Empathy and Social Attribution Skills Moderate the Relationship between Temporal Lobe Volume and Facial Expression Recognition Ability in Schizophrenia

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Objective: While impaired facial expression recognition has been closely associated with reduced temporal lobe volume in patients with schizophrenia, this study aimed at examining whether empathy and social attribution affect such a relationship.

Methods: A total of 43 patients with schizophrenia and 43 healthy controls underwent a facial expression recognition task (FERT) and magnetic resonance imaging. Basic empathy scale and the social attribution task-multiple choice were used to measure empathy and social attribution.

Results: Patients with schizophrenia showed significant positive correlations between the total temporal lobe volume and the FERT-accuracy (FERT-ACC). Diminished temporal lobe volume predicted the impaired facial emotion recognition ability. Both empathy and social attribution played roles as moderators of the path from the left amygdala volume, left fusiform gyrus volume, both sides of the superior temporal gyrus volume, and left middle temporal gyrus volume to the FERT-ACC. In contrast, empathy alone functioned as a moderator between the right fusiform gyrus volume, right middle temporal gyrus volume, and FERT-ACC. No significant interaction was found for healthy controls.

Conclusion: Our results suggest that social cognition remediation training on empathy and social attribution, could buffer the negative effects of small temporal lobe volume on interpersonal emotional communication in patients with schizophrenia.

KEY WORDS: Schizophrenia; Temporal lobe; Social cognitive ability; Empathy; Social attribution; Facial emotion recognition task.

INTRODUCTION

The ability to identify and interpret other people's facial expressions is crucial in our daily life. However, numerous studies have reported that patients with schizophrenia show impairment in the recognition of facial emotions, as well as in the judgement and labeling of facial expressions, recognition memory for unfamiliar faces, and identification of facial identity [1-7]. The difficulties in emotional recognition in schizophrenia have been explained by brain structural abnormalities [8-11]. In particular, temporal lobe dysfunction was reported to be a core element of the deficit in facial emotion recognition in patients with schizophrenia [12,13]. Specifically, the temporal lobe areas associated with facial emotion recognition include the hippocampus [14], amygdala [15-17], fusiform gyrus [18-21], superior temporal [22], and middle temporal [23] regions. Furthermore, the fusiform gyrus, hippocampus, temporal areas, and amygdala regions were all demonstrated to be structurally smaller in patients with schizophrenia than in healthy controls [8,24-30]. Such findings suggest that diminished temporal

lobe volume plays a role in the impaired facial emotion recognition in patients with schizophrenia.

Facial emotion recognition deficits have been studied in the context of social cognition, or the mental mechanisms associated with perceiving, understanding, and interpreting the social world [31], in patients with schizophrenia [32]. Social cognition can be divided into three domains: 1) the ability to perceive social information, 2) understanding of other's cognitive or affective states and 3) decision-making while considering other's goals [33]. In this perspective, facial recognition ability falls into the first domain, social perception. While patients with schizophrenia show deficits in all three domains [6,34,35], previous studies have consistently demonstrated that the lack of facial emotion recognition is related to reduced temporal lobe volume. In particular, a review stated that abnormalities in face processing in schizophrenia are strongly associated with structural abnormalities in regions such as fusiform gyrus, superior temporal sulcus, amygdala and prefrontal cortex [36].

On the other hand, the current study also focused on the role of empathy and social attribution, which are incorporated in the second domain of social cognition, on the relationship between diminished temporal lobe volume and facial emotion recognition. Empathy is one of the most important personality traits that plays a role in social interaction and communication [37]. Also, social attribution, or mental state attribution, denotes the cognitive capacity to reflect upon one's own and others' mental states such as beliefs, desires, feelings and intention [38]. While several studies have shown that empathic or social attribution ability and social perception are independent constructs [39,40], other studies proposed that the level of empathic ability could affect facial emotion processing [37]. In addition, given that some social cognition programs (e.g., a computerized program practicing recognition of others' mental states) have shown a positive effect on facial affect recognition [41], it is assumed that enhancing empathic or social attribution ability would attenuate the effect of reduced temporal lobe volume on facial emotion recognition. Based on these previous findings, we hypothesized that empathy or social attribution ability could moderate the relationship between diminished temporal lobe volume and abnormalities in facial emotion recognition in schizophrenia.

In this study, we attempted to investigate whether em-

pathy and social attribution, constructs that involves social understanding domain of social cognitive ability, would buffer the relationship between temporal lobe volume and facial emotion perception skills in schizophrenia. Our hypothesis was that 1) a diminished temporal lobe volume would be associated with a deficit in facial emotion recognition in schizophrenia; and 2) empathy and social attribution, would act as moderators of the relationship between the temporal lobe volume and facial expression recognition in schizophrenia.

METHODS

Participants

A total of 86 subjects, who were recruited from both the Ilsan Paik hospital and local communities, participated in this study. The subject pool was comprised of patients with schizophrenia as well as healthy controls (Table 1). All patients were assessed for Axis I disorders by a psychiatrist, based on the Structured Clinical Interview for the Diagnostic and Statistical Manual of Mental Disorders, 4th edition. None of the patients had a lifetime history of central nervous system disease, alcohol or drug abuse, mental retardation, or head injury with loss of consciousness. All patients with schizophrenia were undergoing treatment with atypical antipsychotics. The exclusion criteria for the initial screening included identifiable neurological disorders, head injury, and any personal or family history of psychiatric illness. Healthy controls had no prior or present mental disorder. All participants provided a written informed consent prior to their enrollment in the investigation (Ispaik-2018-11-006).

