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Original Research Article

Development of a cognitive-linguistic assessment protocol in Hindi for patients with traumatic brain injury

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ABSTRACT

Background: Traumatic brain injury (TBI) can affect language, cognition, social communication, and functional academic skills. A culturally and linguistically appropriate assessment protocol is needed for Hindi-speaking adults with TBI.
Methods: This descriptive tool-development study included 60 native Hindi-speaking adults: 50 healthy controls and 10 individuals with a history of TBI. The cognitive-linguistic assessment protocol in Hindi (CLAP-H) assessed receptive language, expressive language, cognitive skills, social skills, and reading/number concepts.
Results: CLAP-H was developed and culturally adapted for Hindi-speaking adults. The manuscript reports a strong correlation between CLAP-H and the Hindi Montreal Cognitive Assessment (H-MoCA) ($r=0.839$, $p=0.002$), significant between-group differences across listed tasks, an overall Cronbach's alpha of 0.892, and area-under-the-curve values ranging from 0.789 to 0.994. These findings should be interpreted cautiously because the TBI sample comprised only 10 participants.
Conclusions: CLAP-H may provide a structured approach to assessing cognitive-linguistic performance in Hindi-speaking adults with TBI. Further validation using a larger, independent sample and clearly reported psychometric methods is required before diagnostic accuracy can be established.

Keywords: Traumatic brain injury, Cognitive-linguistic assessment, Hindi, Validity, Reliability

INTRODUCTION

Traumatic brain injury (TBI) refers to damage to the brain caused by an external force such as a blow, bump, jolt, fall, road traffic accident, sports injury, or penetrating object. It is widely recognized as a major global public health concern and has been described as a "silent epidemic" due to its substantial contribution to mortality, disability, and long-term neurological consequences. TBI can result in a wide range of impairments, including cognitive, behavioral, emotional, endocrine, and psychiatric disorders that significantly affect an individual's quality of life and functional independence.[1-3]

The neuropathology of TBI is commonly divided into primary and secondary injuries. Primary injury occurs at the moment of impact and includes skull fractures, cerebral contusions, diffuse axonal injury, and intracranial hemorrhage caused by the transfer of mechanical energy to the brain. Secondary injury develops minutes to hours after the initial trauma and results from complex physiological processes such as cerebral edema, ischemia, increased intracranial pressure, impaired cerebral blood flow, hypoxia, and seizures, which can further exacerbate neurological damage.[2]

TBI can also be classified as focal or diffuse, depending on the extent and location of brain damage, and as open (penetrating) or closed (non-penetrating) injury based on

whether the skull and dura mater are breached. Furthermore, TBI severity is categorized as mild, moderate, or severe using clinical measures such as the Glasgow Coma Scale (GCS), duration of loss of consciousness, and post-traumatic amnesia. Mild TBI and concussion are increasingly viewed as existing on a continuum rather than as distinct conditions. Given its high prevalence and significant socioeconomic burden, particularly in developing countries, accurate assessment and timely management of TBI remain essential for improving patient outcomes and reducing disability.[1-3]

The objective of this study was to develop and culturally adapt the CLAP-H and to examine its content and construct validity, concurrent validity against the H-MoCA, ability to distinguish the TBI and healthy-control groups, and reliability.

METHODS

Research design and participants

The present study employed a descriptive tool-development research design to develop and validate the CLAP-H for adults with TBI. Participants were recruited using purposive sampling. The required sample size was determined using G*Power software, resulting in a total sample of 60 participants to ensure adequate statistical power. The study comprised 10 individuals with a history of TBI (Group I) and 50 age-matched healthy adults (Group II). The study was conducted at the Ali Yavar Jung National Institute of Speech and Hearing Disabilities (Divyangjan), Kolkata. The healthy participants served as the normative control group for the development and validation of the assessment protocol. Study period (June 2024-April 2026).

Inclusion and exclusion criteria

Group I: Individuals with TBI

The inclusion criteria were: (1) brain injury resulting from a road traffic accident; (2) Glasgow Coma Scale score greater than 13; (3) native Hindi speakers; and (4) age between 22 and 70 years.

Participants were excluded if they had a previous history of neurological conditions, learning or language disabilities, psychiatric disorders, or drug/alcohol abuse.

Group II: Healthy adults

The inclusion criteria for the control group were: (1) average intellectual functioning; (2) native Hindi speakers; and (3) age between 22 and 70 years.

Participants were excluded if they had any history of learning disability, fluency disorder, language impairment, cognitive impairment, or neurological condition.

