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High-Order Language Processing Difficulties in Patients With Schizophrenia: Cross-linguistic and Cross-cultural Results From the Hindi Version of a Newly Developed Language Test

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Objective: **To detect subtle linguistic performance deficits in patients with schizophrenia, a test battery was developed in Hindi vernacular language.**

Method: **It was a replication study of observational, analytical, and case-control design. Total of 86 participants, namely 43 patients with schizophrenia and 43 controls, were recruited into the study. The patients were evaluated by using PANSS (positive and negative symptoms scale for schizophrenia) for recruitment into the study. Participants from the general population were evaluated with GHQ-12 (General Health Questionnaire-12) to be found to fit as healthy controls. Subsequently, the linguistic performance of patients (on HLFT: Hindi linguistic function test) was compared with that of controls. The HLFT battery was designed, containing 3 blocks by using antonyms, synonyms, homonyms, hyperonyms, hyponyms, distractors, and adages.**

Result: **Patients scored significantly less than that of controls in identifying antonyms, distractors, and hyponyms while in identifying homonyms they scored significantly more than that of controls. At block I (antonyms) score of 15.5; at homonym score of 5.5; at hyponym (as in hyponym plus distractor combination) score of 2.5, the sensitivity and specificity for using them as a cutoff to screen for schizophrenia are 60.5% and 67.4%; 86% and 41.9%; 81.4% and 46.5%, respectively.**

Conclusion: **Ambiguity processing of taxonomic representation such as antonymia, homonymia, hypo-/hyperonymia, synonymia, and also understanding of adages might be significantly impaired in patients with schizophrenia. The HLFT battery could be used as a quick and sensitive instrument to detect and quantify the linguistic difficulties of patients with schizophrenia.**

Key words: schizophrenia/language impairment/semantic deficits/ambiguities/delateralization/formal thought disorder/alogia/hyperpriming/linguistic paradigm

Introduction

Schizophrenia is characterized by disordered cognition, including a “gain of function” in psychotic symptoms and a “loss of function” in specific cognitive functions, such as working and declarative memory.[1] According to Bleuler, language-based “loosening of association” between thought process and thought, emotion, and behavior is pathognomonic for the so-called “schizophrenic symptoms complex.”[2] To overcome the obscure relationship between thought and association disorder of Bleuler’s approach, Andreasen shifted the focus of investigation from “thought” to more objectively measurable “language behavior.”[3,4] Language impairment, indeed seems to be one of the core phenomenological characteristics of patients with schizophrenia.[5,6] Although normal with regard to segmental phonology and morphological organization,[7] there are obvious word-finding difficulties in patients with schizophrenia.[3,8]

Abnormalities in nonverbal communication are a hallmark of schizophrenia.[9] Patients with schizophrenia show a broad range of language dysfunction consisting of impairments of both microlinguistic (ie, lexical and morphosyntactic skills) and macrolinguistic (ie, pragmatic and discourse level processing) abilities.[10] These dysfunctions, in part reflect underlying semantic memory–related impairments.[11] Such impairments are linked particularly to formal thought disorder (FTD), and are associated with impaired semantic priming,[12–15] categorization,[16,17] and association.[18,19] Semantic priming refers to the observation that a response to a target (eg, dog) is faster when it is preceded by a semantically related prime (eg, cat) compared to an unrelated prime (eg, car).[20] Semantic association allows the prediction of related concepts and facilitates memory retrieval during communication.[21] Two forms of semantic association are defined: compositional and noncompositional.[22] Two types of noncompositional association are also defined[22]: (1) where the third item is presented lexically in the presented features (eg, "computer-virus"); and (2) where two words fuse semantically to evoke a third unpresented word from semantic memory, eg, "honey", "stings" activates "bee." The Hindi linguistic function test (HLFT) battery, used in this study to detect language impairment in patients with schizophrenia, indexes this first type of noncompositional semantic association.

The thought disorder in schizophrenia is uniquely distinctive and when compared to subjects with bipolar disorder, siblings, and controls, those with schizophrenia are found to be more impaired in comprehension, attention, semantic organization, and fluency and complexity of speech.[23] Particularly vague and ambiguous terms seem to irritate subjects with schizophrenia which might be a pathognomonic marker for psychotic language processing.[24]

Some studies investigating comprehension deficits attributed reduced comprehension to deficient working memory,[25] some found deficits in semantic processing,[26] some investigators ascribe a less central role to language and focus on alternate explanations such as dysfunctional executive control.[27] However, Marini et al[10] in their study found that reduced attention performances and deficit in executive functions were predictors of language impairment. They concluded that language production in schizophrenia is impaired mainly at macrolinguistic (pragmatic and discourse) level processing. It is disordered and filled with irrelevant pieces of information and derailments. Such erratic discourse may be linked to the inability to use pragmatic rules and to cognitive deficits involving executive abilities such as attention, action, planning, ordering, and sequencing. Berberian et al[28] have concluded in their study that semantic verbal fluency deficits are the consequence of the ways in which the impairment of the executive function manifests itself. Also, Piras et al[29] demonstrated in their study that higher cerebellar GABA concentrations were associated with lower phonemic fluency and reduced number of phonemic switches in patients with schizophrenia implying dysfunctional executive control. Troiani et al[30] have described a model of narrative production in their study using fMRI, which involves at least 2 components, including a linguistic component and an executive resource component. Phonological, morphological, and semantic processes are important for the production of single words. Forming these words into a coherent sentence calls for the recruitment of the higher level processes of planning and organization (including working memory). These linguistic and cognitive processes are organized in a top-down manner to accommodate the adaptive flexibility needed to produce a coherent narrative.[31,32]

Ratana et al[9] concluded in their study that despite the different methodologies, earlier studies demonstrated that speech and language disturbances can be quantified using computational and statistical methods. There are studies[33,34] whereby analysis of free speech samples was conducted, suggesting the important role for language analysis in psychiatry diagnosis. These earlier studies also established that there was a recognizable pattern of disturbances in speech and language observed in those with a known diagnosis of mental illness that can be predicted with statistical accuracy.[9] These computational methods may well be a circuitous method in understanding the importance of expression of feelings and thoughts.[9] Voppel et al[35] in their study concluded that "our results add to the mounting evidence that a multitude of quantifiable linguistic measures are affected in schizophrenia spectrum disorders. Combining and fine-tuning these measures can help to accurately classify psychiatric disorders in a fast, noninvasive, reliable way." However, despite this, the issue of dimensionality and taxonomy with machine learning algorithms remains a concern. Application of clustering algorithms to stratify psychiatric disorders poses problems as participants may not belong to any class. In addition, there is the question as to whether healthy participants should be clustered separately or included with other patients. Within the classification itself, some classes may be small or not well defined.[9]