Measures

MRI acquisition and volume

A 1.5 T scanner was used to conduct magnetic resonance imaging (MRI) (Magneton Avanto; Siemens, Erlangen, Germany). Foam pads provided by the manufacturer were used to minimize head motion. High-resolution T1-weighted MRI images were acquired with the following parameters: an acquisition matrix of 227×384, a field-of-view of 210×250, a voxel size of $0.9 \times 0.7 \times 1.2$, a total of 87,168 voxels, an echo time of 3.42 ms, a repetition time of 1,900 ms, a 1.2-mm slice thickness, and a flip angle of 15°.

Table 1. Participants' demographic information (n = 86)

Variable	Patients with schizophrenia (n = 43)	Healthy controls (n = 43)	*p* value
Demographics			
Sex			
Male	16 (37.2)	20 (46.5)	0.382
Female	27 (62.8)	23 (53.5)	
Age (yr)	43.42 ± 10.83	39.93 ± 13.21	0.184
Education (yr)	13.37 ± 2.80	14.58 ± 3.67	0.089
Pre-morbid IQ/IQ	99.36 ± 10.32	107.97 ± 8.58	< 0.001
DOI (yr)	12.87 ± 8.34	-	
CPZeq (mg)	470.50 ± 607.15	-	
Brain volume (mm³)			
TIV	1,542.59 ± 156.45	1,564.45 ± 151.74	0.513
LHV	2.99 ± 0.42	3.26 ± 0.42	0.004
RHV	3.32 ± 0.59	3.62 ± 0.40	0.008
LAV	0.88 ± 0.11	0.96 ± 0.10	< 0.001
RAV	0.85 ± 0.14	0.94 ± 0.10	0.001
LFV	7.86 ± 1.11	8.40 ± 1.21	0.036
RFV	7.59 ± 1.25	8.26 ± 1.16	0.008
LSTV	5.93 ± 0.90	6.38 ± 0.95	0.026
RSTV	6.33 ± 0.92	6.83 ± 1.01	0.019
LMTV	13.54 ± 1.96	14.90 ± 2.06	0.002
RMTV	13.57 ± 2.05	15.04 ± 2.00	0.001
FERT and social cognitive scales			
BES	66.78 ± 8.67	74.95 ± 7.99	< 0.001
SAT-MC	8.81 ± 4.79	14.50 ± 3.69	< 0.001
FERT-ACC (%)	0.52 ± 0.18	0.73 ± 0.12	< 0.001
FERT-RT (ms)	2,123.04 ± 351.80	1,740.74 ± 267.04	< 0.001

Values are presented as number (%) or mean ± standard deviation.
DOI, duration of illness; CPZeq, chlorpromazine equivalent; TIV, total intracranial volume; LHV, left hippocampus volume; RHV, right hippocampus volume; LAV, left amygdala volume; RAV, right amygdala volume; LFV, left fusiform gyrus volume; RFV, right fusiform gyrus volume; LSTV, left superior temporal gyrus volume; RSTV, right superior temporal gyrus volume; LMTV, left middle temporal gyrus volume; RMTV, right middle temporal gyrus volume; BES, basic empathy scale; SAT-MC, social attribution task-multiple choice; FERT-ACC, facial expression recognition task-accuracy; FERT-RT, facial expression recognition task-response time.

The voxel-based morphometry (VBM) was performed using the Computational Anatomy Toolbox (CAT12; developed by Christian Gaser, University of Jena, http://dbm.neuro.uni-jena.de/cat) with the SPM12 software package (Wellcome Department of Cognitive Neurology, London, UK) [42,43]. The structural T1 images were registered to an ICBM East Asian template and normalized using the DARTEL algorithm [44,45]. Thereafter, while all images were segmented into gray matter, white matter, and cerebrospinal fluid [45], they were modulated to obtain volume differences in gray matter using the Jacobian transformed tissue probability maps. The volume of the temporal lobe regions (left hippocampus volume, LHV; right hippocampus volume, RHV; left amygdala volume, LAV; right amygdala volume, RAV; left fusiform gyrus volume, LFV; right fusiform gyrus volume, RFV; left superior temporal gyrus volume, LSTV; right superior temporal gyrus volume, RSTV; left middle temporal gyrus volume, LMTV; and right middle temporal gyrus volume, RMTV) was extracted using the Neuromorphometrics atlas, available in SPM 12 (http://neuromorphometrics.com) (Fig. 1). These regions of interest were determined based on the regions that were found to be associated with facial recognition and schizophrenia in previous studies [13-31].

Basic empathy scale (BES)

The BES, a 5-point 20-item scale developed by Jolliffe and Farrington [46], was used to measure the levels of empathy. This scale consists of two sub-constructs: cognitive empathy and affective empathy. The total score ranges from 20 to 100, higher scores indicating greater levels of empathy. In this study, the whole scale revealed an excellent internal consistency (α = 0.87), while the cognitive empathy (α = 0.79) and the affective empathy subscales
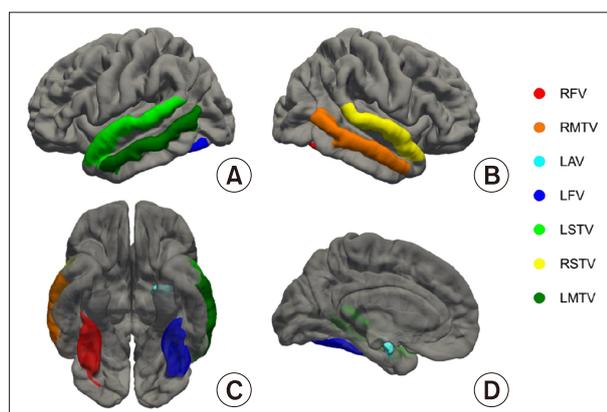
Fig. 1. Regions of interest for examination of the temporal lobe volume and FERT-ACC in patients with schizophrenia shown in (A) left view, (B) right view, (C) bottom view, and (D) left hemisphere. FERT-ACC, facial expression recognition task-accuracy; RFV, right fusiform gyrus volume; RMTV, right middle temporal gyrus volume; LAV, left amygdala volume; LFV, left fusiform gyrus volume; LSTV, left superior temporal gyrus volume; RSTV, right superior temporal gyrus volume; LMTV, left middle temporal gyrus volume.