Assessment tools

Two assessment measures were used in the study: the newly developed CLAP-H and the Montreal Cognitive Assessment (MoCA). The CLAP-H was developed specifically for Hindi-speaking adults aged 22-70 years with a history of TBI. The protocol assesses five major domains commonly affected following TBI: receptive language, expressive language, cognitive skills, social skills, and reading/number concepts. The selection of these domains was guided by existing evidence regarding communication, cognitive, and functional difficulties associated with TBI. The MoCA, developed by Nasreddine et al was used as a standardized measure of cognitive functioning. The Hindi adaptation of the MoCA has demonstrated satisfactory validity and reliability in the Indian population.

Development of CLAP-H

The development of CLAP-H was completed in two phases. Phase I involved tool construction, including identification of domains and subdomains, development of assessment tasks, generation of pictorial stimuli, and expert validation. The domains and subdomains were identified through an extensive review of relevant TBI literature and consultation with experienced professionals. Task materials and culturally appropriate stimuli were selected from educational resources and reviewed by linguistic experts. Digital pictorial stimuli were generated using artificial intelligence-based platforms and subsequently evaluated for clarity, familiarity, and iconicity.

The finalized protocol included tasks assessing word comprehension, sentence comprehension, confrontation naming, lexical retrieval, communication of basic needs, visual working memory, digit span, deductive reasoning, emotional understanding, reading comprehension, and arithmetic problem-solving.

Phase II involved administration of the finalized protocol to individuals with TBI and age-matched healthy adults. Written informed consent was obtained from all participants before assessment. All assessments were administered individually by a qualified Speech-Language Pathologist under standardized testing conditions.

Validation and psychometric properties

The psychometric properties of CLAP-H were established using multiple validation procedures. Content validity was examined using the content validity index (CVI), based on ratings provided by experienced Speech-Language Pathologists. Construct validity was assessed to determine whether the protocol adequately measured the intended cognitive-linguistic constructs. Concurrent validity was established by examining the relationship between CLAP-H and MoCA scores. Discriminant

validity was evaluated by comparing the performance of individuals with TBI with that of healthy controls, following the principles described by Campbell and Fiske (1959).[5]

Test-retest reliability was evaluated by re-administering the protocol to a subset of participants after a two-week interval. Reliability coefficients were calculated to determine the stability and consistency of scores across administrations.

Procedure and statistical analysis

Following informed consent, demographic and relevant clinical information was collected from each participant. The CLAP-H and MoCA were administered individually by a Speech-Language Pathologist. The obtained data were coded and entered into a database for statistical analysis.

Statistical analyses were performed using IBM SPSS Statistics Version 26. Descriptive statistics were used to summarize participant characteristics and test performance. The Mann-Whitney U test was used to examine differences between the TBI and control groups. Non-parametric correlation analyses were performed to examine associations between CLAP-H and other relevant measures. Principal component analysis (PCA) was conducted to examine the underlying factor structure of the protocol. Receiver operating characteristic (ROC) analysis was performed to evaluate the diagnostic accuracy and discriminative ability of CLAP-H. Reliability analyses were conducted to establish the internal consistency and temporal stability of the developed protocol.

RESULTS

The purpose of the present study was to develop a cognitive linguistic assessment protocol for people with TBI and to validate the tool in Indian population. The tool was developed linguistically and culturally in accordance with the Indian Hindi speaking population. The sample consisted of 60 native Hindi speaking participants aged 22-60 years. The participants composed of 50 healthy age matched peers (mean age-36.78 and SD 12.95) and were categorized for the ease of identification as Group I, while the 10 participants had history of TBI (mean age- 36.9 and SD-12.13) and were named group II (Figure 1).

Content validity is essential in tool development to ensure that the tool accurately and comprehensively measures the intended construct, especially when dealing with a specialized population like individuals with TBI. In the context of your CLAP-H, content validity is crucial because it confirms that the tool captures all relevant aspects of cognitive and linguistic abilities affected by TBI, as well as any linguistic nuances specific to Hindi. Content validity was carried out using PCA, first the raw score was extracted. PCA was conducted, extracting only 1 component, word naming, which had the Eigen value greater 1 accounting for 84.77% of total variance (Table 1 and 2).[6-8]

