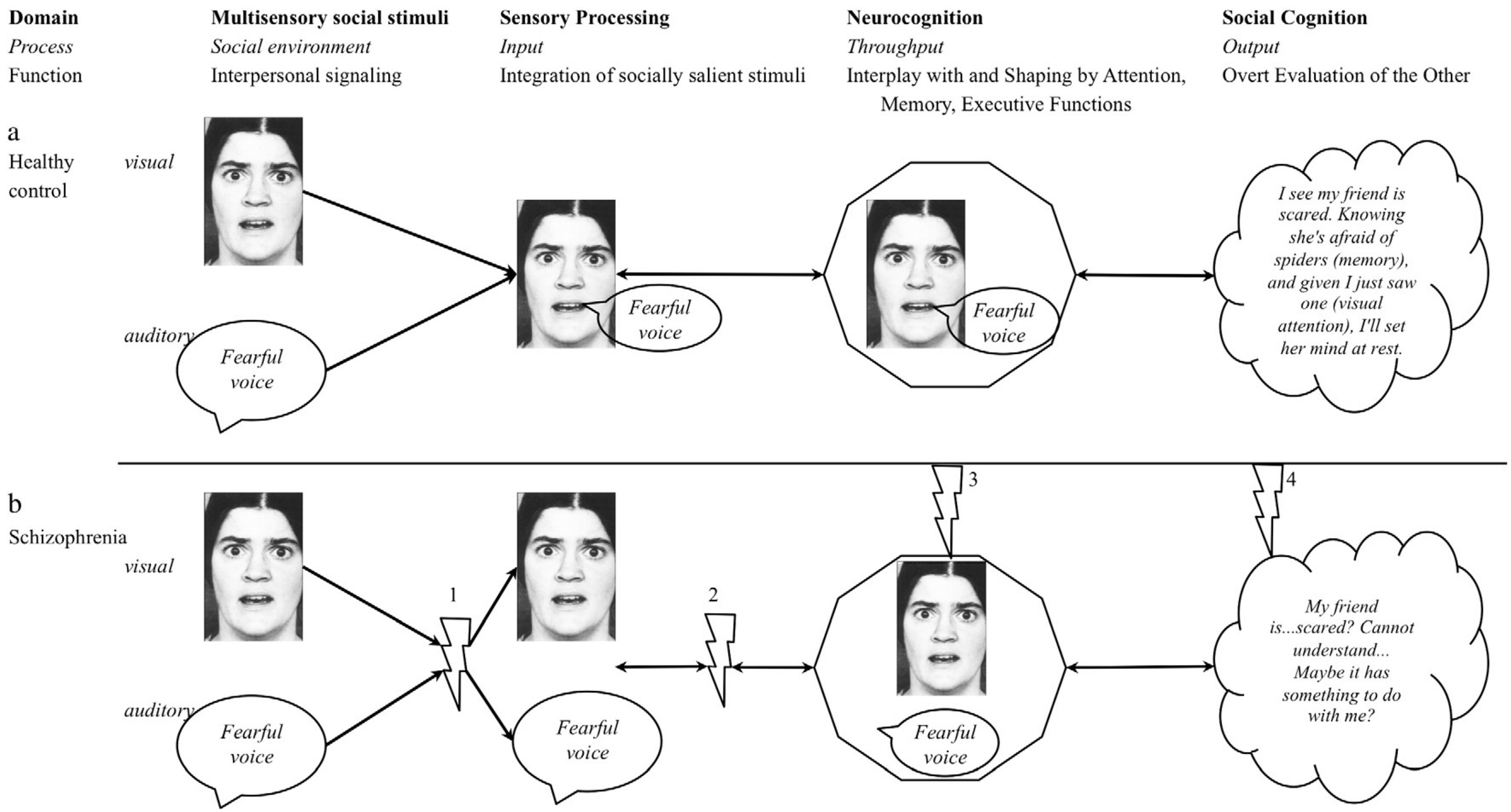

Fig. 3. Depiction of cognitive processing of socially relevant stimuli in healthy controls (a) and schizophrenia patients (b). In individuals with schizophrenia, this process can be impeded at various steps as follows (indicated by the numbered lightning bolts): 1. impaired multisensory integration; 2. disintegration between sensory processing and neurocognition; 3. neurocognitive deficits; and 4. impaired social cognition.

social stimuli might be positioned relatively distant to their attention-controlled SC evaluation.

4.4. Sensory processing/neurocognition/social cognition

With respect to the *Ctrl* group, the omnibus models revealed a high degree of interrelatedness between sensory processing, neurocognition, and social cognition. In contrast, the omnibus models revealed that the patients in the *Sch* group have disintegration between SP and NC. Fig. 3 depicts how—within a conceptual cognitive model that includes subsequent stages of social stimuli processing—relationship patterns differ between schizophrenia patients and control subjects; Fig. 3 also indicates the location of several likely deficits within this processing pathway.

This study shows clearly that relationships between sensory processing, neurocognition and social cognition vary as one progresses along the continuum from healthy individuals to schizophrenia patients. Specifically, our results point to disintegration between sensory processes that determine the input of multisensory emotional stimuli and the NC operations that are involved in processing these stimuli. For this study, we intentionally used multisensory emotion tasks to assess sensory processing. Future research should also use sensory processing paradigms that include unisensory tasks and/or non-social stimuli.

The search for additional validation of the cognitive model of psychosis should not only address historical notions of *disintegration* by the founders of schizophrenia research, but should also seek to elucidate "otherness" and a "lack of empathic communication." A better understanding of these features will be essential to unraveling the true nature of schizophrenia and the full spectrum of psychotic illnesses.

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Contributors

All authors (J.J. de Jong, B. de Gelder and P.P.G. Hodiamont) contributed the design of the study and its protocol. J.J. de Jong undertook the clinical and neuropsychological assessments of all participants, managed the literature searches and carried out the statistical analysis. J.J. de Jong and P.P.G. Hodiamont wrote the first draft of the manuscript. All authors contributed to and have approved the final manuscript.

Conflict of interest

No possible direct or indirect financial or personal relationships, interests and affiliations relevant to the subject matter of the manuscript have occurred in the past or present or are expected in the foreseeable future for all (three) authors.

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