To discover the etiological aspects of a psychiatric disorder, it is important to investigate the link between behavior and brain activity. Angrilli et al[36] suggested in their study, a functional deficit of Broca's area, a region playing a fundamental hierarchical role between and within hemispheres by integrating many basic processes in linguistic and conceptual organization. They used EEG delta band as a quantitative index of cortical inhibition while participants performed 3 linguistic tasks namely visuoperceptual, rhyming, and semantic judgment. In healthy participants, analysis of 4 quadrants/regions of interest revealed higher delta amplitude in right vs left anterior sites, indicating significant left anterior disinhibition during linguistic processing. Instead, patients showed bilateral delta band distribution and, compared with control subjects, significantly greater delta amplitude (ie, brain inhibition) in linguistic left anterior centers. Patients' left hypofrontality was functionally related to their lack of hemispheric specialization for language and was positively correlated with higher levels of delusions (P1) and conceptual disorganization (P2), Positive and Negative Syndrome Scale and subscales. They concluded that the significant correlation between lack of anterior asymmetry and increased positive symptoms is in line with Crow's hypothesis postulating the etiological role of disrupted linguistic frontal asymmetry on the onset of the key symptoms of schizophrenia.[36] Such a result is in line with prior research carried out with different methods (slow evoked potential[37]). However, delta EEG band might be less suited to highlight an excess of activation of left temporal lobe neurons associated to hallucinations.[36]

Also, most of the studies focused only on one aspect of language and neglected their linguistic features, but to define the role of language processing in the etiology of schizophrenia, it is essential to integrate these findings into one plausible theoretical model, eg, by investigating almost vulnerable high-order linguistic features such as ambiguity resolution, decoding antonyms, synonyms, or hyper-/hyponyms.[24] To delineate the exact nature of semantic deficits in patients with schizophrenia, it is therefore important to target semantic processing directly.[38] A common way to compare semantic processing between individuals with and without schizophrenia is to compare their semantic priming effect.[38] Unfortunately, the behavior of subjects with schizophrenia has been given more attention than the language of these subjects.[24] There is only a small number of studies available, focusing on high-order linguistic features and particularly on the phenomenon of ambiguity.[39] Ceccherini-Nelli and Crow used a psychometric test (CLANG) to evaluate language disturbances and found that language symptoms like semantic/phonemic paraphasias or poverty of speech were superior to nuclear symptoms in discriminating ICD-10 schizophrenia from other psychoses.[40] Ketteler et al have argued that CLANG is not appropriate to detect subtle language symptoms and that CLANG test focuses on symptoms that are more commonly seen during episodes of acute illness.[39]

The linguistic difficulties of the patients with schizophrenia are not easy to detect and quantify, while a quick and sensitive instrument will be of much help as studies in the field have for now, used a desperate (and not comparable) set of research methods. To detect subtle language symptoms in the patients with schizophrenia, we have attempted to develop a test battery in Hindi vernacular language to assess high-order linguistic functions (HOLF) such as ambiguity processing (understanding of ambiguous words: antonyms, homonyms, synonyms, hyperonyms, and hyponyms) and understanding of abstract and nonconcrete (=metaphorical) meanings, keeping in mind the initial phase of development attempted by Ketteler et al[39] (as it was the replication study focusing on the natural language of patients, ie, Hindi vernacular language). As a part of this, we sought to evaluate differences in difficulties in high-order linguistic processing between the patients with schizophrenia and the healthy controls and to correlate symptoms of schizophrenia with difficulties in high-order linguistic processing.

Methods and Materials

It was an observational, analytical, and case-control study. A pilot sample of 43 patients with schizophrenia (26 male and 17 female) and 43 healthy sex and years of education matched controls were taken.

Patients, attending outpatient unit and admitted in wards of psychiatry department at Sarojini Naidu Medical College, Agra, U.P., India and in Institute of Mental Health and Hospital, Agra, U.P., India, giving written informed consent and fulfilling diagnostic criteria of schizophrenia according to ICD-10, in remission period, with minimum 1 and maximum 4 previous hospitalizations, with the severity of illness score 4 or below according to CGI (Clinical Global Impression) Scale and with low PANSS (positive and negative symptoms scale for schizophrenia) scores, were recruited into the study. Median PANSS/median CGI scores were taken as standard remission criteria.

Patients and healthy controls aged between 18 and 50 years and education up to at least VIII Standard/class (secondary school) were recruited into the study. Participants from the general population were evaluated with GHQ-12 to be found to fit as healthy controls for recruitment into the study. Patients not giving written informed consent, with acute harmful substance use except nicotine and caffeine, with a history of electroconvulsive therapy within 3 months, with a history of head injury, seizure, cerebrovascular incidents within 3 months, with more than 4 episodes of schizophrenia, or with duration of illness more than 10 years, were excluded from the study.

Basic Demographic Profile, details and family history of psychiatric illness, total duration of illness, number of previous hospitalizations and history of substance abuse of patients and controls, and years of education, were also recorded. PANSS was used to assess the severity of symptoms of patients with schizophrenia and for recruitment of patients with schizophrenia into the study. The HLFT battery was designed to assess ambiguity processing of antonyms, homonyms, synonyms, hyperonyms, hyponyms, and understanding of adages. ICD-10 criteria were used to establish a diagnosis of schizophrenia. GHQ-12 was used to evaluate participants from the general population to be found to fit as healthy controls. Maximum 2 cases were interviewed per day.

Statistical Analysis

Kolmogorov-Smirnov test was applied to test the normality of continuous variables. Mean (standard deviation) was calculated for normally distributed continuous variables while median (interquartile range) was calculated for variables that were not normally distributed. Receiver Operating Characteristic Curve was used to find out optimum sensitivity and specificity of HLFT battery as a whole or any of the subscales/items; also for deciding cutoff scores for various test variables, eg, antonyms, synonyms, homonyms, etc., or for HLFT battery as a whole. Cronbach's alpha was used to measure the internal consistency of HLFT total scale and subscales. Logistics regression analysis was performed to see the difference in the total HLFT scores between the patients and the controls, because it was normally distributed. It was also performed to see the difference in various HLFT scores between patients and controls that were found significant in univariate analysis. Mann-Whitney *U* test was used to evaluate differences in difficulties in high-order linguistic processing between patients and controls. Also, it was used to evaluate differences in age and years of education between patients and controls. Chi-square test was used to see the difference in sex and group between patients and controls. Spearman correlation analysis was used to see the correlation between HLFT scale-subscales and PANSS scale-subscales. Also, it was used to see the correlation between years of education and various HLFT variables (scores).

