Journal of the International Neuropsychological Society (2013), **19**, 594–600.

doi:10.1017/S1355617713000143

Theory of Mind in Patients with Temporal Lobe Epilepsy

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(Received August 6, 2012; Final Revision January 15, 2013; Accepted January 15, 2013; First Published Online March 5, 2013)

Abstract

Theory of mind (ToM) is a crucial aspect of social cognition and is mediated by a complex neural network. Studies on temporal lobe epilepsy (TLE) suggest that its neuropathological involvement includes several brain regions. Some regions seem to overlap the neural network responsible for ToM, and this overlap provides an opportunity to explore ToM in TLE patients. Another concern is psychosocial problems in TLE, and the study of ToM in TLE could serve as a basis for further understanding the nature of such psychosocial disturbances. Studies on whether TLE patients evidence ToM deficit, however, are scant and controversial. Consequently, we examine whether ToM deficit is evident in TLE. Thirty-one TLE patients and 24 matched controls were recruited and completed four tasks measuring different levels of ToM: false belief, faux pas recognition, processing of implied meanings, and cartoon ToM. The patients were impaired in both basic and advanced ToM. Right TLE had a more wide-ranging picture of deficit than left TLE. ToM appears to be vulnerable to TLE, especially on the right side. Since ToM might contribute to patients' psychosocial adjustment, we thus suggest that a ToM measure be included in regular neuropsychological assessments of such patients. (*JINS*, 2013, *19*, 594–600)

Keywords: Theory of mind, Mentalizing, Social cognition, Temporal lobe epilepsy, Right hemisphere, Neurocognition

INTRODUCTION

Theory of mind (ToM), one of the crucial components of social cognition, refers to the ability to infer another's mental state, such as their beliefs, intentions, and desires (Premack & Woodruff, 1978), and thus is essential to normal psychosocial function (Baron-Cohen, 1989; Doherty, 2009). ToM is a complex psychological faculty that develops from basic to advanced levels, varying in the complexity and mental abilities required for inferring another's mental state (Happe, 1994; Stone, Baron-Cohen, Calder, Keane, & Young, 2003).

Recently, the issue of the neural substrate underlying this psychological ability has attracted great attention. Neuroimaging and lesion studies indicate a distributed neural network responsible for ToM, mainly involving the medial prefrontal cortices (PFCs), orbital PFCs, bank of the superior temporal sulcus (STS), temporoparietal junction (TPJ), bilateral temporal poles (TPs), and amygdala (Brunet, Sarfati, Hardy-Bayle, & Decety, 2000; David et al., 2008; Gallagher & Frith, 2003; Samson, Apperly, Chiavarino, & Humphreys, 2004; Saxe & Kanwisher, 2003; Stone et al., 2003; Wakusawa et al., 2007).

Temporal lobe epilepsy (TLE), a common type of focal epilepsy, is characterized by epileptogenic discharges arising from temporal regions, especially the mesial portions. However, recent studies have indicated that the neuropathological involvement of TLE is wide, including the mesial temporal areas, the STS, the orbital PFCs, and the bilateral parietal regions (Kakeda & Korogi, 2010). Based on such a neuropathological picture, it is thus necessary and plausible to explore ToM in these patients. In fact, little is known about this issue, although other cognitive function changes, such as memory impairment, executive dysfunction, and psychiatric symptoms have often been noted in these patients (Hermann & Seidenberg, 2002; McCagh, Fisk, & Baker, 2009). On the other hand, psychosocial problems occurring in TLE patients

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have been gaining considerable attention in the literature on epilepsy (Fisher et al., 2000; Jacoby, Snape, & Baker, 2005; McCagh et al., 2009). Given the role of intact ToM ability in our adaptive social functioning, studies of ToM in TLE patients will hopefully enhance our understanding of these patients' difficulties in social situations.