$(\alpha = 0.79)$ demonstrated acceptable reliability.

Social attribution task-multiple choice (SAT-MC)

The social attribution test stimulus is based on the work conducted by Heider and Simmel [47] and later adapted by Klin [48,49]. The SAT-MC consists of a 64-second animation of a social drama enacted by a large triangle, small triangle, and a small circle (see original on www.youtube.com under "Heider and Simmel Movie"). After the participants watched the entire animation twice, they were presented 19 multiple-choice questions. Each question was presented with the relevant segment of the animation with 4 answer choices (1 choice depicting the correct emotional intent, 2 choices depicting incorrect emotional intent, and 1 choice on object motion without any emotional intent).

Facial expression recognition task (FERT)

This study used a facial expression recognition test that was modified from the facial affect labeling task [50]. It is a forced-choice emotional identification task that involves the presentation of the Korean Facial Expressions of Emotion [51] faces on the experimental laptop. While such faces were displayed on the left side of the computer screen, the response buttons (rectangles of 5.5 × 3.5 cm) appeared on the right side of the screen following the disappearance of the face. The distance between the re-

sponse buttons was 0.5 cm, and they were aligned equidistantly in a circular formation around the 4-cm central circle. The order of the response choices was fixed and was as follows: from the top right moving clockwise; happy, neutral, sad, surprised, fearful, disgusted, contempt, and angry. Participants were informed of the presence of such eight specific emotions during the task and were asked to provide their response by pressing the button on the screen that corresponded to the emotion displayed with a mouse. After pressing the response button, participants were instructed to quickly place the mouse back on the central circle and to wait. The picture was shown randomly within a block (i.e., a total of sixteen facial emotions). Each subject performed 2 practice blocks and 4 blocks in the original task. The original task consisted of four blocks, separated by an un-timed rest period to prevent fatigue. Participants completed the task in approximately 10 minutes. While the face appeared within 750 ms, the inter-trial interval started at 3,000 ms from the reaction time (RT) and was added to the 1,500 ms of feedback. Immediately after the presentation of each face, a white screen was displayed. Subjects were asked to answer as fast as possible and both the answer accuracy and RT for correct responses were assessed for each emotion. Furthermore, the hit rate (number of correct trials/total number of trials) and RT (time taken to respond with the correct answer) were obtained.

Data Analyses

The Pearson's correlation analysis with bootstrapping at a 5,000-sampling rate was performed to examine the correlations among the variables. Moderating analysis was conducted using the SPSS Macro PROCESS for SPSS 2.16.3 (model number 1) developed by Preacher and Hayes [52]. Finally, the indirect effects were estimated for the variables of interest using both a normal theory approach and non-parametric bootstrapping to provide confidence intervals. Furthermore, the Johnson–Neyman technique was applied to investigate the regions in which the moderating variable had significant effects. Confidence intervals that contain the zero value indicate a non-significant conditional indirect effect and therefore imply a significant moderating effect. In contrast, confidence intervals that do not include the zero value describe a significant conditional indirect effect and a non-significant moderating effect. All significance levels were set at $p < 0.05$ (two-tailed).

RESULTS

Descriptive Statistics

The demographic information as well as the psychological characteristics of patients with schizophrenia and healthy controls is presented in Table 1.

For the correlations between the main variables, significant positive correlations were identified between all the temporal lobe areas and the FERT-ACC (LHV: $r = 0.42$, $p < 0.01$; RHV: $r = 0.37$, $p < 0.05$; LAV: $r = 0.52$, $p < 0.01$; RAV: $r = 0.41$, $p < 0.01$; LFV: $r = 0.42$, $p < 0.01$; RFV: $r = 0.38$, $p < 0.05$; LSTV: $r = 0.39$, $p < 0.05$; RSTV: $r = 0.40$, $p < 0.01$; LMTV: $r = 0.44$, $p < 0.01$; RMTV: $r = 0.42$, $p < 0.01$), between the FERT-ACC and the BES score ($r = 0.46$, $p < 0.01$), as well as between the FERT-ACC and the SAT-MC score ($r = 0.53$, $p < 0.001$). In addition, the FERT-RT was negatively correlated with LMTV, RMTV, and FERT-ACC ($r = -0.32$, $p < 0.05$; $r = -0.34$, $p < 0.05$; $r = -0.59$, $p < 0.001$, respectively). However, there was no significant relationship between all temporal lobe volume and BES and SAT-MC score except LAV ($r = 0.31$, $p < 0.05$; $r = 0.47$, $p < 0.01$, respectively).

With regard to the healthy controls, a significant positive correlation between the FERT-ACC and BES score ($r = 0.38$, $p < 0.05$), as well as between the FERT-ACC and SAT-MC score ($r = 0.32$, $p < 0.05$) was observed. Finally, the FERT-RT was negatively associated with LAV, LFV, RFV, RSTV, and FERT-ACC ($r = -0.32$, $p < 0.05$; $r = -0.31$, $p < 0.05$; $r = -0.41$, $p < 0.01$; $r = -0.35$, $p < 0.05$; $r = -0.57$, $p < 0.001$, respectively). However, in line with patients with schizophrenia, significant relationship was not found between all temporal lobe volume and BES and SAT-MC score.