SPSS 26.0 version was used for data analysis.

Experimental Design and Procedure

A linguistic task (HLFT) was presented to 43 patients with schizophrenia and to 43 healthy controls. The first task (HLFT battery block I) was a warm-up task consisting of 20 antonym relation pairs, while 11 of them were distractors. The second task (HLFT battery block II) represented other mixed high-order linguistic features, including synonymy, hyperonymy, and hyponymy. Each of the synonym and hyponym item groups included 11 items while homonym item groups included 13 items, hyperonym item groups 2 items, distractor item groups 9 items, synonym plus distractor combinations 4 items, synonym plus hyperonym combinations 2 items, synonym plus hyponym combination 1 item, hyponym plus distractor combinations included 3 items. Antonyms are words with opposite meanings. Homonyms are words with more than one meaning. Synonyms are words with similar meaning. Hyperonyms (= superordinates) are words arranged in accordance with increasing hierarchies while hyponyms are the words with decreasing hierarchies (=subordinates).

Instructions were provided in the HLFT battery, also individuals were given instructions by the examiner as mentioned in the HLFT battery: please mark if the first word or first 2 words match with the second or third word in the line, respectively (for details see HLFT battery in the Hindi language attached).

Example (regarding the homonymy task):

Money (✓)	River (✓)	Bank

Example (regarding the hyperonymy/hyponymy task):

Mango (✓)	Apple (✓)	Fruit

Distractors were arranged by using one or two distractors on position one and/or two:

Street (X)	Wall (X)	Jaw

Or

Almond (X)	Cobra (✓)	Snake

Example (regarding the hyperonymy/hyponymy task):
Distractors were arranged by using 1 or 2 distractors on position 1 and/or 2:
Or
Additionally, 3 simple classical adages with 1 clause and 3 compound classical adages with 2 clauses (HLFT battery block III) were tested by giving 2 or 3 answer alternatives for each adage.
Examples (simple adages):

1. Early bird catches the worm.
2. A bad workman quarrels with his tools.

Examples (compound adages):

1. When in Rome, do as Romans do.
2. As you sow, so shall you reap.

Standardization/Calibration of HLFT Battery

The first draft of HLFT battery was delivered to a cohort of 20 persons (of both sex, from both urban and rural population, and class/standard eighth or middle school completed). After delivery to the first cohort, the battery was simplified by eliminating words difficult to understand, and new and easy words were inserted. Also, 3 examples in block I and 5 examples in block II were inserted to instruct the subjects that only these very kinds of relations or matches you must think of. Then, a modified draft of the HLFT battery was applied to the second cohort of 20 persons (of both sex, from both urban and rural population, and class/standard eighth or middle school completed) and their performance increased. Then 3 simple proverbs (in addition to 3 compound proverbs in block III) were added in block III to boost the confidence of subjects.

Henceforth, HLFT was fully calibrated and standardized for educational qualification and was ready to deliver to patients with schizophrenia and controls.

Results

Demographics

No significant differences were found between the patients and the controls in sex or years of education (tables 1–4). Age showed a significant difference between the patients and the controls (table 4). Median CGI score and median PANSS score were 3 (3, 4) and 53 (43, 66), respectively, indicating that most patients were in remission (table 5). Median duration of illness was 7 (4, 10) years.

Association Between Schizophrenia Status and Various HLFT Scores

There was no significant difference in the overall linguistic performances (Total HLFT scores) between patients and controls ($P = .341$). However, in adjusted analysis with sex, age, and years of education, there was a significant association in the overall linguistic performances (total HLFT scores (table 6).) between patients and controls ($P = .021$). Here, subjects with schizophrenia scored less than that of the controls. The R^2 of the model came to be .187. Also, the difference between the 2 groups, namely patients with schizophrenia and healthy controls, was highly significant in identifying HLFT block I (antonyms; $P = .019$), block I-distractors (I-D) ($P = .014$), block II homonyms (H) ($P = .016$), and block II hyponym plus distractor combinations (H0 + D) ($P = .002$) (table 5). Logistic regression was applied with schizophrenia status as outcome and the HLFT variables which were found to be significant in univariate analysis (block I, block I-distractors, H and H0 + D). There was no significant difference in the block I, block I-distractor, H and H0 + D scores between patients and controls, after adjusting for years of education ($P > .05$). The R^2 of the model came to be .203. Similarly, There was no significant difference in the block I, block I-distractors, H and H0 + D scores between patients and controls, after adjusting for age of participants ($P > .05$). The R^2 of the model came to be .288.

Table 1. Group

	Frequency	Percent
Schizophrenic	43	50.0
Control	43	50.0
Total	86	100.0

Table 2. Sex

	Frequency	Percent
Male	52	60.5
Female	34	39.5
Total	86	100.0

Table 3. Sex and Group Cross-tabulation

			Group		Chi-square, P value
			Schizophrenic	Control	
Sex	Male	Count	26	26	.000,1.000
		% within Sex	50.0%	50.0%	
	Female	Count	17	17	
		% within sex	50.0%	50.0%	
Total		Count	43	43	
		% within sex	50.0%	50.0%	

Receiver Operating Characteristics Curves and Cutoff Scores for Screening for Schizophrenia

HLFT block I, block II H, and block II H0 + D combinations scoring an area under the curve of 0.647, 0.650, 0.683, respectively (figures 1–5) and corresponding *P* value of .016, .012, .001, respectively (table 7), highlight its usefulness in detecting language dysfunction, a hallmark of schizophrenia. At HLFT block I score of 15.5, block II H score of 5.5, and block II H0 + D combinations score of 2.5, the sensitivity and specificity for using these scores as a cutoff to screen for schizophrenia are 60.5% and 67.4%; 86% and 41.9%; 81.4% and 46.5%, respectively (figures 1–5 and table 7).