In the literature, however, only three studies have explored the issue of ToM in TLE, and they focused merely on specific aspects of advanced ToM in their patients (Schacher et al., 2006; Shaw et al., 2007; Giovagnoli et al., 2011). With regard to basic ToM, tasks such as false belief reasoning have not yet been explored in such patients. In addition, the results of the findings of the previous studies were inconsistent. Two studies reported that patients with TLE evidenced impaired ToM, as measured by the Faux Pas Recognition (FPR) test (Schacher et al., 2006; Giovagnoli et al., 2011), whereas Shaw and co-workers noted normal ToM ability in patients with TLE before they received anterior temporal lobectomy. Methodological issues, such as whether other domains of cognitive deficits in these patients (Hermann & Seidenberg, 2002) might account for the contradictory findings, are needed to further clarify this area. The issue of whether patients with TLE evidence changes in ToM ability also needs to be clarified.

Contemporary neuroimaging and lesion studies have shown that the right hemisphere plays a predominant role in ToM (Brunet et al., 2000; David et al., 2008; Happe, Brownell, & Winner, 1999; Shamay-Tsoory, Tomer, Berger, Goldsher, & Aharon-Peretz, 2005; Wakusawa et al., 2007). Accordingly, ToM should be more markedly impaired in patients with right TLE than in those with left TLE. In fact, Schacher and co-workers (2006) did report that their patients with right TLE performed worse than those with left TLE on the FPR test. Nevertheless, such findings conflict with the observations of two other studies (Giovagnoli et al., 2011; Shaw et al., 2007).

In the present study, we aimed to explore the following issues: (1) Are patients with TLE impaired in ToM? (2) If so, is the impairment predominantly evident in patients with right TLE?

METHODS

Participants

Thirty-one patients with TLE were recruited *via* referrals from neurologists at the Department of Neurology, National Taiwan University Hospital. TLE was diagnosed according to the International League Against Epilepsy classification (1981) ("Proposal for revised clinical and electroencephalographic classification of epileptic seizures. From the Commission on Classification and Terminology of the International League Against Epilepsy," 1981). Of these 31 TLE patients, 18 patients were recruited based on clinical diagnosis supported by electroencephalography (EEG), all of which showed recurrent, unprovoked seizures arising from the temporal lobe. EEG epileptogenicity was defined as localized interictal abnormalities, such as spikes and/or slow waves, and localized ictal EEG, such as the occurrence of a diminution in voltage or the occurrence of rhythmic theta activity (Chiu et al., 2010). Structural Magnetic Resonance Imaging (MRI) showed focal lesions compatible with the location indicated by clinical diagnosis and EEG in eight TLE patients. The remaining five TLE patients were selected according to clinical impression supported by the structural MRI evidencing a clear pathological abnormality over the medial temporal regions (e.g., medial temporal sclerosis). Patients with clear frontal pathology, as shown by the structural MRI and a history or current diagnosis of severe psychiatric disorders (e.g., major depressive disorder, psychosis), were excluded.

For further analysis, we classified the patients into right (RTLE), left (LTLE), and bilateral (BTLE) TLE groups based on the probable lesion site determined by the EEG and/or MRI. MRI was used to determine the lesion site if conflict between the EEG and MRI was found. On this basis, 11 TLE patients were classified as LTLE, 13 as RTLE, and 7 as BTLE. Patients classified into each TLE subgroup had consistent lateralization in EEG and MRI, except for two of the BTLE patients. These two patients had bilateral medial temporal lobe pathology on the structural MRI, whereas their EEG epileptiform discharges were observed solely on the left medial temporal regions at the time of recruitment. There were no significant differences in age at onset, disease duration, seizure frequency, and number of antiepileptic drugs (AED) used among the three TLE groups (all $p > .1$; see Table 1).

Twenty-four normal control participants (NCs) were selected and underwent the same procedure of assessment as the patients. Participants were excluded if there was a history of traumatic brain injury, psychiatric disorder/symptoms, or any otherwise severe central nervous system or systemic disease relevant to cognitive impairment.

