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A bottom-up model of functional outcome in schizophrenia

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Schizophrenia results in poor functional outcomes owing to numerous factors. This study provides the first test of a bottom-up causal model of functional outcome in schizophrenia, using neurocognition, vocal emotional cognition, alexithymia, and negative symptoms as predictors of functional outcome. We investigated a cross-sectional sample of 135 individuals with schizophrenia and 78 controls. Using a series of structural equation modelling analyses, a single pathway was generated among scores from the MATRICS Consensus Cognitive Battery (MCCB), vocal emotion recognition test, Toronto Alexithymia Scale (TAS), Brief Negative Symptom Scale, and the Personal and Social Performance Scale. The scores for each dimension of the MCCB in the schizophrenia group were significantly lower than that in the control group. The recognition accuracy for different emotions (anger, disgust, fear, sadness, surprise, and satire, but not calm) was significantly lower in the schizophrenia group than in the control group. Moreover, the scores on the three dimensions of TAS were significantly higher in the schizophrenia group than in the control group. On path analysis modelling, the proposed bottom-up causal model showed a strong fit with the data and formed a single pathway, from neurocognition to vocal emotional cognition, to alexithymia, to negative symptoms, and to poor functional outcomes. The study results strongly support the proposed bottom-up causal model of functional outcome in schizophrenia. The model could be used to better understand the causal factors related to the functional outcome, as well as for the development of intervention strategies to improve functional outcomes in schizophrenia.

Schizophrenia is characterized by positive and negative symptoms and widespread deficits in neurocognition¹, social cognition², and functional outcome³. Functional outcome is one of the most important evaluation indexes of recovery from schizophrenia. In fact, measurements of functional outcome are highly correlated with the degree of neurocognitive impairment in schizophrenia⁴. However, increasing evidence suggests that social cognition mediates the relationship between neurocognition and functional outcome^{5–8}, including working performance, vocational outcomes⁹, independent living and social functioning¹⁰, as well as quality of life¹¹. Additionally, a previous meta-analysis found that functional outcome was more strongly associated with social cognition than with neurocognition¹². Social cognition is a broad field encompassing the psychological operations of perceiving as well as interpreting and processing information to adapt to social interactions. The most widely studied aspects of social cognition in schizophrenic patients include emotional processing, social perception, attribution bias, and mentalizing¹³.

Emotional processing plays a critical role in schizophrenia research, as patients often display aberrant emotional response, expression, and recognition. Emotional recognition is crucial in interpersonal communication as it refers to the ability of individuals to effectively recognize other people's emotions, through facial expressions as well as the prosodic components of vocal communication. Emotional processing is believed to involve at least two separate processes, namely, vocal expressions processed through cortical-based mechanisms associated with perception and effortful stimulus evaluation, and facial expressions processed through subcortical emotional and mnemonic mechanism¹⁴. Previous studies have suggested that facial expressions represent an effective way to convey basic or simple emotions, while vocal expressions may be more suitable for communicating complex emotional information¹⁵, such as attitude and social intention¹⁶ and satire¹⁷. Therefore, the ability to recognize vocal emotions is an important component of social competence¹⁵ and an organic combination of emotion and language. Previous research has largely focused on the recognition of facial emotion; thus, there are few studies examining the role of vocal emotion recognition in schizophrenia. However, given the important role that vocal

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emotion recognition plays in social cognition, we aimed to further clarify its relationship with neurocognition and functional outcome in schizophrenia.

Another example of impaired social cognition that commonly occurs in patients with schizophrenia is alexithymia, an emotional disorder characterized by the inability to identify and describe one's emotions^{18,19}. Individuals with a high degree of alexithymia have difficulty recognizing facial expressions, especially those with negative valence²⁰. However, the relationship between alexithymia and vocal emotional recognition remains unclear. Some studies reported a relationship^{21,22}, yet others have failed to find one²³. Moreover, the presence of alexithymia has been identified to predict poorer social and daily functioning, exceeding the contribution of previously determined factors, including neurocognition and social cognition (e.g. theory of mind and emotion recognition)²⁴. Therefore, exploring the relationship between them is warranted.

The presence of negative symptoms, which refers to a lack of and/or decrease in normal behaviour and subjective experience, including blunted affect, alogia, anhedonia, avolition, and asociality, has long been considered a hallmark of schizophrenia²⁵. Importantly, these symptoms were related to social cognition, including the recognition of facial emotion and theory of mind²⁶, and were recently found to be related to alexithymia²⁷. However, the connection between alexithymia and negative symptoms has received little empirical support. Furthermore, the presence of negative symptoms is a strong predictor of a range of poor clinical outcomes²⁸, including more serious functional impairments²⁹, poorer psychosocial functioning^{30,31}, poorer life skills and quality of life³², lower subjective well-being³³, lower recovery rates³⁴, and poor prognosis and response to medication³⁵.

