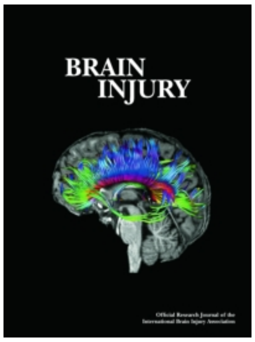

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Assessment of higher level cognitive-communication functions in adolescents with ABI: Standardization of the student version of the functional assessment of verbal reasoning and executive strategies (S-FAVRES)

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Abstract

Background: Childhood acquired brain injuries can disrupt communication functions needed for success in school, work and social interaction. Cognitive-communication difficulties may not be apparent until adolescence, when academic, environmental and social-emotional demands increase.
Objective: The Functional Assessment of Verbal Reasoning and Executive Strategies for Students (S-FAVRES) is a new activity-level measure of cognitive-communication skills in complex, contextual and integrative tasks that simulate real world communication challenges. It is hypothesized that S-FAVRES performance would differentiate adolescents with and without acquired brain injury (ABI) on scores for Accuracy, Rationale, Reasoning Subskills and Time.
Methods: S-FAVRES was administered to 182 typically-developing (TD) and 57 adolescents with mild-to-severe ABI aged 12–19. Group differences, internal consistency, sensitivity, specificity, reliability and contributing factors to performance (age, gender, brain injury) were examined statistically.
Results: Those with ABI attained statistically lower Accuracy, Rationale and Reasoning sub-skills scores than their TD peers. Time scores were not significantly different. Performance trends were consistent across tasks, administrations, gender and age groups. Inter-rater reliability for scoring was acceptable.
Conclusion: The S-FAVRES provides a reliable, functional and quantifiable measure of subtle cognitive-communication difficulties in adolescents that can assist speech-language pathologists in planning treatment and integration to school and real world communication.

Keywords

Cognitive-communication, mild brain injury, mTBI, concussion, acquired brain injury, adolescent, paediatric, assessment, communication, reasoning, executive functions

History

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Introduction

Success in school, work and social interaction requires facility with complex communication skills. Beyond the basic processing and production of sentences, full community participation demands the ability to discern, analyse, explain, discuss, interpret, negotiate, persuade or problem-solve at the level of text or discourse. Childhood acquired brain injuries (hereafter, ABI) can result in cognitive and communication impairments that impede academic, social and vocational success [1–16]. Childhood ABI can disrupt later development, with evidence of widening performance gaps relative to peers with earlier age at onset or increased time post-injury [10,17–19]. The impact of a paediatric ABI may not be fully realized until adolescence when the academic, environmental and social-emotional demands increase and more sophisticated skills are required [3,20–24]. There is a critical need for assessment measures that are sufficiently challenging to detect these subtle, later emerging, cognitive-communication deficits in adolescence [3,7,15,24–36].

Development of measures designed specifically to assess cognitive and linguistic functioning after paediatric ABI has been a relatively recent step forward. The Cognitive and Linguistic Scale (CALS), by Slomine et al. [35], is a quantitative scale designed for serial bedside measurement of cognitive functioning in children aged 2–19. It is comprised of 20 items which assess arousal, responsivity, emotional regulation, inhibition, attention, response time, orientation, memory, receptive language, expressive language, initiation, pragmatics, problem-solving, visuoperceptual ability, visuospatial ability, self-monitoring and cognitive safety. The Paediatric Test of Brain Injury (PTBI) by Hotz et al. [37] is a criterion referenced measure designed to assess neurocognitive language and literacy abilities in children with brain injuries aged 6–16. The authors indicate that the 30 minute test helps to establish baseline levels of cognitive-linguistic abilities in the acute stage of recovery while identifying strengths and weaknesses, to inform intervention, track recovery patterns and guide decision-making for school re-integration.

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Test items assess a range of skills from basic developmental skills (orientation, command following), to more advanced skills including: narration, discourse comprehension, recall and organization of semantically-related information, story retelling, picture recall, digit span and word fluency.