The participants were all right-handed, and there were no significant group differences among the four study groups (LTLE, RTLE, BTLE, and NCs) in age, gender, educational level, and IQ (Chen, Hua, Zhu, & Chen, 2008) (all $p > .05$; see Table 1). The study was approved by the Ethical Research Committee of National Taiwan University Hospital, and all participants signed informed consent forms. We acknowledged that all human data included in the present study were obtained in compliance with the Helsinki Declaration.

ToM tasks

Four standardized ToM tasks in Chinese revised by Yeh, Hua, and Liu (2009) were used to measure ToM ability, specifically the False Belief test (FB), Faux Pas Recognition test (FPR), Implication Stories test (IS), and Cartoon ToM tasks (CTOM). The psychometric properties of these tasks are well established, with acceptable test–retest reliability (correlation coefficients range from 0.86 to 0.92), internal consistency (alpha coefficients range from 0.50 to 0.76), and criterion validity (Yeh et al., 2009).

The FB test comprises 6 stories, based on the paradigm used in the studies by Perner and Wimmer (1985) and

Table 1. Characteristics of the demographic and clinical variables

	TLE ($n = 31$) *M* (*SD*)			NCs ($n = 24$) *M* (*SD*)	
	LTLE	RTLE	BTLE		*p* value
Male/female	5/6	8/5	5/2	13/11	.719[b]
Age, yr	37.55 (14.70)	43.31 (11.83)	46.14 (13.07)	37.75 (16.77)	.453[a]
Education, yr	14.36 (2.29)	14.15 (3.11)	13.29 (2.98)	14.29 (2.97)	.862[a]
IQ	99.00 (13.19)	100.31 (14.24)	98.00 (15.83)	108.62 (10.31)	.067[a]
Age at onset, yr	24.45 (12.27)	24.00 (16.71)	25.29 (9.69)	NA	.981[a]
Disease duration, yr	13.27 (6.69)	19.38 (14.04)	25.29 (17.19)	NA	.707[b]
Seizure frequency	1.15 (1.21)	1.30 (1.25)	1.50 (1.22)	NA	.848[a]
AED number	1.69 (0.63)	2.00 (1.00)	2.57 (1.90)	NA	.676[b]

Note. TLE = temporal lobe epilepsy; LTLE = left temporal lobe epilepsy; RTLE = right temporal lobe epilepsy; BTLE = bilateral temporal lobe epilepsy; NCs = normal control; M = mean; SD = standard deviation; NA = not applicable; yr = years; IQ = intelligence quotient; seizure frequency = number of seizure attacks in one month prior to neuropsychological assessment; AED number = number of antiepileptic drugs used.
[a]Analysis of variance with Scheffe *post hoc* comparison.
[b]Kruskal-Wallis test.

Wimmer and Perner (1983). Participants are instructed to read stories. Each story is followed by a question to assess whether participants can recognize that the characters have beliefs or knowledge about the world that are different from their own perspectives. For each story with a false belief, 1 point is given for each correct answer.

The FPR test consists of 10 stories. Participants read stories, all of which describe a situation where a speaker says something that is socially inappropriate (Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999). At the end of each story, three questions are asked to evaluate whether participants could recognize a speaker saying something inappropriate, and that these remarks could cause negative consequences for the listener that the speaker does not intend. The first question concerns whether anyone had said something s/he should not have said. The second question concerns who has made the (faux pas) remark. The last question concerns how the listener feels after hearing the faux pas remark. For each story, 1 point is given for each correct answer. The maximum score on each story is, therefore, 3.

The IS test is composed of five short stories with implied meaning, such as a joke, white lie, or pretend situation (Happe, 1994; Happe, Malhi, & Checkley, 2001). Participants read each story, and then they answer two questions to evaluate their ability to understand indirect speech. The first question concerns an understanding of the implied meaning in dialogues, and the second question requires a mentalistic attribution to the character's mental state. For each short story, 1 point is given for each correct answer, so the maximum score is 2 points.