Correlation Between Symptoms of Schizophrenia (as Measured by PANSS) and Linguistic Performance (as Quantified by HLFT)

There was a significant inverse correlation between the total PANSS scores and block II distractor combinations score ($P < .05$) (table 8) and also between the PANSS general psychopathology scores and block II distractor combinations score ($P < .05$) (table 9). There was a significant inverse correlation between the PANSS negative scores and block II distractor combinations and adages (HLFT block III) ($P < .05$) (table 10). Positive symptoms of schizophrenia inversely correlated with HLFT scores and subscores except synonym plus distractor combinations, though not significantly (table 11). There was a significant inverse correlation between the CD/FTD (conceptual disorganization/FTD) scores and antonyms, HLFT block II, synonyms, hyponyms, adages (HLFT block III), and overall linguistic performance (total HLFT scores, $P < .05$) (table 12).

Incoherence Across Clause Boundaries (Differential Proverb/Adage Solving Abilities)

The difference between scores of compound and simple adages was found to be not significant in patients as well as in controls ($P > .05$) (table 13).

Table 4. Group Statistics (Demographics) and Association Between Schizophrenia Status and Various HLFT Variables

Variables	Schizophrenic Median	Schizophrenic IQR	Controls Median	Controls IQR	Mann-Whitney *U*	*P* Value[a]
Age	38	29, 44	30	25, 36	549	**.001**
Years of education	12	10, 15	10	10, 14	821.5	.365
Block I	14	11, 17	17	14, 18	653.5	**.019**
Block II	40	32, 44	40	32, 46	898.5	.822
Block III	4	3, 5	5	3, 6	788.5	.230
Block I-antonyms	8	6, 9	8	7, 9	887	.739
Block I-distractors	8	4, 9	9	8, 10	642	**.014**
Homonyms combination	8	7, 11	7	4, 9	648	**.016**
Synonyms combination	8	6, 10	9	6, 10	891	.769
Hyponyms combination	10	7, 11	10	8, 11	912.5	.916
Hyperonyms combination	2	1, 2	2	2, 2	883.5	.630
Distractors combination	4	3, 7	7	4, 8	708	.060
Synonym combination plus distractor	2	2, 3	3	2, 3	713.5	.055
Synonym plus hyperonym combinations	1	1, 2	1	0, 2	792	.225
Synonym plus hyponym combination	1	0, 1	1	0, 1	903	.817
Hyponym plus distractor combinations	2	1, 2	2	2, 3	586	**.002**
SA	2	2, 3	3	2, 3	835.5	.407
CA	2	1, 3	2	1, 3	810.5	.300

Note: CA, compound adages; HLFT, Hindi linguistic function test; IQR, interquartile range; SA, simple adages.
[a]Mann-Whitney *U* test.

Table 5. Group Statistics—Clinical Status

Variables (Schizophrenic)	Median	IQR
No. of hospitalizations	3	2, 4
CGI Score	3	3, 4
Total PANSS Score	53	43, 66
Positive Symptoms Score	11	8, 14
Negative Symptoms Score	15	10, 21
General Psychopathological Symptoms Score	27	22, 33
CD/FTD Score	1	1, 1
TDI (in years)	7	4, 10

Note: CGI, Clinical Global Impression; FTD, formal thought disorder; IQR, interquartile range; PANSS, positive and negative symptoms scale for schizophrenia; TDI, total duration of illness.

Table 6. Group Statistics: Total HLFT Score

	Group	*N*	Mean	Std. Deviation
Total HLFT score	Schizophrenics	43	55.79	12.001
	Controls	43	58.19	11.344

Note: HLFT, Hindi linguistic function test.

The differential proverb/adage scores in the simple and compound adages between patients and controls were found to be not significant ($F = 0.160$, $P = .691$).

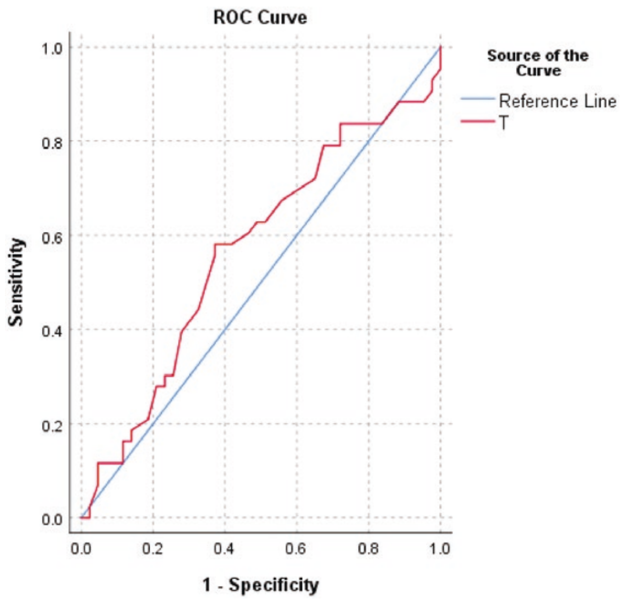

Fig. 1. Receiver operating characteristics (ROC) curve for total Hindi linguistic function test (HLFT) score (T).

Internal Consistency of HLFT Battery

The internal consistency of the HLFT battery was assessed using Cronbach's alpha which was good (.731) (table 14).

Correlation Between Years of Education and HLFT Variables

There was a significant direct correlation between the years of education and all variables of HLFT except distractors and Hyperonyms combination ($P < .05$) (table 15).

Discussion

The main result of our study was that subjects with schizophrenia faced significantly more difficulty in identifying the antonyms, hyponyms, and distractors than that of healthy controls (table 4). Our expectation[39] was that homonymy would be the biggest challenge in solving our HLFT battery. Surprisingly, they scored significantly more in solving homonyms than that of the controls ($P = .016$) (table 4). This tendency could be correlated inversely with positive symptoms of schizophrenia and specifically with CD/FTD, though not significantly (tables 11 and 12). Also, this tendency could be correlated directly with negative symptoms, general psychopathology, and overall symptoms of schizophrenia, though not significantly (tables 8–10). In our opinion, this might be treated as a defect in linguistic performance since continuation

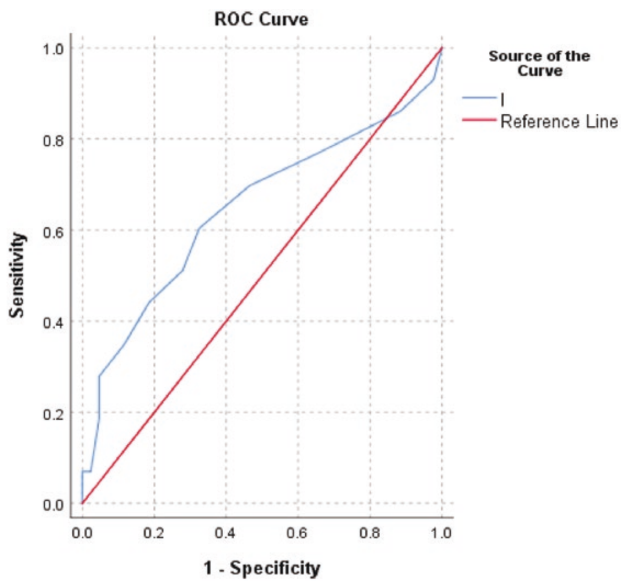

Fig. 2. Receiver operating characteristics (ROC) curve for block I score.

