

Brief Communication

An Indian, Comic-based, Online-EEG Paradigm for Theory of Mind: An Exploratory, Pilot Study on Schizophrenia Patients

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ABSTRACT

Background: False-belief (FB) tasks are used to assess the theory of mind (ToM) functioning, which has been found to be impaired in schizophrenia. FB task stimuli used so far in neuroimaging studies in schizophrenia have been sentence-based ones. We aimed to validate an Indian, colour-comic based FB task by using an online-electroencephalogram (EEG) paradigm discriminating schizophrenia patients and healthy controls. **Materials and Methods:** Fifteen schizophrenia patients and 15 healthy controls performed online FB task during a 256-channel-EEG recording. 'Content' and 'known-groups' validity were examined using offline behavioural measures. Evoked gamma spectral-power in four regions of interest (ROIs) was compared between groups. Social functioning was also assessed. **Results:** Strength of classifying the groups was significant for both the number of correct responses and the reaction-times on the FB tasks. Social functioning was found to be poorer in patients. On the comparative analysis of evoked gamma spectral-power in the ROIs, very small effect size and observed power were noted. **Conclusion:** 'Content' and 'known-groups' validity of the culturally undermined comic-based FB task are good. Our findings reiterate that ToM functioning is impaired in schizophrenia. Our results were inconclusive in inferring whether evoked gamma spectral-power could be used as a neural validator for poor ToM functioning.

Key words: *Electroencephalogram, evoked power, false-belief, schizophrenia, theory of mind*

INTRODUCTION


Theory of mind (ToM) functioning, a principle domain of social cognition, has been defined as the ability to infer intentions, dispositions and beliefs of others.^[1] The 'False-belief (FB)' task (also called

'unexpected transfer task'; classical one being the 'Sally-Anne' task), is most commonly used to test ToM functioning.^[2,3] Notably, it has been consistently found to be impaired in patients with schizophrenia.^[2-4]

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Pertinently, studies have attempted eliciting neural correlates of ToM functioning in schizophrenia. While the majority of the neuroimaging studies testing this task in schizophrenia have been functional magnetic resonance imaging (fMRI) studies;^[5,6] they have employed sentence-based FB tasks. As a methodological improvement, we primarily aimed to validate an Indian, colour-comic based FB task stimuli, rather than sentence-based ones.

Research suggests that neural circuits in schizophrenia patients are unable to enhance the gamma response required during higher cognitive load and hence show lower gamma measures, compared to healthy controls, during cognitive task performance.^[7] Hence, activity in the electroencephalogram (EEG) gamma frequency range might be better suited to study activation from specific brain regions in response to ToM tasks that require higher-order cognitive processing.^[8] With the hypothesis that schizophrenia patients have greater ToM deficits and reduced evoked gamma oscillatory response to ToM stimuli, a surrogate objective of our study was to compare behavioural and EEG-evoked gamma oscillatory response to FB stimuli (Indian, comic-based), between schizophrenia patients and healthy controls.

MATERIALS AND METHODS

This exploratory pilot study was approved by the Institutes Ethics Committee. Written informed consent was taken from all the participants (and their primary caretakers in case of patients) before enrolling them for the study.

Participants

Using purposive sampling, 15 right-handed male patients, in the age group of 18–50 years, with the first episode of schizophrenia (illness duration <2 years and no past symptomatic remission) as per the International Classification of Disease, 10th revision, Diagnostic Criteria for Research (ICD-10 DCR), were recruited. They also met clinical remission criteria^[9] on the Positive and Negative Syndrome Scale (PANSS)^[10] items currently. These patients were on a stable dose of antipsychotic medication; antipsychotic equivalents were calculated according to the minimum effective dose method.^[11] The healthy control group included 15 right-handed age, gender and handedness-matched subjects with no past or family history of psychiatric illness. Healthy controls were screened with the General Health Questionnaire (GHQ)-12;^[12] only those with scores <3 were included. Additionally, all the participants required a minimum of 8 years of formal education, normal vision and hearing and sufficient mastery in Hindi to undergo the task. Exclusion criteria

were a history of neurological illness, significant head injury, substance dependence (excluding nicotine and caffeine), other psychiatric disorders, disruptive behaviour (suicidal or homicidal) that warranted immediate intervention or a history of electroconvulsive therapy within previous 6 months.