The CTOM tasks include 10 funny cartoon pictures. Each picture assesses participants' abilities to infer the characters' mental states, specifically their beliefs, intentions, or motives (Bibby & McDonald, 2005; Brunet et al., 2000; Gallagher et al., 2000; Happe, et al., 2001). Each picture is shown to participants and is followed by two types of questions. The first question is open-ended (implicit form), asking participants why the picture is funny; the second one is presented in a more explicit manner (explicit form) (e.g., what the motives of the character in each cartoon picture are). For each cartoon picture, participants' responses are recorded and scored on a scoring system of 2 points for correct answers, 1 point for answers mainly based on physical inference, rather than mentalistic attribution, and 0 points for incorrect answers.

Based on the demands of mental abilities necessary for performing ToM tasks, we classified the tests into basic and advanced levels. The FB test is regarded as a basic ToM task, since it has long been the most common way that basic ToM is assessed in the ToM literature and even serves as a reliable indicator that an individual has acquired basic ToM (Doherty, 2009; Perner & Wimmer, 1985; Wellman, 2002; Wimmer & Perner, 1983). In contrast, the FPR and IS tests, as well as the CTOM tasks, were used to assess advanced ToM, as these tasks involve more complex aspects of social interaction and necessitate higher levels of ToM, such as detection and comprehension of white lies, jokes, irony, and faux pas.

Tests of Cognitive Functions

The Verbal Comprehension Index (VCI), obtained by Vocabulary, Similarities, and Information subtests of the Chinese version of the WAIS–III (Chen & Chen, 2002), was used to measure verbal function. The Logical Memory (LM) subtest of the WMS-III-Taiwan version was used to measure verbal episodic memory function (Hua et al., 2005). The Modified Card Sorting Test (MCST) (Nelson, 1976) was used to measure executive function.

Statistical Analysis

The TLE and NCs group were compared by *t* test for parametric variables and χ^2 test for nonparametric variables. Analysis of variance (ANOVA) with Scheff *post hoc* pairwise comparison was performed to examine group differences.

https://doi.org/10.1017/S1355617713000143 Published online by Cambridge University Press

However, if the data violated the assumption of homogeneity of variance, the Kruskal-Wallis test with Mann-Whitney pairwise comparisons was used. Effect size was calculated to measure the size differences between the TLE and NCs groups, as well as among the four study groups on the ToM tasks. For nonparametric variables, the approach to estimating effect size was suggested by Field (Field, 2010). In addition, statistical power was analyzed for parametric variables. To examine relationships between variables, Pearson's correlation analysis was performed. Unless otherwise specified, the statistical significance was set at $p < .05$. All statistical results were calculated using SPSS 13.0 for Windows (SPSS Inc., Chicago, IL).

RESULTS

ToM ability

The t test showed significant group differences between the TLE and NC groups on the FB ($t = -3.107$; $df = 53$; $p = .003$; $\text{eta}^2 = 0.13$; power = 0.80), FPR ($t = -6.752$; $df = 53$; $p = .000$, $\text{eta}^2 = 0.42$; power = 1.0), IS ($t = -3.576$; $df = 53$; $p = .001$; $\text{eta}^2 = 0.19$; power = 0.94), and CTOM scores (Implicit form: $t = -5.584$; $df = 53$; $p = .000$; $\text{eta}^2 = 0.37$; power = 1.0; Explicit form: $t = -3.832$; $df = 53$; $p = .000$, $\text{eta}^2 = 0.22$; power = 0.96). Patients with TLE performed worse than those in the NC group on all four ToM tasks (all $p < .01$; see Table 2).