Moderation Effects

To examine the interaction between the temporal lobe volume and the social cognitive abilities in the FERT, moderation analyses were performed. Sex, age, years of education, pre-morbid IQ, illness duration, chlorpromazine equivalent and TIV were set as covariates. Our results indicated the direction of the interaction between the temporal lobe volume and the social cognitive abilities to be consistent with our hypothesis (Fig. 2).

Interaction between temporal lobe volume and BES

After controlling for the covariates, the LAV positively predicted the FERT-ACC (B = 3.83, $t = 2.85$, $p = 0.008$), while the BES also positively predicted the FERT-ACC (B = 0.05, $t = 2.48$, $p = 0.019$) in patients with schizophrenia. These results identified a significant direct effect of both the LAV and BES on the FERT-ACC. Furthermore, the interaction between LAV and BES had a significant effect on the FERT-ACC (B = -0.05, $t = -2.42$, $p = 0.022$), and the R^2 was increased due to the interaction ($\Delta R^2 = 0.06$, $\Delta F = 5.84$, $p = 0.022$). Specifically, those participants who demonstrated high levels of BES performed better in the FERT-ACC, regardless of their diminished LAV.

Similarly, after controlling for covariates, the LSTV positively predicted the FERT-ACC (B = 0.66, $t = 2.79$, $p = 0.009$), while the BES positively predicted the FERT-ACC (B = 0.06, $t = 2.80$, $p = 0.009$) in patients with schizophrenia. These results indicated a significant direct effect of both the LSTV and BES on the FERT-ACC. Furthermore, the interaction between LSTV and BES had a significant effect on the FERT-ACC (B = -0.01, $t = -2.67$, $p = 0.012$), and the R^2 was increased due to the interaction ($\Delta R^2 = 0.07$, $\Delta F = 7.12$, $p = 0.012$).

Similar significant interactions were found in other temporal lobe areas, including the LFV, RFV, RSTV, LMTV,
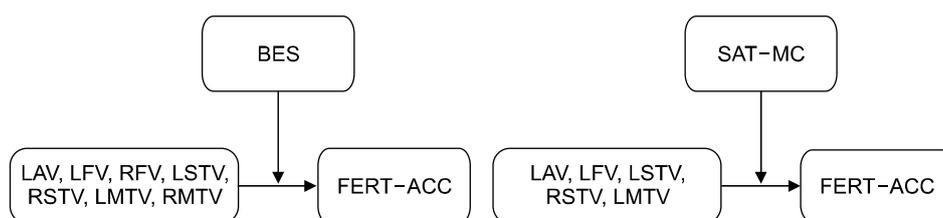

Fig. 2. BES and SAT-MC as moderators of the relationship between the temporal lobe volume and FERT-ACC in patients with schizophrenia. LAV, left amygdala volume; LFV, left fusiform gyrus volume; RFV, right fusiform gyrus volume; LSTV, left superior temporal gyrus volume; RSTV, right superior temporal gyrus volume; LMTV, left middle temporal gyrus volume; RMTV, right middle temporal gyrus volume; BES, basic empathy scale; SAT-MC, social attribution task-multiple choice; FERT-ACC, facial expression recognition task-accuracy.
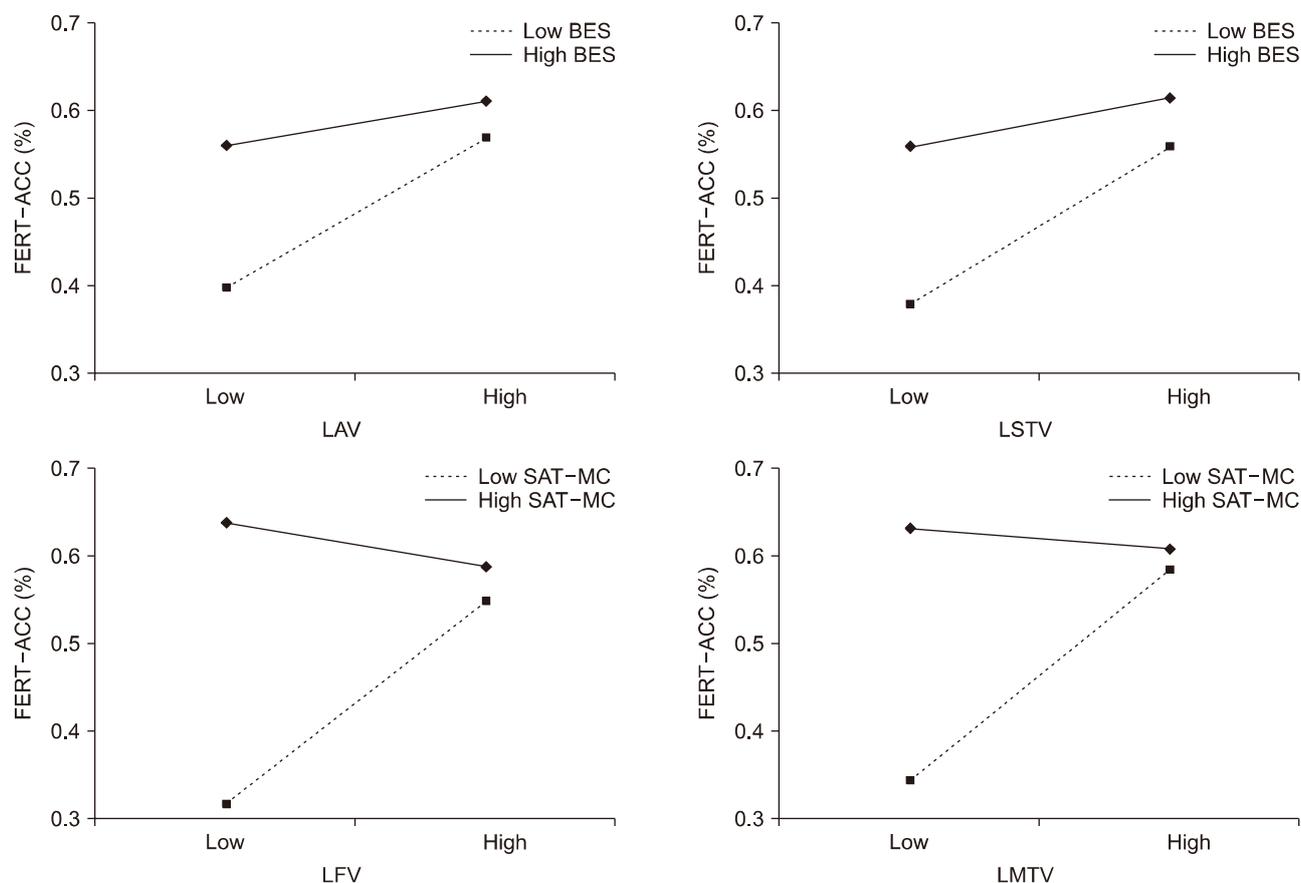
Fig. 3. Interaction effects between the temporal lobe volume and social cognitive abilities on prediction of the FERT-ACC in patients with schizophrenia.