There continues to be a need for adolescent measures that detect subtle cognitive-communication deficits that emerge at later stages of recovery, later stages of paediatric development or under conditions of sufficient cognitive challenge. Such deficits are characteristic of individuals with mild brain injuries, but also those in later stages after moderate-to-severe brain injuries. The need for such a measure has been reported widely in the literature. For example, a multidisciplinary review of paediatric outcome measures identified the need for additional measures of executive functioning, prospective memory and social cognition [32]. McKinlay's [30] review of 87 studies of mild paediatric brain injury recommended development of measures that are sufficiently sensitive to evaluate the outcomes of mild traumatic brain injury. Ciccia et al. [3] reported the need for development of a measure of higher level adolescent cognitive-communication functioning that assessed beyond the sentence level and employed complex communication tasks. A new measure, The Student version of the Functional Assessment of Verbal Reasoning and Executive Strategies (S-FAVRES), was designed to evaluate higher level cognitive-communication functioning in adolescents after brain injury. This paper describes the rationale, development, standardization and evidence for reliability and validity of the S-FAVRES.

Rationale for development of the S-FAVRES

The development of the S-FAVRES is grounded in four evidence-based principles.

Principle #1: Adolescent: Assessments must account for the maturational changes that are occurring in the typically-developing adolescent brain

Adolescence is a period of considerable physical, cognitive, emotional and communicative development, which spans the period from puberty to the second decade of life [3,38,39]. Neurological changes in adolescence include increases in white matter volume, synaptic proliferation and pruning, brain region connectivity, speed or efficiency of transmission and top-down inhibitory control [39–42]. Associated cognitive improvements occur in speed of processing, attention, executive functioning, social cognition (face processing, emotional recognition, social evaluation, mentalizing or theory of mind), social competence, efficiency of information transfer, organization, integration, flexibility, goal-setting, abstract thinking and reasoning [3,38,40,41,43–47]. Communication development in adolescence includes: increased sentence length, increased syntactic or grammatical complexity (e.g. use of complex embedded clause structures), comprehension of complex forms (e.g. ambiguous sentences, proverbs, metaphor, inference), increased social communication and development of vocabulary for academic and employment settings [3,43,48,49]. Adolescent assessment measures must challenge the cognitive and communication skills that are emerging or refining at this time [3,13,24,49]. Ciccia et al. [3] recommended the design of adolescent measures that reflect the continued development of executive functions, social cognition, higher-level language, working memory, self-regulation and self-monitoring.

Principle #2: Communication: Design tasks specifically to evaluate the type of cognitive-communication deficits that occur in adolescence after ABI

Cognitive-communication deficits are difficulties in communication (auditory comprehension, verbal expression, discourse, social interaction) that occur as a result of underlying cognitive disturbance (attention, memory, organization, speed of processing, reasoning, problem-solving, executive functions) [16,29,50,51]. Adolescents with ABI demonstrate a wide range of cognitive-communication impairments. These encompass the domains of expressive language, comprehension of spoken and written texts, reasoning, problem-solving, executive functioning and metacognition. This combination of difficulties can lead to problems for the adolescent with ABI in their daily life activities as described in the sections below.

Expression

Expressive difficulties may include problems with word finding or generation of coherent, organized, informative or relevant discourse [32]. In terms of social communication, individuals with ABI may have excessive, impoverished, dysfluent or tangential discourse with egocentric or restricted topic selection, inappropriate humour, overly familiar remarks, inappropriate levels of self-disclosure, difficulties with social perception or reduced facility with listener-oriented behaviours [7,12,22,25,41,43,44,49,52–59]. Detection of expressive cognitive-communication difficulties requires assessment tasks at the level of discourse, complex written formulation, social communication, interaction, conversation, social problem-solving and perception of conversation partner cues and perspectives [28,60].

Comprehension

Comprehension (auditory and written) difficulties after ABI include challenges in understanding advanced lexical forms, non-literal information (irony, sarcasm, humour), complex syntactic structures, implied information and gist or main idea [3,4,17,26,27,41,57,61]. These difficulties may arise from underlying problems with working memory, organization, executive functions, inhibition, initiation and self-regulation [22,24,41,50,62–64]. Sensitive comprehension measures are likely to be those that demand processing of text, implied or non-literal information, inference, context clues and gist or a central theme rather than those with questions relating to literal level retrieval of explicit facts [27,65,66].

Reasoning, problem-solving, executive functioning, self-regulation and metacognition

Reasoning, problem-solving, executive functioning and self-regulation underlie successful communications and they are often disrupted after ABI [13,18,27,45,56,64,67–75].