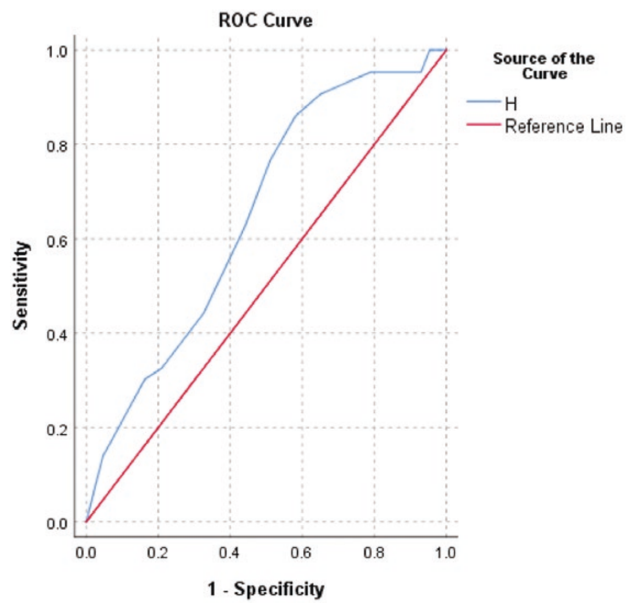

Fig. 4. Receiver operating characteristics (ROC) curve for homonym (H) score.

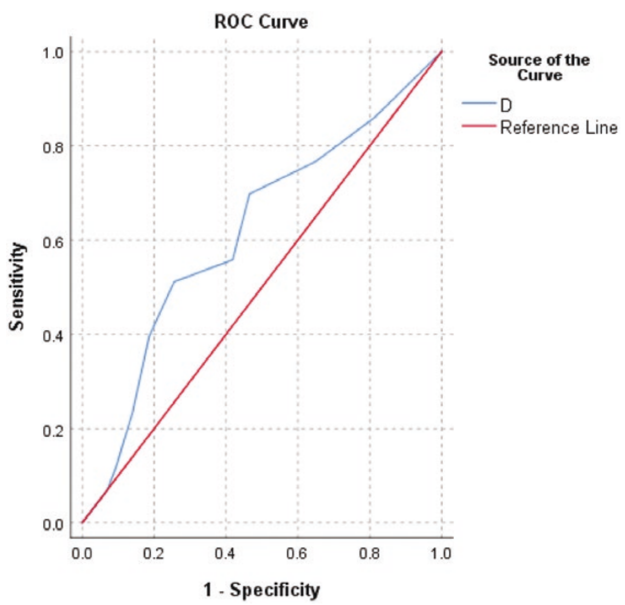

Fig. 3. Receiver operating characteristics (ROC) curve for block I-distractor (I-D) score.

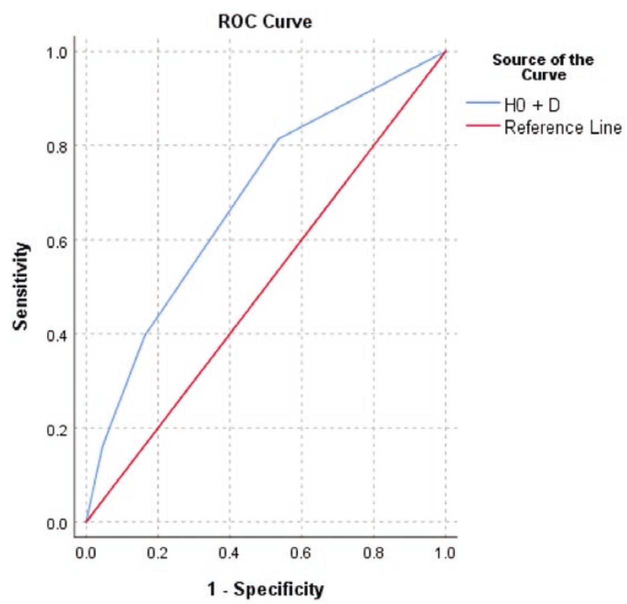

Fig. 5. Receiver operating characteristics (ROC) curve for hyponym plus distractor (H0 + D) score.

Table 7. ROC Curve Statistics for HLFT Variables That Found Significant in Univariate Analysis

Scores	Total HLFT	Block I	Block I-Distractor (I-D)	Homonym (H)	Hyponym Plus Distractor (H0 + D)
Area under curve (AUC) with *P* value	0.567 (*P* = .284)	0.647 (*P* = .016)	0.617 (*P* = .056)	0.650 (*P* = .012)	0.683 (*P* = .001)
Cutoff score for screening	—	15.5	—	5.5	2.5
Sensitivity	—	60.5	—	86	81.4
Specificity	—	67.4	—	41.9	46.5
Positive predictive value (PPV)	—	65	—	59.7	60.3
Negative predictive value (NPV)	—	63	—	75	71.4
Positive likelihood ratio (PLR)	—	1.9	—	1.5	1.5
Negative likelihood ratio (NLR)	—	0.6	—	0.3	0.4

Note: HLFT, Hindi linguistic function test; ROC, receiver operating characteristics.

Table 8. Correlation Between PANSS Total Scores and HLFT Variables

Variable	Correlation Coefficient[a]	*P* Value
Block I-antonyms	−.100	.524
Block I-distractors	−.174	.263
H: Homonyms combination	.078	.618
S: Synonyms combination	−.123	.433
Ho: Hyponyms combination	.075	.634
Hr: Hyperonyms combination	.125	.425
D: Distractors combination	−.374	.013
S + D: Synonym + distractor combination	−.205	.188
S + Hr: Synonym plus hyperonym combination	−.222	.153
S + Ho: Synonym plus hyponym combination	0	1.000
Ho + D: Hyponym plus distractor combination	−.259	.093
HLFT block I	−.214	.168
HLFT block II	−.175	.263
HLFT block III	−.180	.248
HLFT total	−.203	.193

Note: There was a significant negative correlation between the distractor combination and the PANSS total scores ($P < .05$). HLFT, Hindi linguistic function test; PANSS, positive and negative symptoms scale for schizophrenia.
[a]Spearman Correlation.