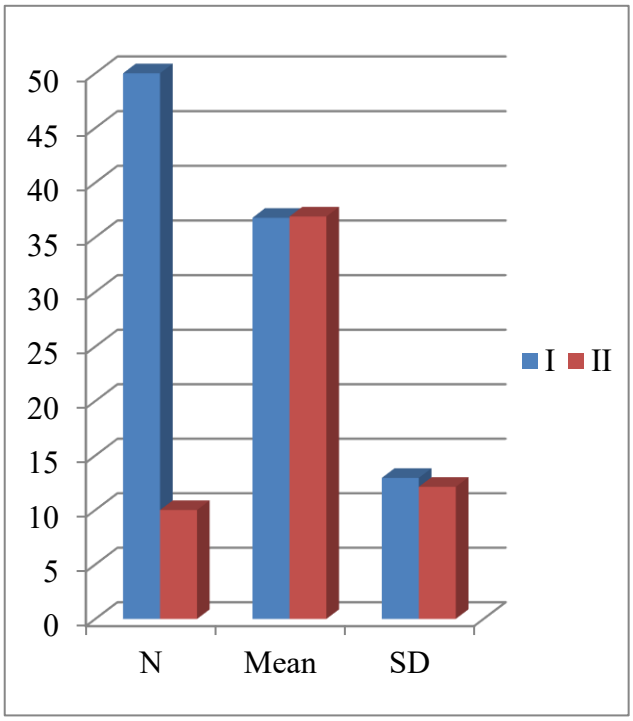

Figure 1: Demographic data of the participants.

Concurrent validity is essential for verifying that a newly developed tool produces results comparable to those of an established standard when measuring the same construct. In case of CLAP-H, concurrent validity is critical for establishing that the tool accurately assesses cognitive-linguistic abilities in line with other validated tools, in this case with H-MoCA, thus confirming its utility in both clinical and research settings. For this, participants of Group II were assessed with newly developed CLAP-H and an already established assessment for cognition H-MoCA to see the correlation between both the values to obtain concurrent validity. The p value came out to be 0.002 which shows the values of CLAP-H and H-MoCA to be statistically significant. The value of correlation coefficient is (r=0.839). The correlation results presented in the table indicate a significant relationship between the total score of the assessments and the H-MoCA score. The correlation coefficient (r) is 0.839, indicating a strong positive correlation between the total score and the MOCA score. This suggested that as the total score increases, the MOCA score also tends to increase, reflecting a relationship between the cognitive abilities assessed by both measures. The p=0.002, which showed statistically significance at the conventional alpha level of 0.05. This result indicates that there is a less than 0.2% probability that the observed correlation occurred by chance. Thus, we can confidently conclude that the relationship between the total score and the MOCA score is statistically significant (Table 3).

Table 4 summarizes the performance of individuals with TBI and age-matched healthy adults across the five domains of the CLAP-H. Overall, participants with TBI (Group I) was demonstrated higher mean scores and lower variability than healthy adults (Group II) across all domains and subdomains. In the receptive language domain, Group I achieved near-ceiling scores in both word comprehension and sentence-level linguistic comprehension, whereas Group II exhibited comparatively lower performance. Similar findings were observed in the expressive language domain, where Group I attained perfect scores in confrontation naming and lexical naming and near-perfect scores in communication of basic needs, while Group II showed lower mean scores and greater variability. In the cognitive skills domain, substantial differences were observed between the groups. Group I outperformed Group II in visual working memory, digit span, judgment, and deductive reasoning tasks, indicating better performance in memory, attention, reasoning, and executive functioning abilities.

The largest differences were noted in digit span and deductive reasoning tasks. Within the social skills domain, Group I demonstrated superior emotion identification and emotion-use abilities, suggesting better social-cognitive functioning compared to Group II. Similarly, in the reading and number concepts domain, Group I achieved higher scores in following directions, following instructions, arithmetic calculations, and word problem-solving tasks.

The Mann-Whitney U test revealed statistically significant differences between the groups across all domains ($p<0.01$). These findings indicate that the CLAP-H effectively distinguishes between individuals with TBI and healthy adults and demonstrates strong discriminative validity. The consistently higher scores obtained by Group I across all domains highlight clear differences in cognitive-linguistic performance between the two groups assessed in the study (Table 4).

The reliability analysis of the CLAP-H revealed excellent internal consistency across all domains. The overall Cronbach's Alpha value was 0.892, indicating good reliability of the protocol. Several subdomains, including sentence level comprehension, confrontation naming, semantic categories, digit span, emotion identification, and use of emotion, demonstrated perfect reliability ($\alpha=1.000$). Other subdomains such as word naming, visual working memory, basic needs, factual judgment, following directions, following instructions, and basic mathematics also showed exceptionally high reliability coefficients ranging from 0.986 to 0.998. Although Word Problem had the lowest reliability score ($\alpha=0.990$), it still indicated excellent internal consistency. Overall, the findings confirm that CLAP-H is a highly reliable tool for assessing cognitive-linguistic abilities (Table 5).