Verbal reasoning is fundamental to communication such as expressing an opinion, making a complaint, understanding arguments, conveying decisions, recognizing falsehoods, persuading or negotiating. Verbal reasoning also underpins complex auditory comprehension, reading comprehension, analysis of information, new learning, academic writing, discussions and evaluation of communication at work or school [68,76]. Processes involved in verbal reasoning include encoding, analysis, integration, inference and manipulation of relationships and these processes occur whenever individuals must draw conclusions that go beyond what is explicitly stated [68,69,76]. Verbal reasoning is mediated by specific areas of the prefrontal cortex, but the brain activation sites vary depending on task features such as task content (semantic, perceptual), complexity, task familiarity, bias and uncertainty [69]. Reasoning tasks also involve contributions from other processes such as working memory, inhibitory control and regulation of attention toward relevant details and away from irrelevant information [69]. Therefore, verbal reasoning is a complex, multi-process mental activity that involves multiple cognitive operations and multiple regions of the brain.

Problem-solving involves a series of cognitive steps that include: (1) Identifying or defining the problem, (2) Generating alternative solutions, (3) Decision-making to weigh alternatives and select strategies, (4) Planning and implementing and (5) Monitoring, Evaluating, Refining and Revising [13,56,70,71]. After ABI, individuals may experience any of the following difficulties with verbal reasoning and problem-solving: minimal inferential thinking; general inefficiency with abstract ideas and relationships; inability to see relationships among problems, goals and relevant information; inflexibility in generating or evaluating possible solutions; impulsivity; inability to assess a situation and predict consequences; reduced efficiency (slow rate and low productivity); deterioration of performance with increasing processing load; and deficient performance on complex tasks requiring organization, persistence or self-monitoring [2,13,27,45,56,72,77].

Executive functions are integrative, superordinate cognitive processes that enable goal-setting, planning, organizing, monitoring and flexible adaptation of behaviour to fit a particular task or context [73]. Anderson's [74] model of executive functioning, based on a review of childhood brain injury, includes: (1) Attentional control (attending selectively, inhibiting irrelevant responses, sustaining attention, regulating and monitoring of actions to achieve goals); (2) Information processing (fluency, efficiency and speed of output); (3) Cognitive flexibility (shifting between response sets, learning from mistakes, devising alternative strategies, dividing attention and processing multiple sources of information concurrently); and (4) Goal-setting (developing new initiatives and concepts, planning. actions, strategic approach to tasks).

Difficulties with reasoning, problem-solving and executive functions can affect higher-level communications including: social interactions, problem-solving communications, workplace communications and discussions for new learning [13,16–18,33,41,44,62,64,74,75,78].

Successful communication also requires self-regulation and meta-cognition [64,79]. Stuss's [80] model of frontal systems includes four functions within the frontal lobes, each with distinct neuroanatomical correlates within and beyond the frontal lobes: (1) Energization or the process of initiating and sustaining a response; (2) Executive Functions which include: Task Setting and Task Monitoring; (3) Behavioural/Emotional Regulation; and (4) Metacognition and Integration, which includes a 'higher order' integrative and co-ordinating function necessary to accomplish complex, novel tasks. Self-regulatory and executive functions are also inherent in social problem-solving stages, as can be seen in the following components of Crick and Dodge's [81] Social Information Processing model: interpreting cues, clarifying goals, generating alternative responses, selecting and implementing a specific response and evaluating the outcome. Social communication also requires an interpersonal awareness referred to as Theory of Mind or the ability to understand the views and beliefs of another person [82]. Perspective taking of others has been included in concepts of meta-cognition [80] and has also been correlated with paediatric development of executive functioning [83]. In individuals with brain injury, correlations have been found between self-awareness, theory of mind, communication, executive functions and social problem-solving [12,56,84,85] and these skills have been found to contribute to social outcomes in children and adolescents after moderate-to-severe brain injury [12,41,86] as well as mild brain injury [31,87]. There is clearly a need for assessment measures that evaluate the impact of reasoning, problem-solving executive functions and self-regulatory deficits on communication [13,24,27,50,88–90].