The performances of the four study groups on the ToM tasks were as follows (see Table 2): (1) On the FB test, the Kruskal-Wallis test showed a significant group difference ($\chi^2 = 12.97$; $df = 3$; $p = .005$; $\text{eta}^2 = 0.24$); Mann-Whitney pairwise comparison showed that the RTLE ($p < .01$) and the BTLE ($p < .05$) groups performed worse than NCs. (2) On the FPR test, the Kruskal-Wallis test showed a significant group difference ($\chi^2 = 25.94$; $df = 3$; $p = .000$; $\text{eta}^2 = 0.48$); Mann-Whitney pairwise comparison revealed that all three TLE groups [RTLE, $p < .001$; LTLE, $p < .01$; BTLE $p < .01$] performed worse than NCs. (3) On the IS test, ANOVA showed significant group differences [$F = 5.375$; $df = 3$, 51, $p = .003$, $\text{eta}^2 = 0.24$; power = 0.916]; Scheffe *post hoc* pairwise comparison showed that the RTLE group ($p < .01$) performed worse than NCs. (4) On the cartoon ToM task, ANOVA showed significant group differences in the implicit [$F = 11.42$; $df = 3$, 51, $p = .000$; $\text{eta}^2 = 0.40$; power = 0.999] and explicit forms of questions [$F = 6.274$; $df = 3$, 51, $p = .003$; $\text{eta}^2 = 0.24$; power = 0.919]; Scheffe *post hoc* comparison revealed that the RTLE ($p < .001$) and LTLE ($p < .01$) groups performed worse than NCs in the implicit form whereas only the RTLE group ($p < .01$) performed worse than NCs in the explicit form.

Pearson correlation analysis was conducted to examine relationships between seizure-related variables and ToM. The results did not show significant correlation between performance on ToM tasks and seizure-related variables, including age at seizure onset, disease duration, seizure frequency, and number of AED used (all $p > .05$).

Cognitive Function

Except for the tests of episodic memory function, there were no significant group differences on tests of other domains of cognitive function (see Table 3). Correlation analysis was performed to rule out the influence of poor verbal episodic memory performance on ToM tasks, and no significant correlations were found between these subtests of the WMS-III and ToM tasks (all $p > .05$). Moreover, we minimized the possible memory load, such as presenting all the ToM materials to participants during the administration, and used the built-in memory control questions in the ToM tasks (Yeh et al., 2009).

DISCUSSION

The aim of the present study was to examine ToM in patients with TLE. We observed that patients with TLE did perform significantly worse than their normal counterparts, as reflected by deficits in false belief reasoning, faux pas recognition, the ability to comprehend implied meanings in the verbal stories, and the ability to infer other's mental states *via* visual material. Moreover, we found that their range of impaired ToM seemed to be wider; that is, the patients

Table 2. Performance on ToM function in patients with TLE and NCs

	TLE *M* (*SD*)	LTLE *M* (*SD*)	RTLE *M* (*SD*)	BTLE *M* (*SD*)	NCs *M* (*SD*)	The potential range for scores
FB test	4.45** (1.69)	5.36 (1.21)	4.15†† (1.68)	3.57† (1.90)	5.50 (0.72)	0-6
FPR test	18.65*** (4.69)	20.45†† (4.89)	17.31††† (3.95)	18.29†† (5.41)	25.04 (2.12)	0-30
IS test	7.87* (1.23)	8.27 (1.01)	7.46## (1.39)	8.00 (1.15)	9.00 (1.06)	0-10
CTOM tasks						
Implicit form	10.03*** (2.54)	10.36## (2.80)	9.23### (2.20)	11.00 (2.58)	13.79 (2.39)	0-20
Explicit form	11.58*** (2.80)	12.00 (2.41)	10.84## (2.79)	12.29 (3.45)	14.38 (2.52)	0-20

FB = False Belief test; FPR = Faux Pas Recognition test; IS = Implication Stories test; CTOM = Cartoon ToM tasks.
*$P < 0.05$, **$p < 0.01$, ***$p < 0.001$, independent-samples t test.
†$P < 0.05$, ††$p < 0.01$, †††$p < 0.001$, Kruskal-Wallis Test with Mann-Whitney pairwise comparison.
#$P < 0.05$, ##$p < 0.01$, ###$p < 0.001$, ANOVA with Scheffe *post hoc* comparison.