Table 9. Correlation Between PANSS General Psychopathology and HLFT Variables

Variable	Correlation Coefficient[a]	*P* Value
Block I-antonyms	.049	.757
Block I-distractors	−.056	.723
H: Homonyms combination	.178	.255
S: Synonyms combination	.063	.690
Ho: Hyponyms combination	.209	.179
Hr: Hyperonyms combination	.136	.384
D: Distractors combination	−.302	**.049**
S + D: Synonym + distractor combination	−.216	.164
S + Hr: Synonym plus hyperonym combination	−.178	.252
S + Ho: Synonym plus hyponym combination	.162	.299
Ho + D: Hyponym plus distractor combination	−.168	.282
HLFT block I	−.087	.580
HLFT block II	−.004	.979
HLFT block III	−.011	.942
HLFT total	−.030	.846

Note: There was a significant negative correlation between the distractor combination and the PANSS general psychopathology scores ($P < .05$). HLFT, Hindi linguistic function test; PANSS, positive and negative symptoms scale for schizophrenia.
[a]Spearman Correlation.

of this tendency resulted in hyperpriming, ie, finding relation between unrelated words (tables 8–12), which points towards gain of function in psychotic symptoms and loss of function in cognitive abilities. Likewise, the patients showed difficulty in solving block I-distractors than that the controls which could be correlated inversely with symptoms of schizophrenia, though not significantly (tables 8–12). Our hypothesis was, patients with low symptom load would perform better on the linguistic test. Regarding our findings, various HLFT scores and subscores highly inversely correlated with the standard instrument for scoring symptoms load in schizophrenia (PANSS) (tables 8–12). According to our data, antonymy, hyponymy, distractor, synonymy, understanding of adages, overall ambiguity resolution, and overall linguistic performance (tables 8–12) were significantly impaired in subjects with schizophrenia. During normal language processing, the semantic relationships between individual words are constantly computed and are compared with the relationships that are stored within semantic memory. This semantic memory-based stream of analysis is likely to proceed partially in parallel

Table 10. Correlation Between PANSS Negative Symptoms and HLFT Variables

Variable	Correlation Coefficient[a]	*P* Value
Block I-antonyms	−.140	.371
Block I-distractors	−.219	.159
H: Homonyms combination	.053	.733
S: Synonyms combination	−.213	.169
Ho: Hyponyms combination	.017	.915
Hr: Hyperonyms combination	.179	.251
D: Distractors combination	−.352	**.021**
S + D: Synonym + distractor combination	−.261	.091
S+ Hr: Synonym plus hyperonym combination	−.161	.302
S+ Ho: Synonym plus hyponym combination	−.070	.655
Ho + D: Hyponym plus distractor combination	−.266	.085
HLFT block I	−.260	.093
HLFT block II	−.247	.110
HLFT block III	−.381	**.012**
HLFT total	−.273	.077

Note: There was a significant negative correlation between the distractor combination, HLFT block III and the PANSS negative symptoms scores ($P < .05$). HLFT, Hindi linguistic function test; PANSS, positive and negative symptoms scale for schizophrenia.
[a]Spearman Correlation.

Table 11. Correlation Between PANSS Positive Symptoms and HLFT Variables

Variable	Correlation Coefficient[a]	*P* Value
Block I-antonyms	−.202	.195
Block I-distractors	−.070	.655
H: Homonyms combination	−.118	.450
S: Synonyms combination	−.167	.285
Ho: Hyponyms combination	−.217	.162
Hr: Hyperonyms combination	−.276	.073
D: Distractors combination	−.157	.315
S + D: Synonym + distractor combination	.141	.368
S + Hr: Synonym plus hyperonym combination	−.229	.139
S + Ho: Synonym plus hyponym combination	−.191	.219
Ho + D: Hyponym plus distractor combination	−.003	.987
HLFT block I	−.115	.461
HLFT block II	−.180	.249
HLFT block III	.107	.494
HLFT total	−.155	.322

Note: There was a negative correlation between PANSS positive symptoms all HLFT variables except synonym plus distractor combination and HLFT block III; though this correlation was not significant ($P > .05$). HLFT, Hindi linguistic function test; PANSS, positive and negative symptoms scale for schizophrenia.
[a]Spearman Correlation.

Table 12. Correlation Between CD/FTD and HLFT Variables

Variable	Correlation Coefficient[a]	*P* Value
Block I−antonyms	−.371	**.014**
Block I-distractors	−.140	.371
H: Homonyms combination	−.063	.688
S: Synonyms combination	−.315	**.040**
Ho: Hyponyms combination	−.374	**.013**
Hr: Hyperonyms combination	−.227	.143
D: Distractors combination	−.182	.242
S + D: Synonym + distractor combination	.028	.856
S + Hr: Synonym plus hyperonym combination	−.125	.423
S + Ho: Synonym plus hyponym combination	−.336	**.027**
Ho + D: Hyponym plus distractor combination	−.143	.362
HLFT block I	−.244	.115
HLFT block II	−.319	**.037**
HLFT block III	−.351	**.021**
HLFT total	−.342	**.025**

Note: There was a significant negative correlation between the CD/FTD scores and the antonyms, synonyms, hyponyms, synonym plus hyponym combination, HLFT block II, HLFT block III (adages), and total HLFT scores ($P < .05$). CD, conceptual disorganization; FTD, formal thought disorder; HLFT, Hindi linguistic function test.
[a]Spearman correlation.

with algorithmic, combinatorial, integrative streams of processing in which lexico-semantic information is integrated combinatorially with syntactic and thematic structure to come up with propositional representations of meaning.[41] Ditman and Kuperberg[42] suggested that, at least some of the sentence-level language abnormalities characteristic of schizophrenia may arise from the imbalance in operation of these streams such that, at least at the speeds at which normal language comprehension proceeds, patients are overly dependent on the semantic memory-based stream at the expense of the combinatorial integrative streams. They further implied that, although, for the most part, schizophrenia patients understand language normally, they encounter problems when there are increased demands on integrating all incoming information such as at the end of clauses or sentences, upon encountering ambiguity, and when the initial outputs of these streams contradict one another. They further added that recent electrophysiological evidence suggested that language impairment in schizophrenia results from a dysfunctional interaction between these streams in an effort to build up higher order meanings.