Integrated functions

Communication in daily life requires the integrated execution of a range of higher order processes including reasoning, problem-solving, executive functioning, meta-cognitive and self-regulatory skills [2,13,16,85,91,92]. These highly interrelated functions possess shared as well as unique features and each engages multiple regions of the brain [3,13,22,24,30]. For adolescents with ABI, 'specific' cognitive or language functions may remain intact, but the 'integrative' or co-ordinating functions may be impaired [43,62,91,93]. This warrants an integrated approach to the evaluation of adolescent communication whereby tasks engage multiple processes simultaneously [25,41,56].

Principle #3: Complexity: Assessment measures must be sufficiently complex to be sensitive to subtle or higher level cognitive-communication deficits

Cognitive-communication deficits may be subtle or higher level in that they may emerge, not in structured standardized testing, but only when the cognitive, linguistic, emotional or social demands are sufficiently challenging [27,41,66,90,94,95]. A key question then is how to construct cognitive-communication measures of sufficient challenge to detect subtle deficits that are associated with frontal system involvement, mild brain injury, executive functions, later stages of adolescent development or that persist over time [30,41]. Top down control associated with pre-frontal brain regions is most likely to be required in tasks or situations that are novel, rapidly changing, have ambiguous stimuli, require convergence of diverse information, involve analysis of multiple responses or competing alternatives or require maintenance of goal-directed activity in the context of intervening, irrelevant or potentially interfering events [96]. Subtle deficits associated with mild injury are more apparent on measures that include timed scores to detect challenges with speed of processing [30,93,97]. Sensitivity to subtle cognitive-communication deficits is enhanced through tasks that involve text, inference, complex lexical semantic operations, memory demands, generative rather than confrontation naming, strategic learning, reasoning, problem-solving, executive functioning and metacognitive skills [13,90,98,99].

Principle #4: Context: In order to be ecologically valid and predictive, assessment measures should be contextualized and evaluate at the activity/participation level of functioning

Traditional standardized tests with structured tasks at the word and sentence level have minimal resemblance to the complex, contextually rich and integrative tasks of daily life [8,15,28,41,88,100–104]. There has been a call for development of activity level measures that have more relevance to performance in daily life [3,13,29,30,74,88]. According to the World Health Organization's (WHO) International Classification of Functioning, Disability and Health [105], comprehensive assessment includes impairment level measures that methodically analyse the level of breakdown, activity measures that challenge contextual and integrative functioning and environmental measures that evaluate the communication demands of the classroom or work environments [29,88]. Chevignard et al.'s [106] systematic review of paediatric assessment measures recommended more testing at the level of activity/participation in the WHO framework and measures with greater ecological validity and academic relevance.

Assessment measures may be more predictive of real world functioning if they closely approximate the complex communication contexts of daily life [3,90,107]. Improved ecological validity would be expected in tasks that simulate complex, real world communications with inclusion of: 'life size' amounts of information, context, communication partners, roles, multiple stimuli, shifting attention, flexibility, interaction, generation, perception, new learning, organization, planning, time management, self-evaluation and self-regulation [3,12,15,41,85,93,108,109]. More difficulties would be expected in circumstances that demand the interplay between cognitive, communication and emotional regulation skills and the multi-tasking and self-regulation that is inherent in everyday social interactions and daily problem-solving [3,13,93]. In summary, assessment procedures may be more sensitive, predictive and ecologically valid if they include contextual integrative activities in which combined skills or simultaneous demands are required [3,103,106].

The Functional Assessment of Verbal Reasoning and Executive Strategies: Student Version (S-FAVRES)

The Student Version of the Functional Assessment of Verbal Reasoning and Executive Strategies (S-FAVRES) was designed to detect subtle, persisting, cognitive-communication deficits in adolescents with ABI. It is an activity level, functional-integrative measure that evaluates the interplay between complex comprehension, complex expression, social communication, verbal reasoning, problem-solving and executive functioning. The purpose of the S-FAVRES is to assess cognitive-communication skills in complex tasks that are contextually rich, integrative and similar to the communication challenges of daily life. The S-FAVRES was developed to meet the following goals:

(1) Evaluate higher level cognitive-communication skills associated with adolescent development;
(2) Assess cognitive-communication deficits characteristic of ABI;
(3) Detect subtle or higher level deficits associated with frontal and pre-frontal systems and mild brain injury;
(4) Provide standardized data from typically-developing adolescents (hereafter, TD) and those with ABI (aged 12–19);
(5) Demonstrate acceptable levels of validity, reliability and clinical utility; and
(6) Predict functioning beyond the clinical environment through ecologically valid, functional, activity-level assessment.