LAV, left amygdala volume; LFV, left fusiform gyrus volume; LSTV, left superior temporal gyrus volume; LMTV, left middle temporal gyrus volume; FERT-ACC, facial expression recognition task-accuracy; BES, basic empathy scale; SAT-MC, social attribution task-multiple choice.

and RMTV. In contrast, an absence of significant results was found between the LHV, RHV, RAV and the FERT-ACC in patients with schizophrenia. See Table 2 for the complete results on the interaction between temporal lobe volume and BES. The examples of interactions were plotted in Figure 3.

Interaction between temporal lobe volume and SAT-MC

After controlling for the covariates, the LFV positively predicted the FERT-ACC (B = 0.09, t = 2.70, p = 0.011), while also the SAT-MC positively predicted the FERT-ACC (B = 0.08, t = 2.83, p = 0.008) in patients with schizophrenia. These results suggest a significant direct effect of both the LFV and SAT-MC on the FERT-ACC. In addition, the interaction between the LFV and SAT-MC had a significant effect on the FERT-ACC (B = −0.01, t =

−2.23, p = 0.033), while the R^2 was increased due to the interaction (ΔR^2 = 0.03, ΔF = 4.97, p = 0.033). Therefore, those participants who demonstrated high levels of SAT-MC performed better in the FERT-ACC, regardless of their diminished LFV.

Similarly, after controlling for the covariates, the LMTV positively predicted the FERT-ACC (B = 0.06, t = 2.83, p = 0.008), while the SAT-MC also positively predicted the FERT-ACC (B = 0.09, t = 3.32, p = 0.002) in patients with schizophrenia. These results indicated a significant direct effect of both the LMTV and SAT-MC on the FERT-ACC. Furthermore, the interaction between the LMTV and SAT-MC had a significant effect on the FERT-ACC (B = −0.01, t = −2.71, p = 0.011), while the R^2 was increased due to the interaction (ΔR^2 = 0.05, ΔF = 7.32, p = 0.011). See Figure 2 for interaction graphs of the selected results.

Significant interactions with the SAT-MC were also

Table 2. Regression analysis examining moderation effects between temporal lobe volume and social cognitive abilities on FERT-ACC in schizophrenia (n = 43)