As a result, impairments in social cognition and the presence of negative symptoms are both core features of schizophrenia and are closely associated with poorer functional outcomes. However, the specific factors and pathways that lead to functional impairment are still unclear. In general, previous research has focused mainly on the neurocognitive deficits and negative symptoms, and often failed to simultaneously examine other relevant factors³⁶. Therefore, whether these important outcome factors lie on one or multiple pathways is unknown. For the first time, we used structural equation modelling to simultaneously evaluate a bottom-up causal model characterizing the pathways among them in a population of Chinese schizophrenia patients. We hypothesized that these variables would form a single pathway, from neurocognition to vocal emotional cognition to alexithymia to negative symptoms to poor functional outcomes.

Results

Demographic information, cognition, symptoms, and functional results. Table 1 shows demographic information and other scale scores of the participants included in the study. There were no significant group differences in age or education, but there was a significant difference in gender ($\chi^2 = 15.52$, $p = 0.000$) between patients and controls. A total of 61% of the patients scored between 31 and 70 on the Personal and Social Performance Scale (PSP), suggesting that a majority of the patients had moderate to severe functional impairment. The scores for each dimension of the MATRICS Consensus Cognitive Battery (MCCB) were significantly lower in the schizophrenia group than in the control group. Additionally, the recognition accuracy of different emotions (anger, disgust, fear, sadness, surprise, and satire, but not for calm ($t = -1.28$, $p = 0.201$)) in the schizophrenia group was significantly lower than that in the control group. Compared with other emotions, the accuracy of disgust was the lowest in the patients ($F = 111.78$, $p = 0.000$). Finally, the scores for the two dimensions and total scores of the TAS were also significantly higher in the schizophrenia group than in the control group (detailed in Table 1).

Measurement model. Model 0 examined the degree to which the latent variables for neurocognition, vocal emotional cognition, alexithymia, and negative symptoms loaded on their respective indicators (Fig. 1). This first model is essentially a confirmatory factor analysis, and the model fit was extremely good, indicating that the latent variables and indicators were strongly associated.

Initial model and final model. We then added neurocognition, vocal emotion cognition, alexithymia, negative symptom, and functional outcome to create a single path in the model (Fig. 2), and the model fit was good. Next, modification indices from the AMOS software were used to determine some paths that could be discarded to improve the fit. The abovementioned modifications resulted in a more streamlined model that also had a good fit (Fig. 3). The model reflects a relatively linear sequence leading from neurocognition to vocal emotion cognition to alexithymia to negative symptoms and to functional outcome. Compared to the initial model, the final model is more parsimonious (requiring fewer constructs and connections), and the fit indices are slightly higher. Further, given that it is more parsimonious, the model is also more stable. Based on these results, a final trimmed model that uses a single path running from neurocognition to vocal emotion cognition to alexithymia to negative symptoms to functional outcome was selected. This model was chosen based on it being more concise and having better fit indices than the untrimmed model. The statistical results of model fitting degree are shown in Table 2.

Discussion

Overall, this study showed that there were deficits in neurocognition, vocal emotional recognition, and alexithymia in the schizophrenia group. Importantly, we evaluated models of outcome in schizophrenia ranging from micro-level neurocognition to macro-level functional outcomes. The observed data fit the proposed bottom-up model. We demonstrated that these variables formed a single pathway, from neurocognition to vocal emotion cognition to alexithymia to negative symptoms to poor functional outcomes.