The previously published adult version of the FAVRES [90] has been described as an activity level measure with utility in detecting subtle cognitive-communication deficits, delineating the effects of mild traumatic brain injury, planning treatment and planning for return to work or school [26,88,90,107,110–112]. After the development of the adult version, there was a call for an adolescent version. A research version of the student FAVRES (hereafter S-FAVRES) differentiated adolescents with and without ABI [44]. The S-FAVRES was recommended as an emerging measure by the Paediatric Traumatic Brain Injury Workgroup in their recommendations for common outcomes measures [32].

A primary aim of the S-FAVRES is to maximize ecological validity while maintaining the objectivity of standardized testing. It is an activity level measure designed to optimize ecological validity by simulating daily life contexts while increasing complexity, integration of processes and qualitative assessment. S-FAVRES tasks were designed to approximate the complex communications of daily life in order to predict and plan for functioning beyond the clinical environment. At the same time the S-FAVRES was intended to provide the benefits of practicality, standardization and normative data (accuracy, time) that are not usually inherent in real world assessment.

The S-FAVRES consists of four verbal reasoning tasks, which present novel situations within a meaningful context. The contexts are similar to what an individual might encounter at school or in family and social situations. The four tasks are presented in Table I.

Each of the four tasks simulates a different type of situation that is commonly encountered in daily life. The *Planning* task requires the individual to plan an event by reviewing several options presented in entertainment listings and then to deduce which choice best fits the described parameters of time, money, appropriateness, etc. Eleven 'foils' or inappropriate options are included in the task to evaluate the examinee's ability to use the process of elimination. The *Scheduling* task requires the student to prioritize and organize school and extracurricular activities to produce a weekly

Table I. S-FAVRES tasks.

Four Reasoning tasks
1. *Planning an Event*: Analyse entertainment listings to decide on an event within the constraints of time, money and appropriateness to the participants.
2. *Scheduling*: Analyse a 'things to do' list and messages to organize weekly school and social activities according to priorities and time constraints.
3. *Making a decision*: Analyse a story, draw conclusions about the main character and decide on an appropriate gift.
4. *Building a case*: Analyse a sequence of events in a daily journal and prepare a written complaint and set of solutions to a problem.

schedule. The *Making a Decision* task presents information in the form of a short story. The student must interpret dialogue, draw conclusions about the characters and then select an appropriate gift for the main character. This task includes inferencing and perspective taking. *Building a Case* is a task in which all of the facts are presented in the form of a daily journal. The examinee must read the events, draw conclusions about responsibility for the events and write a letter of complaint to a store manager. The task also requires that the student generate potential solutions for the problem.

The types of scoring for the S-FAVRES are presented in Table II.

The *ACCURACY SCORE* is determined by awarding points for the examinee's response choice and provides an indication of the individual's accuracy in considering the facts, eliminating irrelevant information and weighing options in order to make a choice. The *RATIONALE* score is based on the student's stated reasons for choosing a particular answer and points are awarded based on the relevance and detail of the rationale. The *TIME SCORE*, or length of time for completion of each task, provides some indication of the student's speed and efficiency in completing complex activities. Accuracy and Rationale scores are awarded on a 6-point scoring system (0–5) based on the number of factors accounted for in the examinee's written response. The *ANALYSIS OF REASONING SUB-SKILLS* is a post-hoc analysis of answers to scripted questions in which the examiner asks the student about *how* they solved the problem. It provides the examiner with an opportunity to compare reasoning skills across tasks and gives some indication of self-awareness. It places the student in the role of collaborator in examining his/her verbal reasoning skills. The *Strengths and Weaknesses Checklist* provides a qualitative analysis of the student's observed behaviours during test completion.

The S-FAVRES challenges verbal reasoning in communication according to the functionally based construct outlined in Table III. The items within the construct represent potential

Table II. Types of S-FAVRES scores.

Types of scores
Accuracy: Score for correct answer
Rationale: Score for reasons provided for choosing a particular answer
Time: Efficiency with which examinee completed the task
Analysis of reasoning sub-skills: Post-hoc analysis of the process the examinee engaged in to derive an answer.
Strengths and weaknesses checklist: Qualitative scoring of behaviours.

Table III. The functional construct of verbal reasoning underlying the S-FAVRES.