Assessments

Socio-demographic and clinical data were collected from all the participants. Handedness was assessed using the Sidedness Bias Schedule (SBS) – Hindi version.^[13] Social functioning was assessed using the Social Occupational Functioning Scale (SOFS).^[14]

False-belief task

The stimuli used for this study were prepared based on comic characters and situations. The comics were created using characters and situations available on www.pixton.com (free version). Each of the characters was customised such that they represent characters in the Indian context. The language used in these stimuli was exclusively Hindi.

Content validity

Eleven consultants/senior residents/clinical and child psychologists/research officers from the Departments of Psychiatry, Clinical Psychology and Psychiatric Social Work (having experience of working on EEG/event-related potential (ERP); mean experience in mental health = 9.36 years) rated 15 stories (sets of stimuli) on three questions – whether the stimulus (1) tested the construct of FB as in the original, (2) depicts ‘Indianness’ of characters and situations and (3) is ideal for ERP experiments – on a Likert scale (1 = strongly disagree; 5 = strongly agree). Stories that received a score of <4 (agree) from >25% of the experts were excluded.

The FB task was presented in a set of 15 stories depicting two characters interacting with each other in a specific social situation. The stories were adopted from the ‘false-belief’ stories from the SOCRATIS, a standardised Indian battery for the assessment of social cognition.^[3] There was no repetition of characters in any of the stories. Each story consisted of four separate stimuli [Figure 1]:

- The 1st stimulus consisted of two scenes: The first scene displayed two characters engaged in a situation. In scene 2, one of the characters was shown placing an object (specific to each story) in a specific location. The 2nd stimulus had two scenes: In scene 1, the character who places the object was shown leaving the situation. Scene two shows only the second character. Here, character 2 was shown relocating the object to a new location, away from the first location. In the first three scenes,

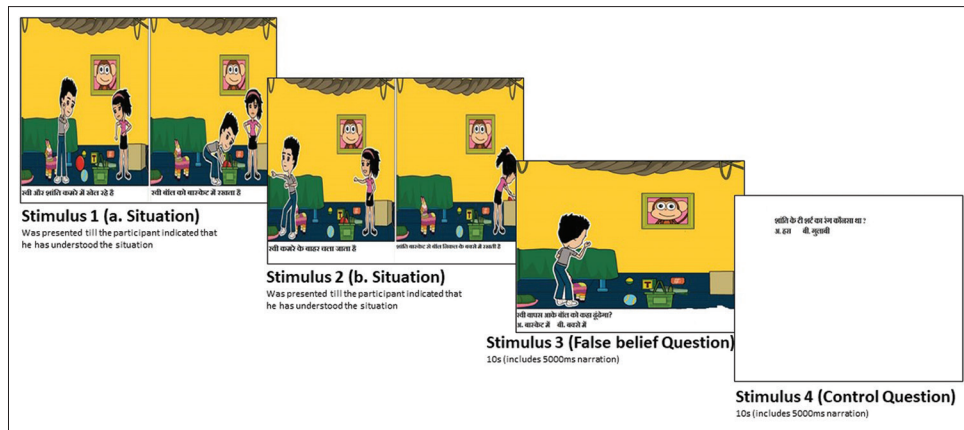


Figure 1: Showing the sample stimuli used to test false-belief attribution

the second character passively observes the first character and his/her activity.

- The 3rd stimulus has the first character entering the situation. The scene is presented with a question, asking where will the first character look for the object, with two options, namely the first and the second location
- The 4th stimulus shows a question asking about any specific detail from the first stimulus with two options, for example: what was the colour of the first character’s t-shirt?

Each of the visual stimuli was simultaneously presented with pre-recorded audio narration.

The first two stimuli were presented until the subject indicated that he has fully understood the situation in the story. The 3rd and 4th stimuli were presented for 10 s duration each. During this time period, the subject had to press either ‘1’ or ‘2’ from the options presented, immediately *after* the completion of audio narration, which was for a duration of 5000 ms.

The 3rd and 4th stimuli were repeated twice randomly. Fifteen such sets of stories followed one another. Hence, response seeking stimuli were 60 in total –30 for ToM responses and 30 for control responses. The question in the 3rd stimulus was framed to elicit a ToM response, and the question in the 4th stimulus was framed to elicit a visual memory response.

EEG recording

All participants underwent an EEG recording. The recording was carried out at the institute’s Centre for Cognitive Neurosciences.