	Schizophrenia group(n = 135)	Health group(n = 73)	Statistics <i>t</i> or χ^2	<i>P</i>
Gender	Male = 83 Female = 52	Male = 24 Female = 49	15.52	0.000
Age(years, mean \pm SD)	43.45 \pm 11.72	40.35 \pm 9.96	1.91	0.057
Education(years, mean \pm SD)	13.06 \pm 2.38	13.64 \pm 2.14	-1.75	0.082
Duration of Illness(year)	19.44 \pm 11.23			
PSP	67.77 \pm 10.80			
Fraction range (n/%)	0–30 (0/0%)			
	31–70 (82/61%)			
	71–100(53/39%)			
BNSS Total	23.36 \pm 12.83			
Anhedonia	5.71 \pm 3.81			
Distress	1.47 \pm 1.35			
Asociality	4.30 \pm 2.35			
Avolition	3.99 \pm 2.60			
Blunted affect	4.50 \pm 3.72			
Alogia	2.63 \pm 2.44			
MCCB Total	45.95 \pm 9.84	56.14 \pm 6.80	-7.89	0.000
Verbal learning	46.97 \pm 10.67	55.82 \pm 8.31	-6.15	0.000
Reasoning and problem solving	46.21 \pm 11.68	56.06 \pm 8.39	-6.37	0.000
Visual learning	45.65 \pm 10.36	51.99 \pm 8.39	-4.42	0.000
Social cognition	46.74 \pm 9.83	49.53 \pm 10.20	-0.550	0.583
Attention	46.14 \pm 10.38	55.71 \pm 7.54	-6.95	0.000
Processing speed	46.22 \pm 9.57	57.41 \pm 7.38	-8.69	0.000
working memory	48.36 \pm 10.17	56.80 \pm 7.38	-6.25	0.000
Voice emotion cognition Total	29.31 \pm 10.03	37.38 \pm 7.21	-6.07	0.000
anger	5.58 \pm 1.99	6.64 \pm 1.45	-4.04	0.000
calm	7.01 \pm 1.67	7.28 \pm 1.11	-1.28	0.201
disgust	2.53 \pm 2.11	3.89 \pm 1.90	-4.58	0.000
fear	3.80 \pm 2.63	4.73 \pm 2.02	-2.62	0.001
sadness	4.27 \pm 2.09	6.19 \pm 1.60	-6.86	0.000
satire	3.03 \pm 2.31	3.97 \pm 2.24	-2.84	0.005
surprise	3.10 \pm 2.25	4.67 \pm 2.15	-4.90	0.000
TAS Total	50.30 \pm 10.08	44.45 \pm 9.50	4.07	0.000
F1	16.42 \pm 5.31	13.01 \pm 5.06	4.49	0.000
F2	12.85 \pm 3.35	10.97 \pm 2.86	4.06	0.000
F3	21.03 \pm 3.33	20.47 \pm 3.07	1.20	0.233

Table 1. Comparisons of demographic, neurocognition, vocal emotion cognition, alexithymia, negative symptoms and functioning variables between two groups. PSP: Personal and Social Performance Scale. BNSS: Brief Negative Symptom Scale. MCCB: MATRICS Consensus Cognitive Battery. TAS: Toronto Alexithymia Scale. F1: Difficulty identifying feelings. F2: Difficulty describing feelings. F3: Externally oriented thinking.

Neurocognition. We found that neurocognitive ability, as measured by each dimension of the MCCB, was significantly worse in the schizophrenia group than in the control group. While the underlying causes of these cognitive impairments are unclear, abnormal brain structures and function observed in patients with schizophrenia are believed to play a major role. In fact, observed abnormalities in the white matter³⁷ as well as whole brain volume may lead to deficits in abstraction/flexibility, language, and attention/concentration. Furthermore, disproportionately larger lateral ventricles have been associated with poorer psychomotor speed and attention/concentration. Both the prefrontal cortex and the hippocampus have been found to be dysfunctional in schizophrenia patients, and additionally, the prefrontal cortex tends to be associated with measures of executive function and the hippocampus correlates with memory and executive function³⁸. Neurocognition is a fundamental cognitive process that can be used as a biomarker for underlying neurodevelopmental problems⁸ that may contribute to higher-level cognitive impairment.

Vocal emotion cognition. We found that the recognition accuracy for different emotions (anger, disgust, fear, sadness, surprise, and satire, but not for calm) in the schizophrenia group was significantly lower than that in the control group. These results are consistent with previous studies³⁹ and are likely because of the interaction between early sensory and late cognitive stage impairments⁴⁰. In fact, some studies have found that schizophre-