1. *Getting the facts*
Can the individual identify the most important facts?
2. *Eliminating irrelevant information*
Can the individual identify and ignore less relevant information in order to focus on more important information?
3. *Weighing the facts*
Can the individual compare or weigh competing options or criteria?
4. *Flexibility*
Can the individual revise a decision or plan of action when presented with new information? Does the individual have the flexibility required to alter a premise or conclusion as the situation requires?
5. *Generating*
Can the individual generate a variety of solutions, options or alternatives with some efficiency?
6. *Predicting consequences*
Can the individual predict potential outcomes, pros and cons or consequences of a choice?
7. *Providing a rationale*
Can the individual provide a rationale or a set of reasons for making a choice?

areas of strength or weakness in reasoning; they are not a set of sequential steps, presumed internal operations, or a hierarchy of abilities. The S-FAVRES assists the clinician in answering the clinical questions for treatment planning that are listed in Table III.

These reasoning sub-skills comprise observable behaviours that are frequently included in models of reasoning, problem-solving and metacognition, that are also areas of breakdown following acquired brain injury [12,13,15,41,56,71,79]. The S-FAVRES scoring provides a means of examining patterns of strengths and weaknesses in performance across functional communication tasks.

Context

The S-FAVRES incorporates materials that simulate naturalistic communications in the real world contexts of school, social and community life. Each S-FAVRES task incorporates 'real life' amounts of information, meaningful contexts, social roles, multiple stimuli, qualitative evaluation, interaction, discourse, integration of novel information and emotional content that requires a social/pragmatic perspective.

Complexity

S-FAVRES tasks were designed to maximize task complexity while maintaining a reasonable level of challenge for typically-developing adolescents. Task complexity is achieved when conditions require analysis of novel information, integration of stimuli, sustained attention, shifting of attention, goal maintenance, management of interference, self-regulation, flexibility and overall engagement of top down control [41,74,96,108]. Cognitive complexity is achieved in the S-FAVRES through incorporation of a minimum of five factors to be analysed, discrimination of relevant and irrelevant information, analysis and weighing of factors in order to draw a conclusion; some degree of inferential thinking; and multi-step tasks that require shifting from one stimulus or modality to another (i.e. from reading to writing to talking). Each task requires more than 10 minutes of sustained processing. Complex comprehension is examined through incorporation of complex sentences, figurative language (metaphor, idioms, humour) and comprehension of discourse at the critical level of interpretation with inference and perspective taking. Verbal expression is examined in tasks that demand generation of expository and persuasive discourse and discussion or interaction with the examiner. Social complexity was realized by incorporating perspective taking, role playing and a variety of types of communication partners (teachers, peers, stores and services). Speed of information processing is measured using standardized time scores. Verbal reasoning is challenged by requiring the examinee to analyse information, weigh factors, draw conclusions and present a rationale for choices. Some aspects of executive functioning are evaluated in tasks that require time management, high-level organization, prioritizing and flexibility. Meta-cognition is examined by asking the individual to reflect on their decisions in the post-hoc analysis for each task. Self-regulation is probed by embedding emotional triggers within the tasks.

Integrated functions

The S-FAVRES uses a functional integrative approach. It analyses higher order processes, not as distinct skills to be isolated or challenged one at a time, but rather as a constellation of possible contributing factors to be considered when evaluating integrated cognitive-communication performance. Beyond the level of individual units of language and discrete cognitive processes; S-FAVRES tasks require simultaneous integration of multiple functions (attention, working memory, reading comprehension, written expression, reasoning, discourse). A variety of types of responses are involved (listing main facts, comparison, divergence and prediction). Similar to daily life communications, examinees shift from reading, to underlining, to writing, to listening, to discussing.

In summary, the S-FAVRES was designed to closely approximate the communication and reasoning requirements of adolescent daily life. At the same time, the S-FAVRES has maintained the advantages of standardized tests including: the gathering of norms, consistent scoring, the measurement of speed and efficiency, analysis of reliability, administration within a reasonable time frame and ease of administration within a hospital, clinic, school or community setting. The aims of this study are: (1) To evaluate the ability of the S-FAVRES Accuracy, Rationale, Time and Reasoning sub-skills scores to differentiate performance of adolescents with and without brain injury; (2) To evaluate the influence of age and gender on S-FAVRES performance; and (3) To examine aspects of reliability and validity of the S-FAVRES including face validity, content validity, construct validity, concurrent validity, internal consistency, sensitivity and specificity, concurrent validity, inter-rater reliability and test–re-test reliability.