Table 3. Performance on cognitive functions in patients with TLE and NCs

	LTLE M (SD)	RTLE M (SD)	BTLE M (SD)	NCs M (SD)	F ($df = 3, 51$)	p value
Verbal function						
VCI	100.27 (17.51)	104.23 (14.11)	104.86 (15.69)	111.54 (10.87)	1.740	.171
Memory function						
LM-I (r.s.)	36.00 (16.07)	29.08$^{##}$ (13.68)	32.43 (16.72)	46.88 (11.68)	5.575	.002
LM-II (r.s.)	20.55$^{#}$ (10.51)	17.62$^{##}$ (10.43)	18.71$^{#}$ (10.58)	31.83 (9.56)	7.587	.000
Executive function						
MCST-c	5.36 (2.25)	5.54 (1.81)	5.71 (1.38)	6.29 (1.23)	1.083	.365
MCST-p	1.64 (2.06)	3.69 (3.57)	3.57 (2.51)	1.50 (2.41)	2.627	.060

r.s. = raw score; LM-I = immediate recall of the Logical Memory; LM-II = delayed recall of the Logical Memory; MCST-C and MCST-P indicate the achieved categories and perseverative errors in the Modified Card Sorting Test, respectively.
$^{#}P < .05$, $^{##}p < .01$, $^{###}p < .001$, analysis of variance with Scheffe *post hoc* comparison.

recruited in this study displayed impairments in both basic and advanced ToM, as compared to previous studies (Giovagnoli et al., 2011; Schacher et al., 2006), in which they merely examined and reported parts of the impaired advanced ToM in their patients. In addition, the present study showed that poor performance on ToM tasks in the TLE patients was not accounted for by either seizure-related factors or impairments in verbal, episodic memory, or executive function. Giovagnoli and co-workers also indicated that ToM impairment could be differentiated from other domains of cognitive impairments in TLE patients. However, due to the small sample size in the patient group, no distinctive profile of cognitive impairments could be specified.

Several factors, such as the social stigma of epilepsy, patients' sense of uncertainty about when or where seizures might occur, and a lack of social support (Fisher et al., 2000; Jacoby et al., 2005), contribute to their psychosocial problems. Recently, Doherty (2009) indicated that ToM plays an important role in our normal psychosocial function. Accordingly, it appears that our findings might have a significant clinical implication for the psychosocial maladjustment in patients with TLE (McCagh et al., 2009). In fact, in the available clinical interviews, some of the TLE patients with impaired ToM did report problems in their social functioning, including difficulties in interpersonal relationships and unemployment, though the issue of ToM and psychosocial function in patients with TLE is beyond the scope of this study. Further investigation on this issue is merited. Moreover, psychiatric comorbidity is not uncommon among patients with epilepsy (McCagh et al., 2009), though the present study excluded TLE patients with severe psychiatric disorders. Future work will hopefully clarify the relationship between ToM and psychiatric disturbances in TLE.

The present results, however, disagree with Shaw and co-workers (2007), who found relatively preserved ToM in patients with TLE. Although the reason for such an inconsistency remains unknown, we suggest that this might be partially due to two methodological issues. The first aspect to be discussed is the issue of sample size. Combining the results of the present study and two previous investigations (Giovagnoli et al., 2011; Schacher et al., 2006), in all of which TLE patients were noted to be significantly less accurate on ToM tasks than their normal counterparts, relatively larger sample sizes were used. In contrast, in Shaw and co-workers' study, only 19 patients and 19 normal controls were recruited. One possible explanation is that such a small number of participants could not demonstrate significant differences. The second aspect is the issue of patient recruitment. We recruited TLE patients with mainly temporal lobe lesions, and some cases involved additional parietal lesions, as evidenced by EEG or positron emission tomography (PET). These brain regions are suggested to be part of the neural network responsible for ToM (David et al., 2008; Samson et al., 2004; Saxe & Kanwisher, 2003; Stone et al., 2003; Wakusawa et al., 2007). In contrast, in the study by Shaw and co-workers, only patients with anterior temporal lesions were recruited, and the degree of brain lesion was variable, from no neuronal loss to complete lesions in the anterior temporal regions. Such patient selection with lesions involving part of the neural substrate possibly nonessential to ToM, and consequently might result in insignificant changes in ToM (Bird, Castelli, Malik, Frith, & Husain, 2004).