The FB task was presented online during the EEG recording, using E-prime by net communication (E-prime extension for net station 2.0, psychology software tools, E-prime Inc. Denver, USA). Data were subjected

to various stages of analysis using the Net Station 5.2 Tools software (Electrical Geodesics, Inc., Eugene, Oregon, USA). An 1100 ms epoch post completion of the auditory narration (*viz.* 4900–6000 ms) was determined to be segmented. Artefact-free segments generated during the FB task were averaged into ToM and visual memory files. For details of the recording and other stages of EEG analysis, please refer Tikka *et al.*^[15]

Four regions of interest (ROIs) were chosen based on the existing neuroimaging evidence.^[16] Refer to Figure 2 for the ROIs and channels chosen for each of them; these were selected as per estimated anatomical cortical projections.^[17] Data pruning was done offline using the MATLAB 8 (The Math Works, Inc., Massachusetts, USA). Spectral-power, expressed in μV , (Fast Fourier Transform routine, Hanning window) was calculated using the Welch’s averaged periodogram method. Frequencies between 30 and 50 Hz were analysed with a resolution of 0.25 Hz.

Statistical analysis

Group differences were computed using independent samples *t*-test and Fisher exact test. A separate analysis of covariance (ANCOVA) was used to examine the confound of visual memory (responses on control stimuli) on ToM measures. For examining ‘known-groups validity,’ we conducted discriminant function analysis.

The normalisation of spectral-power values was achieved by log transformation. A multivariate $2 \times 4 \times 2$ analysis of variance was conducted for the spectral-power data: 2 task levels (FB vs visual memory) \times 4 regions \times 2 groups. In the patient group, Pearson correlation analyses were sought between various variables. The level of significance was kept at 0.05. Statistical analysis was done using the Statistical Package for Social Sciences (SPSS) Statistics for Windows, Version 21.0 (IBM Corp., Armonk, NY, USA).

RESULTS

All participants were men. Age of the patient group (30.40 ± 6.65) was comparable ($t = 1.11; P = 0.28$) to that of the control group (28.13 ± 4.26). Both the groups were also comparable on marital status ($\chi^2 = 1.68; P = 0.39$), occupation ($\chi^2 = 1.22; P = 0.46$) and habitat ($\chi^2 = 2.22; P = 0.26$). Income of the patient group (Rs. 7133.33 ± 1684.67) was found to be significantly lower ($t = 2.41; P < 0.05$) than that of the control group (Rs. 10266.67 ± 4742.92).

Age of onset and duration of illness for the schizophrenia group was 28.13 ± 5.65 years and 19.07 ± 5.92 months, respectively. Mean antipsychotic dose equivalent was 1.19 ± 0.73. The scores on the PANSS were: positive – 10.07 ± 2.28; negative – 11.00 ± 1.60; general psychopathology – 18.6 ± 1.81; and total – 39.67 ± 3.06. Social functioning in the patient group (24.40 ± 2.75) was significantly ($t = 14.67; P < 0.001$) poorer than the control group (14.00 ± 0.00).

None of the 15 stories received a score of <4 (agree) from >25% of experts. Average scores on content validity, ‘Indianness,’ and ERP suitability for the 15 FB stories used were 4.73, 4.64 and 4.45, respectively.

Schizophrenia patients showed a significantly lower number of correct responses and longer reaction times on both the tasks [Table 1]. ANCOVA, using the percentage of correct responses and reaction times for visual memory as covariates, persisted to show the significant differences ($P < 0.05$). With respect to ‘known groups validity,’ i.e., in discriminating schizophrenia patients, the number of correct responses showed a sensitivity and specificity of 78.56% and 92.27%, respectively; and reaction times showed a sensitivity and specificity of 74.98% and 82.35%, respectively. Number of correct responses and reaction times were able to correctly classify 76.7% (Wilks’ $\lambda = 0.64; \chi^2 = 12.47; P < 0.001$) and 86.7% (Wilks’ $\lambda = 0.43; \chi^2 = 23.25; P < 0.001$) of originally classified subjects, respectively.