Predictor	Left					Right				
	B	SE	t	p value	R²	B	SE	t	p value	R²
Amygdala volume										
Constant	−3.65	1.27	−2.88	0.007	0.70	−1.91	1.29	−1.48	0.148	0.61
Sex	0.11	0.05	2.26	0.031		0.068	0.05	1.29	0.207	
Age	−0.00	0.00	−1.91	0.065		−0.01	0.00	−3.21	0.003	
Education	0.01	0.01	0.76	0.456		0.01	0.00	0.87	0.392	
Pre-morbid IQ	0.01	0.00	2.83	0.008		0.01	0.00	2.58	0.015	
DOI	−0.00	0.00	−0.78	0.441		0.00	0.00	0.07	0.944	
CPZeq	−0.00	0.00	−1.81	0.080		−0.00	0.00	−1.83	0.076	
TIV	0.00	0.00	0.35	0.729		0.00	0.00	0.59	0.556	
LAV	3.83	1.34	2.85	0.008						
RAV						1.76	1.36	1.30	0.205	
BES	0.05	0.02	2.48	0.019		0.03	0.02	1.34	0.189	
LAV*BES	−0.05	0.02	−2.42	0.022	0.76					
RAV*BES						−0.03	0.00	−2.27	0.030	0.63
Fusiform gyrus volume										
Constant	−3.27	1.40	−2.33	0.026	0.77	−3.14	1.24	−2.52	0.017	0.67
Sex	0.059	0.05	1.18	0.245		0.06	0.05	1.15	0.258	
Age	−0.01	0.00	−2.87	0.007		−0.01	0.00	−3.57	0.001	
Education	0.01	0.01	1.51	0.140		0.01	0.01	1.40	0.173	
Pre-morbid IQ	0.01	0.00	2.28	0.029		0.00	0.00	2.84	0.008	
DOI	0.00	0.00	0.16	0.875		0.00	0.00	0.19	0.852	
CPZeq	−0.00	0.00	−2.13	0.041		−0.00	0.00	−2.02	0.052	
TIV	0.00	0.00	0.29	0.773		0.00	0.00	0.74	0.464	
LFV	0.37	0.17	2.19	0.036						
RFV						0.33	0.15	2.25	0.031	
BES	0.05	0.02	2.23	0.033		0.05	0.02	2.44	0.021	
LFV*BES	−0.01	0.00	−2.08	0.045	0.81					
RFV*BES						−0.01	0.00	−2.27	0.030	0.74
Superior temporal gyrus volume										
Constant	−4.25	1.46	−2.91	0.007	0.67	−3.94	1.55	−2.54	0.016	0.66
Sex	0.08	0.05	1.71	0.100		0.082	0.05	1.67	0.104	
Age	−0.01	0.00	−2.69	0.011		−0.01	0.00	−2.72	0.011	
Education	0.01	0.01	1.65	0.110		0.01	0.01	1.57	0.126	
Pre-morbid IQ	0.01	0.00	2.45	0.020		0.01	0.00	2.46	0.020	
DOI	−0.00	0.00	−0.21	0.835		−0.00	0.00	−0.40	0.694	
CPZeq	0.00	0.00	−1.52	0.138		0.00	0.00	−1.50	0.143	
TIV	0.00	0.00	−0.11	0.913		0.00	0.00	−0.23	0.819	
LSTV	0.66	0.24	2.79	0.009						
RSTV						0.58	0.23	2.50	0.018	
BES	0.06	0.02	2.80	0.009		0.05	0.02	2.42	0.021	
LSTV*BES	−0.01	0.00	−2.67	0.012	0.74					
RSTV*BES						−0.01	0.00	−2.32	0.027	0.72
Middle temporal gyrus volume										
Constant	−2.92	1.27	−2.30	0.028	0.64	−3.50	1.28	−2.74	0.010	0.65
Sex	0.07	0.05	1.46	0.153		0.08	0.05	1.53	0.136	
Age	−0.01	0.00	−2.52	0.017		−0.01	0.00	−2.74	0.010	
Education	0.01	0.01	1.39	0.173		0.01	0.01	1.27	0.215	
Pre-morbid IQ	0.01	0.00	2.56	0.015		0.01	0.00	2.76	0.010	
DOI	−0.00	0.00	−0.15	0.883		−0.00	0.00	−0.02	0.983	
CPZeq	0.00	0.00	−1.33	0.194		−0.00	0.00	−2.03	0.051	
TIV	0.00	0.00	−0.00	0.999		0.00	0.00	0.80	0.431	
LMTV	0.19	0.09	2.17	0.038						
RMTV						0.21	0.09	2.45	0.020	
BES	0.04	0.02	2.17	0.038		0.05	0.02	2.66	0.012	
LMTV*BES	−0.00	0.00	−2.02	0.052	0.69					
RMTV*BES						−0.00	0.00	−2.49	0.018	0.72

FERT-ACC, facial expression recognition task-accuracy; SE, standard error; DOI, durationof illness CPZeq, chlorpromazine equivalent; TIV, total intracranial gyrus volume; LAV, left amygdala volume; RAV, right amygdala volume; BES, basic empathy scale; LFV, left fusiform gyrus volume; RFV, right fusiform gyrus volume; LSTV, left superior temporal gyrus volume; RSTV, right superior temporal gyrus volume; LMTV, left middle temporal gyrus volume; RMTV, right middle temporal gyrus volume.

Table 3. Regression analysis examining moderation effects between temporal lobe volume and SAT-MC on FERT-ACC in schizophrenia (n = 43)