CLAP-H possesses good to excellent diagnostic accuracy in distinguishing individuals with mild TBI (mTBI) from healthy controls. The area under the curve (AUC) values ranged from 0.789 to 0.994, indicating moderate to excellent discriminative ability across all cognitive-linguistic tasks.

Among subdomains, Word Naming showed highest diagnostic accuracy (AUC=0.994), while Factual Judgment demonstrated the lowest, yet acceptable, discriminative performance (AUC=0.789). All AUC values were statistically significant ($p<0.05$), confirming that each task performed significantly better than chance in identifying affected individuals. Narrow 95% CI observed for several tasks, such as Digit Span, suggest high precision and stability of estimates.

Although some overlap between positive and negative groups was noted, all variables demonstrated acceptable to excellent discrimination, and none exhibited poor diagnostic performance. Overall, the ROC findings support the effectiveness of CLAP-H as a sensitive tool for differentiating individuals with mTBI from healthy adults (Table 6).

Table 1: Extraction of domain component of CLAP-H.

Domains of CLAP-H	Initial	Extraction
Word naming	1.000	0.915
Sentence level	1.000	0.756
Confrontation naming	1.000	0.898
Lexical naming	1.000	0.913
Basic needs	1.000	0.579
Visual working memory	1.000	0.694
Digit span	1.000	0.864
Factual judgment	1.000	0.783
Emotion identification	1.000	0.938
Deductive reasoning	1.000	0.851
Use of emotion	1.000	0.798
Following directions	1.000	0.887
Following instructions	1.000	0.943
Basic maths	1.000	0.965
Word problem	1.000	0.931

Table 2: Variance of PCA.

Component	Initial eigen values			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	12.716	84.776	84.776	12.716	84.776	84.776
2	0.805	5.365	90.141			
3	0.628	4.188	94.329			
4	0.295	1.970	96.299			
5	0.247	1.649	97.949			
6	0.177	1.181	99.130			
7	0.074	0.493	99.623			
8	0.033	0.220	99.843			
9	0.024	0.157	100.000			
10	4.594E-016	3.063E-015	100.000			
11	1.624E-016	1.082E-015	100.000			
12	6.405E-017	4.270E-016	100.000			
13	-1.984E-016	-1.323E-015	100.000			
14	-3.598E-016	-2.399E-015	100.000			
15	-4.630E-016	-3.086E-015	100.000			

Table 3: Nonparametric correlations (concurrent validity) TBI, (n=10).

Correlations	R	P value
CLAP-H vs. H-MOCA	0.839	0.002

Table 4: Comparison between group I normal and group II TBI: Descriptive statistics and nonparametric Mann-Whitney test results (among 5 domains).

Domains	Variables	Group I mean±SD	Group II mean±SD	Z	P value
Receptive language skills	Word naming	19.78±0.545	13.90±3.178	6.050	0.000**
	Linguistic task	10.00±0.000	7.50±2.321	6.227	0.000**
Expressive language skills	Confrontation naming	10.00±0.000	6.80±2.573	6.050	0.000**
	Lexical naming	10.00±0.000	7.50±2.321	6.227	0.000**
	Basic needs	7.98±0.141	5.60±1.955	6.833	0.000**
Cognitive skills	Visual working memory	8.90±1.502	5.70±2.497	3.911	0.000**
	Digit span	8.26±1.536	3.40±1.838	4.857	0.000**
	Factual judgement	5.84±0.422	4.50±1.958	3.888	0.000**
	Deductive reasoning	8.62±1.276	3.80±2.700	4.469	0.000**
Social skills	Emotion identification	9.58±0.702	6.70±2.497	4.073	0.000**
	Use of emotion	9.98±0.141	7.50±2.877	5.267	0.000**
Reading/ arithmetic	Following directions	9.44±1.445	5.10±2.998	4.657	0.000**
	Following instructions	9.52±1.374	5.40±3.134	4.543	0.000**
	Basic math's	9.02±1.097	5.60±3.098	3.960	0.000**
	Word problem	9.18±1.119	4.60±3.134	4.642	0.000**

*Group I=Normal controls (n=50); group II=Participants with TBI (n=10). Values are presented as mean±SD. Mann-Whitney U test revealed significant differences between groups across all variables ($p<0.001$).