Multivariate analysis for gamma spectral-power showed that the interaction of task level × regions × groups was not statistically significant (Greenhouse-Geisser $F = 0.30; P = 0.74$; partial $\eta^2 = 0.01$; observed power = 0.09). Correlation analysis showed that reaction times had a significant negative relationship with SOFS scores ($r = -0.545; P < 0.05$); however, when the duration of illness, the age of onset, PANSS total scores and antipsychotic dose equivalents were

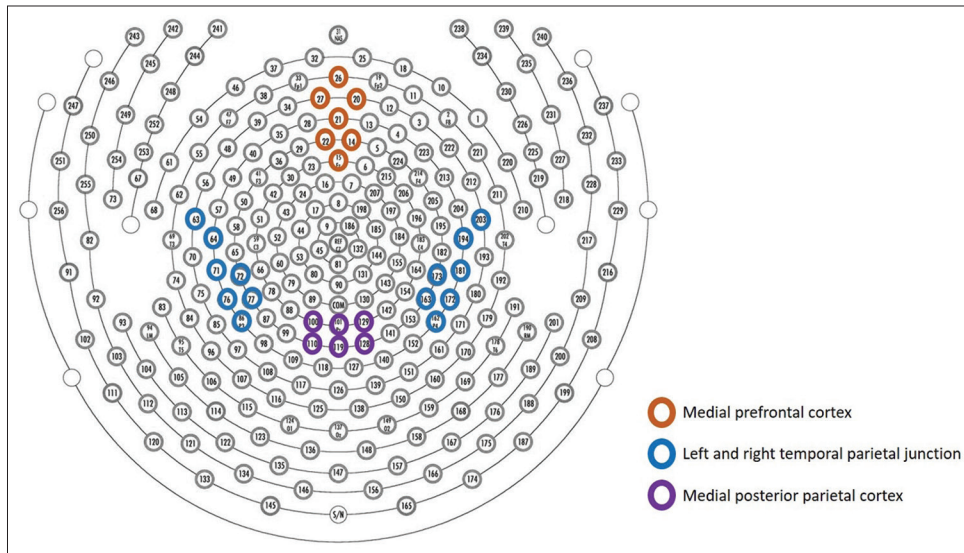


Figure 2: Showing the arrangement of 256 channels on the sensor net; coloured circles denote the channels selected for each region of interest

Table 1: Comparison of various offline measures during the false-belief task

Variables	Schizophrenia (n=15) (mean±SD)	Healthy controls (n=15) (mean±SD)	t (df=28)	P
Offline measures (response rates and reaction times)				
% of correct responses				
False-belief	55.78±21.17	85.11±18.89	4.00	<0.001
False-belief-control (visual memory)	62.22±12.45	79.11±6.36	4.67	<0.001
Reaction time (ms)				
False-belief	1724.69±505.84	743.68±363.24	6.11	<0.001
False-belief-control (visual memory)	2011.49±433.68	861.17±310.39	8.35	<0.001

added as covariates in a partial correlation analysis, this significance was lost ($r = -0.471$; $P = 0.14$). No other statistically significant relations were found.

DISCUSSION

Greater incorrect responses and longer reaction times on the FB task in the schizophrenia group reflect poorer ToM functioning. Our study also showed that this poorer ToM functioning persisted despite controlling for effects of poor visual memory. As the patients in the current study met the criteria for clinical remission, we hereby infer that ToM deficits are fairly present despite improvement in clinical symptoms. Our findings second the recommendation that ToM deficits are indeed trait markers.^[18] While the majority of the studies demonstrate significantly greater inaccuracies and longer reaction times,^[18] some studies report measures comparable with those of healthy controls.^[7] Our study provides evidence for good content and known groups validity for the paradigm used. The psychometric properties are similar to those of other standardised FB tasks for use in India.^[3] Moreover, the tasks were culture-specific. In fact, to the best of our knowledge, this is the first study examining EEG markers for ToM functioning in schizophrenia using comic (or cartoon)-based stimuli, though such studies have been undertaken in a healthy population.^[19]

However, concurrent validity and internal consistency of the paradigm are yet to be explored; this is a prominent limitation of our study. Although we consider the use of colour comics with simultaneous voice-over, rather than the use of a 'sentence based' ones, as a methodological advancement in the tasks, clarification by comparing each of their criterion validity scores is needed. An unanticipated negative correlation between reaction times and SOFS scores, which implies better social functioning in those with longer reaction times in schizophrenia patients, lost its significance when clinical variables like duration of illness, the age of onset, PANSS total scores and antipsychotic dose equivalents were added as covariates. This implicates a confounding role of these clinical variables on the association between reaction times and social functioning. Moreover, a probability of false positive/negative errors, inherent to use of correlation analysis in small samples,^[20] cannot be ruled out.

The evoked gamma spectral-power, studied as a neural validator for poor ToM functioning, did not show statistically significant differences between the groups. Given the low effect size ($\eta^2 = 0.01$) and power (0.09) of the statistical analyses used, we infer that these results are inconclusive.

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Conflicts of interest

There are no conflicts of interest.

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