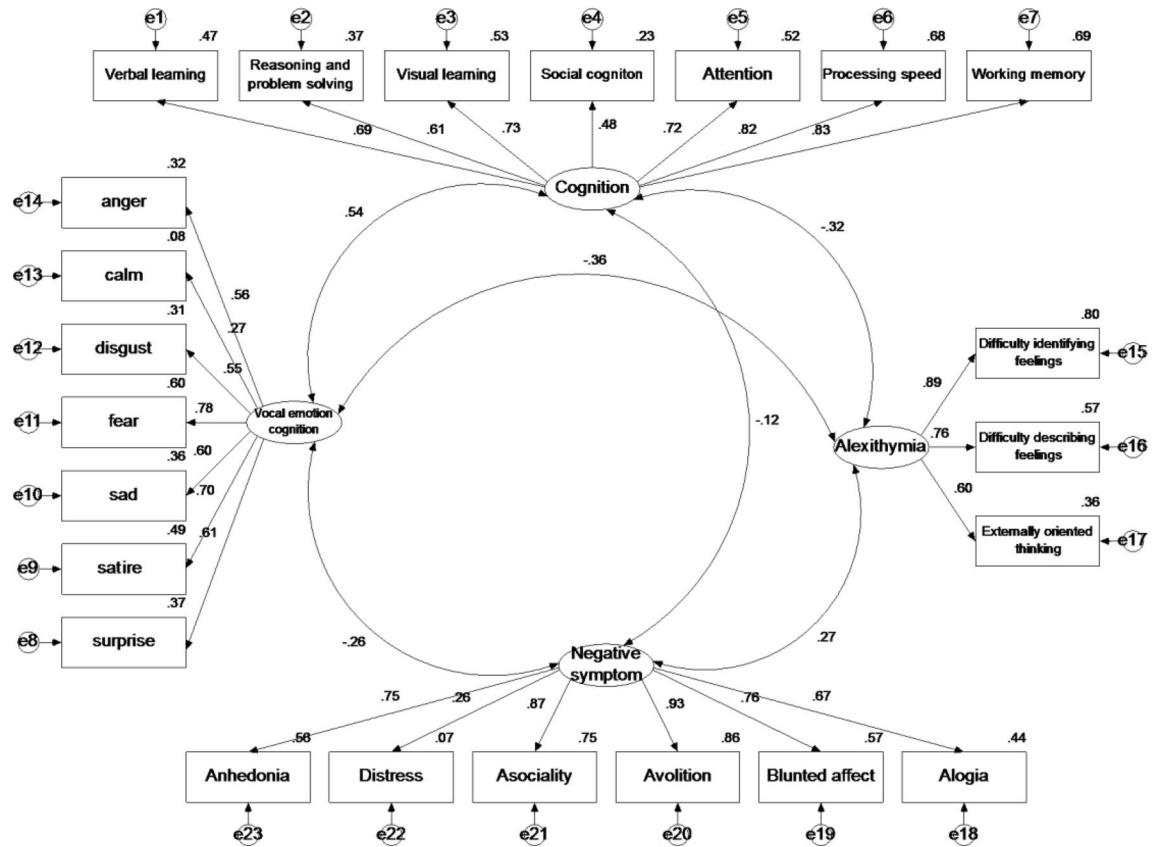


Figure 1. Model 0: Measurement Model. Circles represent unobserved latent variables. Rectangles represent observed measured variables. Values are standardized path coefficients. The figure reflects a measurement model that shows the degree of fit between the four latent variables (neurocognition, vocal emotion cognition, alexithymia, and negative symptoms) and their respective indicators.

nia patients exhibit a deficit in basic auditory processing^{41–43} and lack cognitive control⁴⁰, resulting in deficits in their ability to recognize information and critical acoustic characteristics based upon tone of voice. Finally, schizophrenia patients tend to show a decreased ability to identify emotional prosody. The amygdala, cerebellum and insula play crucial roles in emotional regulation, perception, and awareness. However, volumes of the left amygdala⁴⁴, bilateral cerebellar cortex⁴⁵, and insula⁴⁶ have been found to be lesser in patients with schizophrenia than in healthy controls. Echoing previous studies, this study also showed that it is most difficult for patients to recognize disgust. It is conceivable that reduced recognition of disgust is a form of self-protection; schizophrenics often face stigma and social exclusion as a result of the disease, and reduced sensitivity to social exclusion signals might protect them from social alienation⁴⁷.

Alexithymia. The results of this study are consistent with those of previous studies^{24,27} in that the schizophrenia group exhibited greater levels of alexithymia than the control group, characterized by the absence of emotional experience (including the experience’s associated cognitive appraisal). There are cognitive and emotion mechanisms of alexithymia in schizophrenia. For example, difficulty in identifying feelings and increased externally oriented thinking are associated with more neurocognitive deficits, such as slower processing speed⁴⁸, worse attention, and dysfunctional information processing¹⁸. Furthermore, difficulty in describing feelings can lead to heightened levels of emotional distress⁴⁸.

The bottom-up causal model of functional outcome in schizophrenia. We demonstrated a single pathway that links neurocognition to functional outcomes; with neurocognition linked to vocal emotion cognition, which is linked to alexithymia, which is linked to negative symptoms, which in turn are linked to functional outcomes.