Table 5: Reliability statistics-Chronbach's alpha.

Variables	N	Number of items	Cronbach's alpha (α)
Word naming	5	2	0.986
Sentence level	5	2	1.000
Confrontation naming	5	2	1.000
Lexical categories	5	2	1.000
Basic needs	5	2	0.991
Visual working memory	5	2	0.996
Digit span	5	2	1.000
Factual judgment	5	2	0.993
Deductive reasoning	5	2	0.988

Continued.

Variables	N	Number of items	Cronbach's alpha (α)
Emotion identification	5	2	1.000
Use emotion	5	2	1.000
Following directions	5	2	0.997
Following instructions	5	2	0.997
Basic math's	5	2	0.998
Word problem	5	2	0.990
Total	5	2	0.892

Table 6: ROC analysis through AUC.

Test result variable(s)	Area	Std. error[a]	Asymptotic Sig.[b]	Asymptotic 95% CI	
				Lower bound	Upper bound
Word naming	0.994	0.007	0.000	0.981	1.000
Sentence level	0.850	0.089	0.001	0.675	1.000
Confrontation naming	0.900	0.076	0.000	0.751	1.000
Semantic categories	0.915	0.063	0.000	0.792	1.000
Basic needs	0.947	0.056	0.000	0.836	1.000
Visual working memory	0.865	0.075	0.000	0.719	1.000
Digit span	0.982	0.014	0.000	0.955	1.000
Factual judgment	0.789	0.091	0.004	0.610	0.968
Deductive reasoning	0.940	0.042	0.000	0.858	1.000
Emotion identification	0.858	0.087	0.000	0.687	1.000
Use of Emotion	0.796	0.099	0.003	0.602	0.990
Following directions	0.893	0.064	0.000	0.768	1.000
Following instructions	0.856	0.081	0.000	0.698	1.000
Basic math's	0.882	0.060	0.000	0.764	1.000
Word problem	0.939	0.039	0.000	0.862	1.000
Under the nonparametric assumption					
Null hypothesis: true area=0.5					

DISCUSSION

The present study aimed to establish the sensitivity, specificity, validity, and reliability of the CLAP for TBI in Hindi. The tool was developed to address the need for a structured cognitive-linguistic assessment for Hindi-speaking individuals with TBI. Validation was conducted through content validity, construct validity, concurrent validity, discriminant validity, and test-retest reliability analyses.

Content validity was established using the CVI, a widely accepted method for evaluating the relevance and representativeness of assessment items through expert judgment. Speech-language pathology experts rated the items on a four-point scale, and high CVI values indicated that the test items adequately represented the intended cognitive-linguistic constructs. These findings support the appropriateness and comprehensiveness of CLAP-H for assessing cognitive-linguistic deficits associated with TBI.[6-8]

Construct validity was further examined using PCA. Most variables demonstrated high loadings on a single component, ranging from 0.761 to 0.983. Tasks such as Basic Math, Following Instructions, and Word Problems exhibited particularly high loadings, indicating that they measured a common underlying cognitive-linguistic construct. The extraction of a single dominant factor suggests that CLAP-H effectively captures a unified cognitive-linguistic ability while encompassing multiple related domains.[5]

Concurrent validity was assessed by comparing CLAP-H scores with scores obtained on the H-MoCA. A strong positive correlation was observed between the two measures, indicating that CLAP-H aligns closely with an established cognitive screening instrument. The statistically significant relationship demonstrates that CLAP-H is a valid measure of cognitive functioning and supports its clinical application alongside existing assessment tools.[4]

Discriminant validity was evaluated by comparing the performance of healthy controls (Group I) and individuals with TBI (Group II). Significant differences were observed across all domains, demonstrating the tool's ability to distinguish between neurologically healthy individuals and those with brain injury. In the receptive language domain, individuals with TBI showed difficulties identifying commonly used words and linguistic concepts from pictures. These findings are consistent with studies reporting lexical retrieval and semantic processing impairments following TBI.[5]

In the expressive language domain, participants with TBI performed poorly on confrontation naming and lexical category naming tasks compared to controls. Such deficits are commonly associated with disruptions in frontal and temporal lobe functioning that affect lexical retrieval and semantic processing. Additionally, difficulties in communicating basic needs were observed among participants with TBI. This finding may be attributed to reduced self-awareness and impaired insight, which are frequently reported following mild TBI.[9]