Method

Item development and pilot studies

Eight tasks were designed and evaluated using a set of task development criteria (i.e. task difficulty, relevance to adolescents, ecological validity, clarity, consistency, ease of scoring and practicality). Based on the feedback of two speech-language pathologists, two adolescents without ABI and a special education teacher, five of the original tasks were included in the pilot studies. In the first pilot study, five tasks were administered to 20 typically-developing (TD) adolescents aged 12–19 and then the tasks were evaluated. Students were interviewed regarding task relevance (‘How similar is this task to your daily activities?’, ‘Would you see yourself completing a task like this in your daily life?’) and difficulty (‘Was this task easy, difficult, medium?’). Based on this evaluation, one task was eliminated due to impracticality (> 20 minutes administration). A second pilot study was conducted to refine the four remaining tasks. Participants were 35 high school students in two grade 11 classes (aged 16–17). The students completed the test and participated in a focus group led by the speech-language pathologist and research assistant. The pilot studies allowed for opportunities to observe qualitative as well as quantitative aspects of test participation including aspects of emotional and self-regulation, metacognition, executive functioning, motivation and emotional engagement in the tasks (e.g. expressions of empathy or scorn for particular characters, self-encouragement). The consensus was that the tasks were ‘enjoyable’ and possessed sufficient challenge to be interesting and motivating without seeming too arduous. The test author and two research assistants then analysed the students’ performance in the pilot study by calculating the length of time taken for each task, the frequency of selection of specific responses for Accuracy scores and the frequency of factors included in Rationale responses, as well as the frequency of occurrence of Reasoning sub-skills responses. Based on this analysis and all of the student and clinician feedback provided in the pilot studies, the test author then developed the standardization version of the S-FAVRES.

Standardization

Participants

The S-FAVRES standardization study included 182 TD adolescents aged 12–19 whose performance was compared to that of 57 individuals with ABI aged 12–19. Participants in both groups were required to meet the following criteria: (a) no reported history of learning disability or psychiatric disorder; (b) possess functional use of the English language; (c) able to read at least one page of text at the grade 7 level (Flesch Kincaid Grade Level Ratings for S-FAVRES tasks are: Task 1 = Grade 5.9; Task 2 = Grade 6.7; Task 3 = Grade 5.8; and Task 4 = Grade 3.5); (d) able to write 1–2 paragraphs of intelligible text; and (e) enrolled in school. Participants in the TD group were required to have no history of brain injury by parental report. All participants in the ABI group had medically diagnosed and documented acquired brain injuries of non-progressive origin Aetiology of brain injury in the ABI group was comprised of motor vehicle crashes (44), sport concussions (5), falls (4), stroke/aneurysm (2), encephalitis (1) and unknown aetiology (1). The participant with ABI of unknown origin was found unconscious with no witnesses, then admitted to hospital and diagnosed with severe traumatic brain injury with positive radiological findings. Severity indicators are summarized in Table IV. Glasgow Coma Scale scores were available for 46/57 participants and, of these, 34 (74%) were severe, two (4%) were moderate and 10 (22%) were mild. Of the 11 participants for whom GCS was not available in the clinical history, all had a confirmed medical diagnosis of acquired brain injury; 100% had a period of hospitalization; 73% had experienced loss of consciousness and 64% had positive radiological findings. Of the mildly impaired participants, 70% had loss of consciousness, 60% had a period of hospitalization and 40% had positive radiological findings.

The distribution of time post-injury among the 57 participants with ABI was as follows: 0–6 months (11), 7–12 months (6), 13–24 months (13), 25–36 months (10) and > 36 months (17). Participants with ABI also met the following additional criteria: (a) diagnosed with acquired, non-progressive brain injury, (b) functioning at or above Level 6 (Confused Appropriate) on the Rancho Levels of Cognitive Functioning [113] and (c) able to tolerate at least 1 hour of assessment. Age distributions for both groups are presented in Table V.

The TD group was comprised of 59% (107) females and 41% (75) males, whereas the ABI group was comprised of 40% (23) females and 60% (34) males.