FTD was known to be a basic symptom regarding Bleuler's concept of loosening of associations and is reflected by our findings where this symptomatology might lead to inabilities in processing high-level linguistic features namely antonyms, synonyms, hyponyms, adages, in overall ambiguity resolution and in overall linguistic

Table 13. Difference Between the Scores of Compound and Simple Adages Among Patients with Schizophrenia and Among Controls

Patients with Schizophrenia		N	Mean Rank	P Value
Compound adages-simple adages	Negative ranks	18	12.68	.137
	Positive ranks	8	13.69	
	Ties	18		
	Total	43		
Controls:				
		N	Mean Rank	PValue
Compound adages-simple adages	Negative ranks	17	14.47	.293
	Positive ranks	11	14.55	
	Ties	15		
	Total	43		

Note: Wilcoxon signed rank test was applied to test significance in difference between the scores of compound and simple adages and it was found to be not significant among patients as well as among controls ($P > .05$). Repeated-measures ANOVA was applied to test the differential proverb scores in the simple and compound adages between patients and controls and was found to be not significant ($F = 0.160$, $P = .691$).

Table 14. Internal Consistency of HLFT Battery—Cronbach' Alpha

	Cronbach's Alpha If Item Deleted
Block II	
H	.738
S	.673
H0	.673
Hr	.727
D	.716
S + D	.724
S + Hr	.727
S + H0	.722
H0 + D	.730
Block I-antonyms	.690
Block I-distractors	.732
Block III	.699

Note: The internal consistency of the items used to estimate the HLFT battery was assessed using Cronbach' alpha which came to be .731 (Good). HLFT, Hindi linguistic function test.

Table 15. Correlation Between Years of Education and HLFT Variables

Variable	Correlation Coefficient[a]	P Value
Block I-antonyms	.250	**.020**
Block I-distractors	.158	.147
H: Homonyms combination	.236	**.029**
S: Synonyms combination	.378	**<.001**
Ho: Hyponyms combination	.359	**.001**
Hr: Hyperonyms combination	.141	.197
D: Distractors combination	.223	**.039**
S + D: Synonym + distractor combination	.332	**.002**
S + Hr: Synonym plus hyperonym combination	.347	**.001**
S + Ho: Synonym plus hyponym combination	.320	**.003**
Ho + D: Hyponym plus distractor combination	.224	**.038**
HLFT block I	.281	**.009**
HLFT block II	.482	**<.001**
HLFT block III	.443	**<.001**
HLFT total	.499	**<.001**

Note: There is a significant positive correlation between the years of education and all variables of HLFT except distractors and hyperonyms combination ($P < .05$). HLFT, Hindi linguistic function test.
[a]Spearman Correlation.

performance (table 12). After adjusting for age, sex, and years of education, the patients and the controls differed significantly in overall linguistic performance (total HLFT scores; $P = .021$) which significantly and inversely correlated with CD/FTD. Here, patients with schizophrenia scored less than that of controls. Also, subjects with schizophrenia, with more severe negative symptoms faced greater difficulty in solving adages (table 10). This is consistent with the poverty of speech found in individuals manifesting negative symptoms[43] but could not be attributed to negative symptoms solely in our study (tables 10 and 12) which is consistent with the suggestion provided by psychopathologists that similar cognitive deficits might underlie alogia and FTD.[43] Although Docherty et al asserted in their study that alogia and FTD appear to be distinct symptoms.[44] They concluded in their study that alogia and FTD appear to be associated with unique patterns of fluency performance, implicating separate cognitive mechanisms, to which our findings contradict. Jamadar et al[45] in their SORT (semantic object retrieval task) study found that individuals with more severe FTD were more likely to report an association between unrelated words and attributed it to loosening of associations in FTD, which was reproduced in our study (tables 8 and 12). Also, patients with more severe negative symptoms, with more severe general psychopathology of schizophrenia, and with more severe overall symptoms of schizophrenia were more likely to report associations between unrelated word pairs (tables 8–10). It could not be attributed to FTD solely in our studies (tables 8–12) as seen in previous studies (Jamadar et al,[45] Spitzer et al[46]), reasserting the suggestion provided by psychopathologists that similar cognitive deficits might underlie alogia and FTD.[43] Patients with schizophrenia show problems in selecting context-related ambiguous meanings.[24] Cohen and Servan-Schreiber[47] hypothesized that patients with schizophrenia are not able to store context information in memory. It has been suggested that a failure in processing contextual information may account for the heterogeneous clinical manifestations and cognitive impairments observed in schizophrenia.[47] Titone et al[48] used a priming task by presenting sentences containing homonyms. The result suggested that contextual strength is an important determinant when subjects with schizophrenia fail to inhibit contextually irrelevant meanings. The study was done by Wentura et al[49] yielded evidence for a lack of inhibitory function in thought- (and therefore language-) disordered patients. These results and hypotheses support findings of hyperpriming in our data (tables 8–12). Spitzer et al[46] reported in their study that semantic associations spread further and farther in thought-disordered schizophrenic patients than in normal controls and in nonthought disordered schizophrenic patients (leading to hyper priming). According to the hybrid three process theory,[50] three different mechanisms explain the processing of semantic memory, namely automatic semantic activation, expectancy, and semantic matching. Depending on the involvement of the attention, semantic processing could be separated into 2 relatively independent stages, early automatic semantic activation without the involvement of attention and late contextualization (consisting of expectancy and semantic matching) heavily influenced by attention.[50] Regarding late contextualization, the patients with schizophrenia seem to have problems in forming a meaningful representation of the whole text. On a linguistic level, this contextualization problem is also represented by our results in solving taxonomic relationships and adages. Sekulic et al[51] found a lack in inhibiting semantic alternatives in patients with psychosis and discussed these features for using it in the detection of early psychosis.

A memory impairment should be discussed too but according to one work by Ketteler and Ketteler,[24] more complex subcortical networks should be involved in high specific semantic search movements. Engaging and framing the object search is mediated by the dorsal anterior cingulate, pre-supplementary motor area, and thalamus.[22,52,53] To our taxonomic model, taxonomic networks must be activated, and alternatives have to be inhibited laterally, but if that occurs too much, semantic networks operate too narrow. Regarding semantic creativity, there should be a balance between exhibition and inhibition. Linguists working with children were able to study this phenomenon during language acquisition when there is over-exaggeration, eg, of the word "ball" when children mention everything that is round should be a ball too.[54] Bedi et al[55] in their computational analysis of clinical interviews found that semantic coherence and two syntactic markers of speech complexity and phrase length were significant in predicting the later psychosis development with 100% accuracy. Jamadar et al[45] used fMRI within a group of patients with bipolar disorder and schizophrenia and found that individuals with schizophrenia were more likely to fail to find an association between related word pairs.