Predictor	Left					Right				
	B	SE	t	p value	R^2	B	SE	t	p value	R^2
Amygdala volume										
Constant	−1.05	0.36	−2.90	0.007	0.70	−0.27	0.31	−0.85	0.402	0.73
Sex	0.09	0.04	2.42	0.022		0.07	0.04	1.70	0.097	
Age	−0.01	0.00	−3.31	0.002		−0.01	0.00	−4.23	0.000	
Education	0.00	0.01	0.54	0.592		0.01	0.01	1.46	0.15	
Pre-morbid IQ	0.01	0.00	3.09	0.004		0.01	0.00	2.61	0.014	
DOI	−0.00	0.00	−1.26	0.215		−0.00	0.00	−0.99	0.325	
CPZeq	−0.00	0.00	−2.73	0.010		−0.00	0.00	−2.95	0.006	
TIV	0.00	0.00	0.32	0.748		0.00	0.00	0.54	0.593	
LAV	1.10	0.33	3.39	0.002						
RAV						0.13	0.19	0.69	0.497	
SAT-MC	0.09	0.03	3.62	0.001		0.04	0.02	1.71	0.097	
LAV*SAT-MC	−0.09	0.03	−3.09	0.004	0.76					
RAV*SAT-MC						−0.03	0.29	−1.07	0.294	0.74
Fusiform gyrus volume										
Constant	−0.56	0.32	−1.74	0.091	0.77	−0.33	0.31	−1.05	0.300	0.86
Sex	0.06	0.04	1.40	0.171		0.07	0.04	1.67	0.105	
Age	−0.01	0.00	−3.52	0.001		−0.01	0.00	−4.17	0.000	
Education	0.01	0.01	1.32	0.196		0.01	0.01	1.39	0.176	
Pre-morbid IQ	0.00	0.00	2.480	0.018		0.01	0.00	2.62	0.014	
DOI	−0.00	0.00	−1.15	0.260		−0.00	0.00	−0.81	0.423	
CPZeq	−0.00	0.00	−2.66	0.012		−0.00	0.00	−2.96	0.006	
TIV	−0.00	0.00	−0.70	0.489		0.00	0.00	−0.40	0.697	
LFV	0.09	0.04	2.70	0.011						
RFV						0.03	0.03	1.09	0.283	
SAT-MC	0.08	0.03	2.83	0.008		0.05	0.02	2.29	0.029	
LFV*SAT-MC	−0.01	0.00	−2.23	0.033	0.81					
RFV*SAT-MC						−0.00	0.00	−1.59	0.121	0.88
Superior temporal gyrus volume										
Constant	−0.55	0.31	−1.75	0.089	0.77	−0.70	0.32	−2.19	0.036	0.79
Sex	0.06	0.04	1.51	0.140		0.06	0.04	1.52	0.139	
Age	−0.01	0.00	−3.41	0.002		−0.01	0.00	−3.94	0.000	
Education	0.01	0.01	1.31	0.200		0.00	0.01	0.42	0.680	
Pre-morbid IQ	0.00	0.00	2.40	0.022		0.00	0.00	3.41	0.001	
DOI	−0.00	0.00	−0.62	0.541		−0.00	0.00	−1.24	0.224	
CPZeq	−0.00	0.00	−2.57	0.015		−0.00	0.00	−2.38	0.024	
TIV	−0.00	0.00	−0.60	0.550		−0.00	0.00	−0.90	0.377	
LSTV	0.12	0.05	2.43	0.021						
RSTV						0.14	0.05	3.16	0.004	
SAT-MC	0.07	0.02	3.07	0.004		0.09	0.03	3.36	0.002	
LSTV*SAT-MC	−0.01	0.00	−2.41	0.022	0.81					
RSTV*SAT-MC						−0.01	0.00	−2.76	0.010	0.84
Middle temporal gyrus volume										
Constant	−0.68	0.32	−2.12	0.042	0.78	−0.38	0.33	−1.18	0.247	0.86
Sex	0.06	0.04	1.56	0.128		0.07	0.44	1.59	0.122	
Age	−0.01	0.00	−3.42	0.002		−0.01	0.00	−3.37	0.002	
Education	0.01	0.01	0.98	0.334		0.01	0.01	1.11	0.277	
Pre-morbid IQ	0.01	0.00	2.94	0.006		0.01	0.00	2.65	0.012	
DOI	−0.00	0.00	−1.15	0.260		−0.00	0.00	−1.11	0.275	
CPZeq	−0.00	0.00	−2.40	0.002		−0.00	0.00	−2.66	0.012	
TIV	−0.00	0.00	−0.40	0.689		0.00	0.00	0.17	0.865	
LMTV	0.06	0.02	2.83	0.008						
RMTV						0.02	0.02	1.21	0.234	
SAT-MC	0.09	0.03	3.32	0.002		0.05	0.03	2.18	0.036	
LMTV*SAT-MC	−0.01	0.00	−2.71	0.011	0.83					
RMTV*SAT-MC						−0.00	0.00	−1.53	0.135	0.88

SAT-MC, social attribution task-multiple choice; FERT-ACC, facial expression recognition task-accuracy; SE, standard error; DOI, duration of illness; CPZeq, chlorpromazine equivalent; TIV, total intracranial volume; LAV, left amygdala volume; RAV, right amygdala volume; LFV, left fusiform gyrus volume; RFV, right fusiform gyrus volume; LSTV, left superior temporal gyrus volume; RSTV, right superior temporal gyrus volume; LMTV, left middle temporal gyrus volume; RMTV, right middle temporal gyrus volume.

found at regions LAV, LSTV, and RSTV. In contrast, an absence of significant moderating effects was observed in the SAT-MC between the LHV, RHV, RAV, RFV, RMTV and the FERT-ACC in patients with schizophrenia. See Table 3 for the complete results on the interaction between temporal lobe volume and SAT-MC. The examples of interactions were plotted in Figure 3.

Moreover, moderating effects of either the BES or SAT-MC in the relationship between the temporal lobe volume and the FERT-ACC were not found in healthy controls. Finally, significant results were only seen in the FERT-ACC (in patients with schizophrenia), whereas an absence of significant moderation results was observed when using the FERT-RT as a dependent variable in both patients with schizophrenia and healthy controls.

Probing an Interaction (Johnson—Neyman Analysis)

The Johnson—Neyman analysis was performed to examine the regions in which the moderating variable had significant effects. Several significant results of the Johnson—Neyman analysis are reported below.

For the interaction effect between the LAV and BES on the FERT-ACC, the conditional indirect effect was significant when the raw score of the BES was below 66.31. Conversely, the conditional indirect effect was not significant when the raw score of the BES exceeded 66.31. Similarly, for the interaction effect between the LSTV and BES on the FERT-ACC, the conditional indirect effect was significant only when the raw score of the BES was below 62.53. This implies that in the case of a high BES, the levels of the FERT-ACC remain constant and do not change with the levels of the LAV and LSTV. Overall, the moderating effect was significant only in patients with schizophrenia with high BES (above 66.31 for LAV and 62.52 for LSTV).

For the interaction between LFV and SAT-MC on the FERT-ACC, the conditional indirect effect was significant when the raw score of the SAT-MC was below 6.96. Conversely, the conditional indirect effect was not significant when the raw score of the SAT-MC exceeded 6.96. For the interaction between LMTV and SAT-MC, the conditional indirect effect was significant when the raw score of the SAT-MC was below 5.21. This implies that in the case of a high SAT-MC, the levels of the FERT-ACC remain constant and do not change with the levels of the LFV and LMTV. Overall, the moderating effect was sig-

nificant only in patients with schizophrenia with high SAT-MC (above 5.21 for LFV and 6.96 for LMTV).