With regard to patients' patterns of ToM deficit, the RTLE patients included in the current study evidenced deficits in both basic and advanced ToM, as measured by the FB, FPR, and IS tests and the CTOM tasks. In contrast, the LTLE patients were found to be unimpaired on the FB and IS tests, and on the explicit form of the CTOM task, suggesting that basic ToM and several aspects of advanced ToM, indicated by the ability to recognize implied meanings in utterances and to process ToM under a more explicit context, were relatively preserved in this group. The present study is somewhat limited by the small numbers of patients in each TLE subgroup; it is thus possible that a larger sample would have revealed significantly more impairment of ToM in RTLE patients than in LTLE patients. However, our data did document a more pervasive pattern of ToM deficit in RTLE patients, as reflected by deficits in basic ToM and in all aspects of the advanced ToM examined in the present study. The present finding that RTLE patients show a more prominent deficit of ToM than their LTLE correspondents was somewhat consistent with that of Schacher and co-workers' study (2006), in which their TLE patients exhibited impaired faux pas recognition in comparison with normal controls, and patients with RTLE performed markedly worse on the FPR test than did those with LTLE. From this study's results and those of Schacher and co-workers, it appears that ToM ability might be lateralized to our right hemisphere. This is also in line with the findings of recent neuroimaging studies, which indicate increased activation of the right temporal regions during ToM reasoning tasks (Brunet et al., 2000; David et al., 2008; Wakusawa et al., 2007). In addition, the current finding is basically in line with the position, also derived from brain-damaged patients, that ToM may be predominantly associated with the right hemisphere (Happe et al., 1999; Shamay-Tsoory et al., 2005; Siegal, Carrington, & Radel, 1996). Studies (Happe et al., 1999; Siegal et al., 1996) have suggested that our right hemisphere not only plays a role in ToM, but is also involved in using language in context (pragmatics), such as comprehension of the implicit and nonliteral aspects of language, and that such a pragmatic ability is required for inferring another's mental state. In fact, we did find that the RTLE patients were markedly impaired in ToM and also had difficulty in understanding nonliteral meanings expressed by the protagonists, as reflected by the poorer performance on the test of IS, even though their verbal functioning was comparable to that of their LTLE counterparts.

With regard to the issue of cerebral lateralization of ToM ability, however, inconsistent findings that patients with left TPJ lesions showed impairment in false belief reasoning (Samson et al., 2004) and that LTLE patients showed relatively less accuracy in performance on the test of FPR (Giovagnoli et al., 2011), have also been reported. Hence, whether there exists an effect of lateralization on ToM in patients with TLE, and in turn whether the result has clinical implications, are questions that necessitate further investigation on a large scale.

The BTLE patients, despite having right-sided lesions as well, did not show a pervasive pattern of ToM deficit as found in the RTLE group. The reason for such a paradoxical result remains unclear; however, these patients did document impairments in basic ToM and one aspect of the advanced one, as reflected by impaired abilities to reason about the false belief and to make judgment of faux pas in real-life social situations. It thus appears that BTLE patients may still have difficulties in attributing the mental states of others to some extent. Nevertheless, due to sample size constraint and insufficient data to support the bilateral epileptogenic foci in two of the BTLE patients, a caveat should be taken with care to interpret these preliminary findings and future work should address this issue on a large scale.

In summary, the present study documents ToM impairment in patients with TLE, and especially in RTLE patients, who evidenced deficits in both basic and advanced ToM. Since ToM is one of the core components of social cognitive function, impairment in this psychological ability might affect a normal individual's social and occupational adjustment. We thus suggest that measurement of ToM ability be included in the regular neuropsychological assessment of patients with TLE.

ACKNOWLEDGMENTS

We dedicate the article to the memory of Chih-Chuan Chen and acknowledge him for the help of recruiting participants and data acquisition. Regarding the research funding, the study was supported by NSC95-2413- H-002-018-MY3 from the National Science Council, Taipei, Taiwan. All authors declare no conflicts of interest regarding the work presented in this study.

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