Previous papers emphasize that ability, beliefs, and motivation mediated the connection between visual processing and functional outcome^{28,49}, but did not expand upon the more specific capacity and personality traits, such as emotion cognition, specifically the ability to identify and describe one’s and others’ emotion, which is necessary for schizophrenia patients to integrate into society. Further, they only examined the role of visual processing in the model, ignoring other aspects of basic cognition. Other studies found that poor neurocognitive abilities of schizophrenia patients, such as temporary delay after tone matching⁵⁰, reduced processing speed⁵¹, poor pre-attentive processes and attention-dependent processes^{52,53}, as well as deficits in working

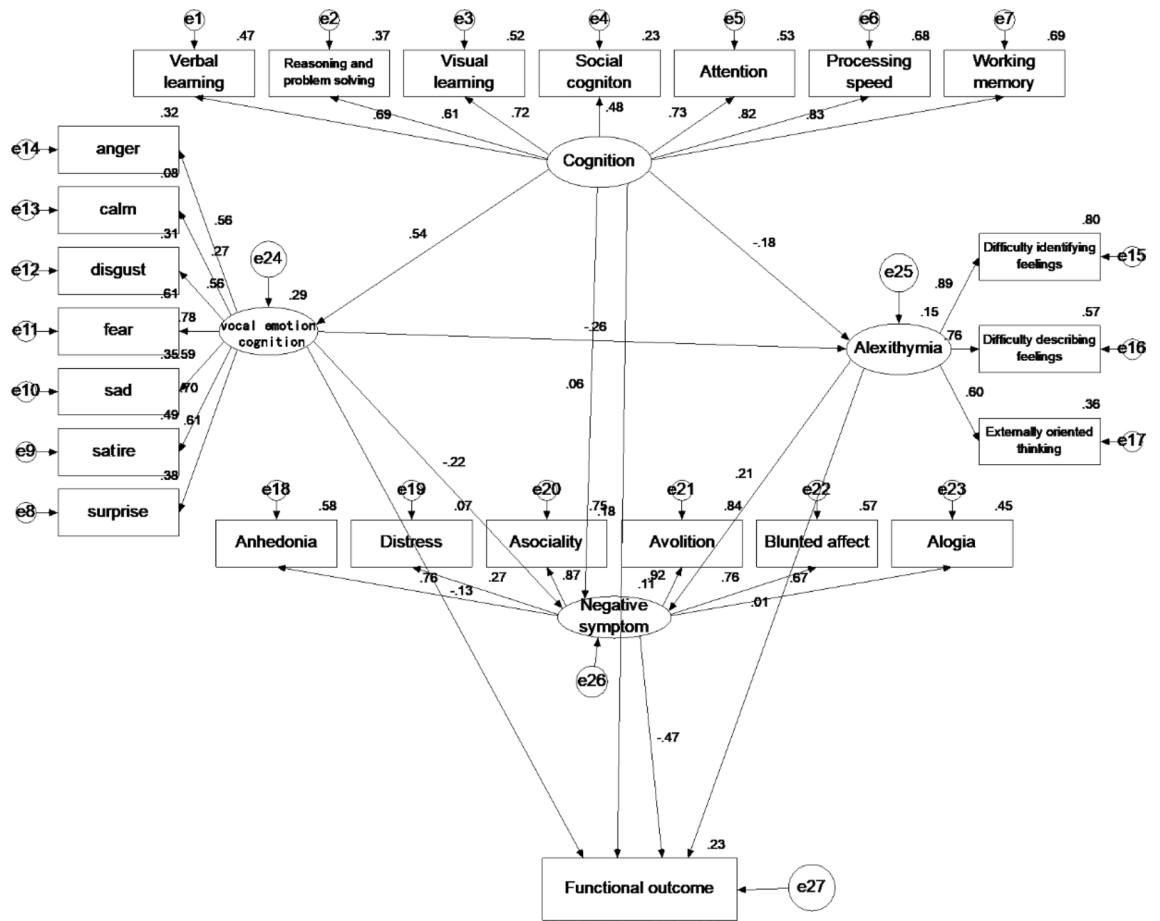


Figure 2. Model 1: Initial Model. This figure is a schematic of the initial, non-trimmed, structural model that includes all of the variables considered.

memory (interruption of the ability to “maintain”)⁵⁴, lead to impairments in the processing of voice pitch and intensity, which then result in difficulties in emotional recognition. Accordingly, this present study used MCCB to investigate the basic cognitive ability of schizophrenia patients in order to obtain more comprehensive results.