DISCUSSION

In the current study, the relationship between the temporal lobe, social cognitive abilities, and facial expression recognition ability in patients with schizophrenia was investigated. Following are reported the main significant results: 1) Patients with schizophrenia showed a significantly reduced temporal lobe volume and poor performances in the FERT compared to healthy controls; 2) A significant positive correlation between the temporal lobe volume and the FERT-ACC was found only in patients with schizophrenia; 3) Diminished LAV, LFV, RFV, LSTV, RSTV, LMTV, RMTV predicted an impaired facial emotion recognition in patients with schizophrenia; 4) Both empathy and social attribution acted as moderators in the relationship between the LAV, LFV, LSTV, RSTV, and the FERT-ACC in patients with schizophrenia. Empathy alone functioned as a moderator on the relationship of the RFV and RMTV with the FERT-ACC in patients with schizophrenia. In contrast, an absence of moderation effects was observed in healthy controls.

The current study demonstrated that patients with schizophrenia have a diminished temporal lobe volume and an impaired facial affect recognition ability as opposed to healthy controls. This is in concordance with previous studies reporting a diminished temporal lobe volume in schizophrenia [8,24,27-30,53]. Furthermore, patients with schizophrenia were demonstrated to have severe deficits in their ability to make social judgements from facial expressions [6,54-56] and a dysfunctional neurophysiological processing for facial and affective facial stimuli [57,58]. Similarly, our study reported that patients with schizophrenia show a lower accuracy and slower speeds in the FERT compared to HC, indicating a difficulty in the emotional processing.

In the current study, the temporal lobe volume showed a significant positive correlation with the recognition ability of the facial emotional expression in patients with schizophrenia. Given that the temporal lobe areas represent the main areas associated with the interpretation of face emotion [12], the diminished temporal lobe volume may lead to difficulties in judging face emotion in patients with schizophrenia. For example, a smaller amygdala has

been regarded as a crucial factor explaining the poorer recognition of emotional expression [5,59,60] and the impaired facial emotional learning [61] in patients with schizophrenia. Similarly, reduced fusiform and middle temporal gray matter volumes were also associated with facial emotion recognition deficits in patients with schizophrenia [12]. However, there was no significant correlation between temporal lobe volume and facial affect recognition in healthy control. This null result might be attributed to the fact that brain volume is not a major factor influencing information processing in healthy controls [62,63].

In addition to the significant correlations between the temporal lobe volume and the FERT-ACC, the diminished LAV, LFV, RFV, LSTV, RSTV, LMTV, RMTV also predicted the impaired facial emotion recognition in patients with schizophrenia. These results are consistent with previous studies reporting an association between the temporal lobe volume and the facial emotion recognition ability in healthy subjects [15,19,23], as well as in patients with schizophrenia [12]. With regard to the amygdala, only the LAV, and not the RAV, significantly predicted the impaired recognition of facial emotional expression. This result is in line with a previous study suggesting the left amygdala to be increasingly associated with emotional processing compared to the right amygdala [64-68]. For example, imaging studies on the reactions to positive and negative non-verbal emotional stimuli identified a predominantly left lateralization of the amygdala response [65,66]. In addition, meta-analyses suggested a greater left, as opposed to the right, amygdala activation during the cognitive processing of emotional stimuli [64,68]. Finally, an absence of significant relationships between both the left and right HV and facial expression recognition in patients with schizophrenia was observed. This may result from the fact that the hippocampus is more closely related to recall of memories, rather than their recognition. In fact, previous studies described that the hippocampus is required for the formation of episodic memories and that it plays an essential role in recollection-based memory (recall), rather than in familiarity-based memory (recognition) [69-71].

Further, empathy and social attribution were found to moderate the influence of the reduced temporal lobe volume on the FERT-ACC in patients with schizophrenia. Our results suggest that, despite the reduced volume of the temporal lobe, patients with schizophrenia with a higher level of empathy and social attribution show a higher recognition ability of facial expression. Furthermore, the role of social cognitive ability in the relationship between the brain structure and facial emotion recognition was revealed. Specifically, our findings are consistent with the existing literature indicating that social cognition remediation training could affect the facial emotion recognition as well as the changes in brain activity [72,73].

In this respect, educating patients with schizophrenia with a biological deficit (e.g., reduced temporal lobe volume) on empathy and social attribution may be helpful for the improvement of face emotion recognition. In fact, several studies showed that training programs focusing on social cognition are effective in improving face emotion recognition in schizophrenia [74-79]. The results from these studies provide evidence of the beneficial effects of social cognition remediation training in schizophrenia by examining the underlying moderation mechanism. In this paper, we propose that training empathy and social attribution would be a more effective way for enhancing the ability to recognize facial emotion in patients with schizophrenia with abnormalities in their brain structures.

There are a few limitations of the present study. First, all the emotions were combined in this investigation and averaged in the FERT calculation. According to Kohler *et al.* [2], patients with schizophrenia performed worse in the recognition of fearful, disgusted, and neutral expressions than in the recognition of happy, sad, and angry expressions. Therefore, analyzing emotions separately in future studies may be meaningful. Second, the current study only theoretically examined the role of social cognitive abilities in the relationship between diminished temporal lobe volume and facial emotion recognition. The clinical implications would be greater if the real effect of social cognition remediation training on patients with schizophrenia with abnormalities in brain structure was investigated. Another limitation of this study is the small number of participants. Yet, it is compatible with group sizes from other studies of brain structure and facial emotion processing in patients [5,12,80]. Finally, this study used a cross-sectional design, and therefore only ensures a significant association among variables. We hope that the current research would pave the way for future research.

The present findings suggest that empathy and social attribution are essential abilities that buffer against the effects of a diminished temporal lobe volume on the impaired facial expression recognition in patients with schizophrenia. Social cognition remediation training programs that enhance empathy and social attribution is suggested as an effective method for the improvement of social adaptation of patients with schizophrenia with smaller temporal brain volumes.

■ **Conflicts of Interest**

No potential conflict of interest relevant to this article was reported.

■ **Author Contributions**

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