Converging behavioral and neural evidence suggests that schizophrenia patients show impairments in establishing coherence across clauses during both the production and comprehension of language. Although these types of deficits can be, in part, attributed to abnormal semantic memory function[56] and working memory or executive function.[57–60] Ditman and Kuperberg[42] have argued that it is also important to define and study these abnormalities within frameworks of normal discourse processing. They further added that this can allow the study of interactions between lexical and semantic information in the surface structure and the establishment of discourse-level coherence in the situation model, giving a more complete picture of how communication breaks down in schizophrenia patients. But probably due to the confounding factors which were years of education (table 15) and group difference based on age, it could not be produced in our study. Although we attempted to test the difference in difficulty in solving simple adages (with one clause) and in solving compound adages (with two clauses) in block III of HLFT Battery (table 13).

Besides behavioral difficulties in solving high-order language tasks, there are neuroanatomic and neurofunctional changes esp. regarding language pathways, in patients with schizophrenia.[61–65] There might be two pathways in forming a neurolinguistic approach to understand language-related symptoms in schizophrenia: first, in the development of schizophrenia, hemispheric imbalance might play a crucial role.[24] The second pathway might be the assumption of interdependency between cortico-fronto-temporal and as shown by recent studies, subcortical neural networks and their importance for the ability to decode high-order linguistic features such as ambiguities.[24] Irritation of high-level linguistic function might lead to typical thought disorders already described by Bleuler[2] (eg, loosening of association). A compensatory activation of the right hemisphere in patients with schizophrenia might be an attempt to avoid linguistic disturbances.[64]

Limitations and Further Research Prospects

Since language is a high-level cognitive phenomenon, a variety of factors other than clinical group status could have an impact on its features. While we were able to match groups based on number, gender, and years of education; age differed significantly between controls and patients. This group difference might partially confound our results. Moreover, there was a significant direct correlation between the years of education and all variables of HLFT except distractors and hyperonym combinations ($P < .05$) (table 15). This also might confound our results as higher education has an effect on vocabulary.[66] The other limitation of our study was that neither HLFT battery nor HOLF test battery was validated. It must be noted here, German and Hindi homonyms and likewise adages are quite different. It was impossible to get the German version of HOLF test translated into Hindi and to check for test-retest reliability and validity or to check for cross-cultural/-linguistic variance. It would be of interest for future researchers, to contrast (and thereby to validate) performance on HLFT/HOLF test with performance in gold-standard measures such as Right Hemisphere Language Battery for evaluating ambiguity processing and metaphor understanding abilities, or to validate HLFT/HOLF test using a validated linguistic paradigm.[36,67,68] Homonyms containing proverbs should be tested in future. As all our patients were on antipsychotic medication, we cannot exclude an effect of medication on ambiguity processing and adages understanding abilities. For future research, we recommend to improve HLFT or HOLF test as an early detection tool for schizophrenia by computational methods and the natural language processing framework incorporated in psychopathology assessments for automatic prediction of schizophrenia, as these psychometric tests like HLFT battery and HOLF test battery could be helpful as complementary to the computational methods for sorting out patients with schizophrenia from other mental disorder's patients with psychosis. Our sample was probably too small to establish and evaluate our instrument, but it gave insight into the complex field of speech processing problems in schizophrenia.

Conclusions

To conclude, subjects with schizophrenia, with more severe negative symptoms, with more severe overall symptoms of schizophrenia, and with more severe general psychopathology of schizophrenia, were more likely to associate unrelated word pairs and also those with more severe negative symptoms and more severe CD/FTD were more likely to miss the correct meaning of adages. Using the HLFT battery we found that ambiguity processing of antonymy, hyponymy/hyperonymy, synonymy, and understanding of adages were significantly difficult for people suffering from schizophrenia. Our research has focused on these linguistic features to develop an early detection tool for schizophrenia. Clinical psychiatry needs easy bedside tests for early detection, so this might be a good option especially compared with high-level technology attempts such as fMRI, etc. The HLFT battery was able to detect difficulty in ambiguity processing and it was statistically significant when compared with healthy controls. Various scores and subscores of HLFT battery correlated significantly and inversely with various symptoms' scores of patients with schizophrenia.

Our findings suggest that language malfunction plays an overarching role regarding either the development or/and symptomatology of schizophrenia which is still not well understood. Within our study, we were able to replicate language difficulties regarding high-level linguistic features even in very different languages such as Hindi and German which leads us to the hypothesis that language might play a crucial role in the etiology of schizophrenia in general. German and Hindi probably have some similarities belonging to the same Indo-European language group, so for future research it would be interesting to compare it to other language groups such as Chinese or Japanese.

In the end, HLFT battery, with its block I (antonym) score of 15.5, homonym score of 5.5, hyponym (as in hyponym plus distractor combination) score of 2.5, and with sensitivity and specificity of 60.5% and 67.4%; 86% and 41.9%; 81.4% and 46.5% for these scores, respectively (table 7), and for using these scores as a cutoff for screening subjects for further diagnostic work-up of schizophrenia, seems promising and it could be used as a screening tool for early detection of psychosis and might lead to a better understanding of the etiology of schizophrenia in general. Also, it could be used as a tool to assess prognosis of the patients with schizophrenia and other patients of mental disorder with psychosis.

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Author Contributions

Dr Srivastava: Main author; conception of the idea of this research, preparing protocol proposal and study report of this research, carrying out data collection, and preparing HLFT battery. Dr Sinha: acted as a guide for the whole research, scrutinized protocol proposal and study report of this research. Also, guided in standardization/Calibration of the HLFT battery. Dr Ketteler: acted as a co-guide for whole research. He helped in understanding his HOLF test battery[39] and helped in formulating hypotheses of the study, eg, patients with low symptom load will perform better on the HLFT battery. Dr Jagtiani: guided in recruiting patients with schizophrenia in Institute of mental health and hospital, Agra, UP, India. He also provided training in delivery of PANSS to patients with schizophrenia.

Ethical Approval

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. All procedures involving human subjects/patients were approved by the following institutions/colleges:

1. Sarojini Naidu Medical College, Agra, UP, India; approval no. IEC/2017/13
2. Institute of Mental Health and Hospital, Agra, UP, India; approval no. 182/17

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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