The present study found three mediating paths (one for vocal emotion cognition, one for alexithymia and one for negative symptoms) between the neurocognition and functional outcomes. Specifically, a reduced sensitivity and generally blunted neural response to the emotional qualities and prosody of speech and music make it difficult for individuals to describe and recognize emotions. This is likely the underlying reason for the interpersonal communication problems associated with alexithymia. Furthermore, the low activation of the emotional recognition brain network potentially causes defects in emotional attention and recognition in alexithymia. Emotional identification impairments are a problem of perceptual representation, causing the individual to lose balance with the socio-emotional world, leading to the emergence of pressure and conflict⁵⁵. Alexithymia patients need to involve their cognitive abilities to a greater extent to explain emotional experience, and when the basic emotional processing is defective, this ability to describe emotion is naturally damaged. Subsequently alexithymia results in reduced empathy and an impaired ability to recognize the emotions of others⁵⁶. These reduced abilities lead to frustration in the social environment, which ultimately leads to negative attitudes and self-beliefs. These dysfunctional attitudes in turn contribute to reduced motivation and interest that are clinically considered as negative symptoms^{28,57}. Finally, negative symptoms and functional outcome are based on a cascade relationship, in which more serious negative symptoms lead to worse functional outcome in patients with schizophrenia. This is consistent with results from previous reports^{32,58} and was also observed in two longitudinal studies^{29,31}. Negative symptoms are an important factor in the overall prognosis of patients with schizophrenia and represent a major hindrance to their return to society⁵⁹. Schizophrenia patients who exhibit more negative symptoms tend to exhibit less interpersonal communication with family members and community members as well as avoidance of family and social functions. They also often show impairment in personal care, self-care, and health. In addition, the chronic process of the disease can also aggravate the impairment of these abilities. Therefore, negative symptoms are direct predictors of functional outcome. Thus, damaged neurocognition causes abnormal vocal emotion recognition, and this abnormal condition leads to damaged emotional expression, which gradually manifest as flat affect in patients, which is the precise core component of negative symptoms.

Importantly, the bottom-up model suggests that it may be possible to intervene in the upstream neurocognitive components in order to prevent the development of social cognition and the negative symptoms, thus interrupting the harmful consequences of this pathway. It may also be possible to develop proper interventions