Within the cognitive domain, significant impairments were observed in visual working memory, digit span, judgment, and reasoning tasks. Individuals with TBI demonstrated poorer performance compared to healthy controls, supporting previous evidence of executive dysfunction and working memory deficits in this population. Performance on digit span tasks was also influenced by educational background, which is consistent with findings that literacy and years of formal education affect working memory performance (Ostrosky-Solís and Lozano, 2006).[10]

The emotional perception and social cognition tasks revealed substantial difficulties among participants with TBI. They exhibited reduced ability to identify emotions from photographs and interpret emotions in real-life situations, particularly complex emotions such as surprise and shock. These findings are supported by previous studies demonstrating deficits in social cognition and emotional processing following TBI. Such impairments can negatively impact social interactions, interpersonal relationships, and overall quality of life.[1,11]

The literacy and functional communication domain also demonstrated significant differences between groups. Participants with TBI experienced greater difficulty following written directions and completing reading-based tasks. These findings suggest impairments in processing speed, comprehension, and higher-order cognitive functioning, which have been reported in previous TBI research.

Reliability of CLAP-H was examined through a test-retest procedure conducted after a three-week interval. Cronbach's alpha values ranged from 0.892 to 1.00, indicating excellent reliability and stability over time. These findings confirm that CLAP-H produces consistent results across repeated administrations and can be used confidently for both clinical assessment and follow-up evaluations.

Overall, the findings provide strong evidence that CLAP-H is a valid, reliable, and sensitive instrument for assessing cognitive-linguistic deficits in Hindi-speaking individuals with TBI. The tool demonstrated excellent content validity, strong construct validity through a single-factor structure, significant concurrent validity with H-MoCA, effective discriminant validity across multiple domains, and high test–retest reliability. Furthermore, the results highlight the wide-ranging impact of TBI on receptive and expressive language, working memory, executive functioning, emotional perception, and literacy skills. Therefore, CLAP-H has considerable potential as a comprehensive clinical tool for diagnosis, rehabilitation planning, and outcome monitoring in individuals with TBI.

Limitations

Despite the promising findings of the present study, several areas warrant further investigation. First, there is a significant lack of research and normative data on mild traumatic brain injury (mTBI) within the Indian context. Given the linguistic, cultural, and socioeconomic diversity of the Indian population, future studies should focus on generating region-specific data to improve the understanding and assessment of cognitive-linguistic impairments following mTBI. Second, prospective studies involving larger and more diverse samples are necessary to enhance the generalizability of the findings. A larger sample size would provide stronger statistical power and allow for a more comprehensive evaluation of the CLAP-H across different populations. Furthermore, future research should control for variables such as educational level, age, socioeconomic status, severity of injury, and affected brain regions, as these factors may influence cognitive-linguistic performance and potentially confound the results. Controlling these variables would help in isolating the specific impact of mTBI on cognitive-linguistic abilities. Additionally, longitudinal studies examining recovery patterns over time could provide valuable insights into the progression of cognitive-linguistic deficits and rehabilitation outcomes. Such investigations would contribute to refining assessment practices and developing more targeted intervention strategies for individuals with mTBI.

CONCLUSION

The research highlights the need for a culturally adapted, comprehensive assessment protocol in Hindi for individuals with mild TBI (CLAP-H), by addressing not just language but also cognitive and academic skills, the CLAP-H offers a valuable tool for clinicians to identify and manage a wide range of impairments that accompany TBI. Furthermore, distinguishing between TBI and aphasia is crucial for accurate diagnosis and effective treatment planning ensuring that individuals with TBI receive the appropriate interventions for their diverse cognitive-linguistic needs. The tool's high construct, content and concurrent validity, along with significant discriminant and reliability measures, supports the tool's effectiveness in diagnosing mTBI.

Future directions

Future development of the CLAP-H should focus on addressing the multilingual nature of the Indian

population. Many participants with TBI demonstrated code-mixing and code-switching behaviors, frequently alternating between languages or combining them inappropriately during communication. Since these language patterns were not specifically assessed in the current version of the tool, future research should incorporate tasks that evaluate bilingual and multilingual language processing. Additionally, the assessment protocol could be enhanced by including more specific and sensitive tasks across various domains to improve the identification of subtle cognitive-linguistic deficits. Another important direction is the longitudinal application of CLAP-H to examine changes in cognitive-linguistic abilities over time. Assessing individuals at different stages following injury and during rehabilitation would provide valuable information regarding recovery patterns and treatment outcomes. Such refinements would strengthen the clinical utility, sensitivity, and comprehensiveness of CLAP-H for individuals with TBI.

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