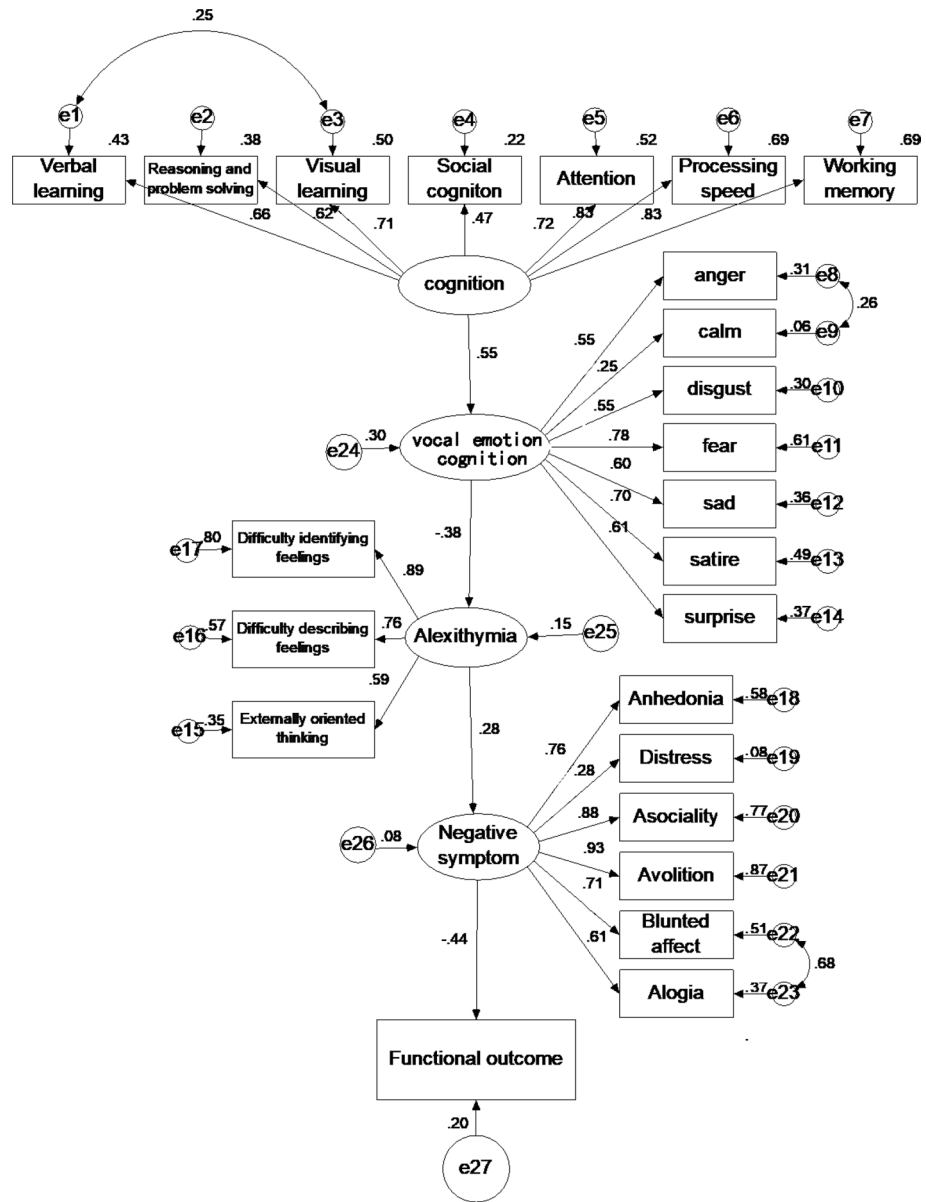


Figure 3. Model 2: Final Model. This figure is the final, trimmed model after modifications. It shows a single path running through cognition, vocal emotion cognition, alexithymia, negative symptom, and functional outcome.

Model	RMSEA	CFI	IFI	TLI	AIC	BIC	Ratio of X ²
Model 0	0.072	0.884	0.886	0.869	500.096	656.649	1.768
Model 1	0.073	0.873	0.876	0.856	522.380	723.986	1.804
Modified model	0.052	0.937	0.938	0.928	456.880	637.518	1.404
Model 2	0.053	0.934	0.935	0.926	455.437	618.011	1.412

Table 2. Model fit statistics.

aimed at improving patients’ ability to recognize and articulate their feelings so that schizophrenia patients could ameliorate negative symptoms and restore functional outcomes. The observed complex associations among the investigated factors strongly suggest that multi-domain and multi-level interventions should be provided as a standard treatment to improve the functional outcome³⁶.

Limitation

The current study has some limitations. First, the use of cross-sectional data for analysis weakens causality inference. Additionally, some studies have found that neurocognitive dysfunction⁶⁰, social cognitive impairment⁶¹, and negative symptoms³¹ are present even in the early stages of schizophrenia, but when exactly each deficit occurs remains unclear. Therefore, future studies using a longitudinal design to determine the temporal relationship between these factors and functional outcomes, and develop specific and effective interventions, are needed. Furthermore, the concept of negative symptoms needs to be further refined. The latent structure of negative symptoms is best conceptualized in relation to the five consensus domains, and this can help make the targeted treatment of schizophrenia more precise and efficient^{25,62}. Another limitation is that only 125 patients were assessed, future research should expand sample size to improve the credibility of statistical results.

Conclusion

The present study demonstrated that cognitive impairment in schizophrenia involves a wide range of non-social and social cognitive fields and clarified the multivariate relationships among neurocognition, vocal emotion cognition, alexithymia, negative symptoms, and functional outcome in schizophrenia. Our results support the hypothesized information processing bottom-up model, whereby neurocognition deficits contribute to vocal emotion cognition impairments and alexithymia, followed by negative symptoms and a reduced functional outcome. Therefore, this integrative model has potential significance in guiding the development of novel treatments and better prognosis for patients with schizophrenia.

Methods

Participants. This study included 135 schizophrenia patients (83 males and 52 females) who met the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V) criteria for schizophrenia and 73 healthy controls (24 males and 49 females) from Beijing HuiLongGuan Hospital. The control participants had no lifetime history of any Axis I disorders or family history of schizophrenia or schizoaffective disorders in their first-degree relatives. The exclusion criteria of all participants included a history of head trauma with loss of consciousness longer than 15 min, substance abuse or dependence within the past 6 months, intellectual disability, debilitating or unstable medical illness, and other neurological diseases. All participants provided written informed consent before undergoing any research procedure. The study protocol was conducted in accordance with the Declaration of Helsinki and was approved by the respective research ethics boards and institutional review boards of Beijing Huilongguan Hospital.

Neuropsychological and psychopathological assessment. *MATRICES consensus cognitive battery (MCCB).* Neurocognition was evaluated using the Chinese version of MATRICS (Measurement and Treatment Research to Improve Cognition in Schizophrenia) Consensus Cognitive Battery (MCCB)⁶³, which includes 10 tests measuring 7 domains: speed of processing, attention, working memory, verbal memory, visual memory, reasoning and problem solving, and social cognition. The composite and subtest scores from the MCCB were converted from raw data to T-scores with a mean of 50 and a standard deviation of 10.

Vocal emotion cognition test. We selected 2 sets of 56 vocal stimuli pronounced by 4 actors (2 men and 2 women). Seven emotional categories were used in this study (anger, calm, disgust, fear, sadness, surprise, and satire); the recorded contents in mandarin Chinese are as follows: “1. What time is it now; 2. It’s eight o’clock now.” Participants were seated in front of a computer in a quiet room to perform this vocal emotion test, which presented vocal clips in a pseudo-random sequence. All vocal stimuli were played binaurally via stereo headphones. After listening to the voice clip, the subjects were directed to use the mouse to select one of seven progress bars on the screen that represent seven different emotions to judge the emotion type expressed by each voice clip they heard. The value represents the number of correctly recognized vocal emotions.

Toronto alexithymia scale (TAS). We used the 20-item TAS-20 to evaluate 3 subscales of alexithymia: (1) difficulty identifying feelings, (2) difficulty describing feelings, and (3) externally oriented thinking. Each item was rated using a five-point Likert scale (from 1, “strongly disagree,” to 5, “strongly agree”); subscales were computed by summing relevant items and the total alexithymia score by summing responses to all 20 items, with higher scores representing a higher degree of alexithymia. The TAS-20 has demonstrated validity, stability, and reliability⁶⁴.

Brief negative symptom scale (BNSS). The severity of negative symptoms in schizophrenia was evaluated using the BNSS, which had 13 items, including 6 subscales: anhedonia, distress, asociality, avolition, blunted affect, and alogia. Each item was scored using a 7-point scale (0, “normal”; 1, “suspicious”; 2, “mild”; 3, “moderate”; 4, “moderate to severe”; 5, “severe”; 6, “extremely severe”). The score of each dimension is equal to the sum of the items contained, and the total score of the scale is equal to the sum of the points of each dimension. The total score of scale ranged from 0 to 78. The higher the score, the more serious the negative symptoms⁶⁵.

Personal and social performance scale (PSP). The PSP mainly evaluates the function of patients in four aspects, and another total score was assessed according to the scoring criteria. The range of the total score is 0–100 points, which is divided into 10 grades. A total score of 71–100 points indicated that there was no difficulty or only a slight difficulty in social function and interpersonal communication; 31–70 points indicated different degrees of

capability defects; and ≤ 30 points indicated that the function was low and the patient needed positive support or close monitoring. In this study, the patient's functional outcome was evaluated using only the total score⁶⁶.

Data analyses. Data were analysed using IBM SPSS Statistics, Version 23.0 (Armonk, NY, USA), and AMOS 17.0. Eighteen (10 patients and 8 controls) participants were excluded from analyses because of missing data or based on outlier scale scores (>3 or <3 standard deviations above the mean). Group differences (patients vs. controls) in demographics, MCCB, vocal emotion cognition task, and TAS scores were examined using an independent sample *t* test for continuous variables and chi-square test for categorical variables. Repeated measure ANOVA for accuracy was conducted with various emotions as the within-subject parameters in patients. Pearson's correlations were conducted to examine the association between MCCB scores and vocal emotional cognition and TAS and BNSS and PSP.

Structural equation modelling was used to summarize relationships among measures described in the previous sections using latent variables and to test the plausibility of causal associations among these constructs. The analysis included patients only. Our measurement model (M0) consisted of neurocognition, vocal emotion cognition, alexithymia, and negative symptoms. Path analysis was then used to test the relationship between neurocognition, vocal emotion cognition, alexithymia, negative symptoms, and functional outcome. In the analysis, neurocognition was treated as the exogenous variable, whereas vocal emotion cognition, alexithymia, and negative symptoms were treated as the mediating variables.

Model fit was assessed using ranges of acceptable fit values, including comparative fit index (CFI) ≥ 0.90 , Tucker mean square index (TFI) ≥ 0.90 , root mean square error of approximation (RMSEA) ≤ 0.06 , and standardized root mean square residual ≤ 0.08 , to indicate that the hypothesized model fits the observed data relatively well.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Author contributions

S.T. designed and coded the experiment. Y.Z., F.F., H.F., Y.W., W.Q., Z.W., and Y.T. recruited and ran participants. H.L. and S.T. analysed and interpreted the data. H.L. drafted the manuscript, and all authors edited and approved of the final manuscript. S.T. and X.Z. supervised the work.

Competing interests

The authors declare no competing interests.

Additional information

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