Procedures

The S-FAVRES testing was conducted by 34 clinically experienced speech-language pathologists and three research scientists in 27 test sites within Canada and the USA. Test sites included acute care hospitals, general hospitals, children's rehabilitation centres, schools and private practice clinics in the community. Institutional Review Board approval was obtained from the Upper Grand District School Board. The test site clinicians obtained consents from parents or adolescents of consenting age. Parents were asked to complete questions regarding history of brain injury, learning disability and psychiatric history. Subjects in the TD group were recruited by the clinicians at each test site through schools, volunteer agencies and sports teams or through the clinicians' extended networks. Students with brain injuries were recruited through the clinicians' clinical populations. The S-FAVRES was administered to individuals according to the test site instructions. To ensure privacy each participant was assigned a research number and no identifying information was maintained in the database. Data were entered into a secure database, with only project researchers having access to this information.

Table IV. ABI participant severity indicators.

GCS severity	Participants	Loss of consciousness (LOC)	Hospitalization	+ Radiological findings (CT, MRI)
Severe	34	100%	100%	100%
Moderate	2	100%	100%	100%
Mild	10	70%	60%	40%
Not recorded in medical records	11	73%	100%	64%

Table V. Age distribution of individuals in acquired brain injury (ABI) and typically-developing (TD) groups.

Age	ABI (n = 57)	TD (n = 182)
12–13	12 (21%)	45 (25%)
14–15	16 (28%)	59 (32%)
16–17	21 (37%)	62 (34%)
18–19	8 (14%)	16 (09%)

Results

Face validity

Face validity refers to whether a test looks as if it is measuring what it is supposed to and appears as such to the test taker. Face validity for the S-FAVRES was established through pilot study focus groups in which subjects indicated that the tasks were similar to their real life activities. Students in the TD sample were also asked to rate the difficulty of each task on a scale of 1 ('insultingly easy') to 10 ('too difficult to complete'). The mean rating of difficulty for task 1 was 3.1 (range = 1–6); for task 2 it was 4.7 (range = 2–8); for task 3 it was 3.4 (range = 1–6); and for task 4 it was 4.7 (range = 1–8). These findings suggest that the S-FAVRES presents cognitive-communication tasks with a range of difficulty levels that are of moderate challenge to TD adolescents.

Content validity

Content validity refers to whether the test items adequately sample the domain that the test purports to measure and it can be assessed by reviewing the empirical foundations of the test items and by surveying experts in the field [26]. The empirical foundations for the S-FAVRES are discussed in the rationale section. Also, 34 speech-language pathologists and neuroscientists were surveyed and 16 questionnaires were returned. The questionnaire and results of the completed surveys are summarized in Table VI.

One of the key findings of the survey was that 100% of respondents strongly agreed or agreed that the S-FAVRES assesses complex comprehension, complex expression, verbal reasoning, problem-solving and executive functioning and some aspects of social perception. Eighty-eight per cent of respondents strongly agreed or agreed that the S-FAVRES evaluates the areas of cognitive communication difficulty faced by their client population. Eighty-one per cent of respondents strongly agreed or agreed that the S-FAVRES tasks would be sufficiently challenging to discriminate performance of those with and without ABI. Sixty-nine per cent of respondents strongly agreed or agreed that the S-FAVRES tasks were similar to the communication tasks their students would face in daily life. Sixty-three per cent of respondents strongly agreed or agreed that the S-FAVRES was an activity level measure according to the WHO's framework [105]. In summary, task development and field-testing of the S-FAVRES involved input from clinicians, students, teachers and researchers in an effort to assess face and content validity.

Table VI. Summary of evaluations of the S-FAVRES by speech-language pathologists and neuroscientists ($n = 16$).

Survey question	Weighted mean evaluation	Respondents by question
The content of the S-FAVRES appears to *evaluate the areas of cognitive-communication difficulty* faced by my client population.	4.6	15
The tasks appear to be *similar to the communication tasks my students would face in daily life*.	4.3	15
The tasks appear to be *sufficiently challenging* to discriminate normal functioning from that of brain injured subjects.	4.5	14
The S-FAVRES appears to be more of a *measure of disability or activity limitations* than of impairment (using the WHO framework).	4.0	14
I think this test *evaluates complex comprehension* (beyond the paragraph level and at the level of critical thinking).	4.7	16
I think this test *evaluates complex expression* (at the level of discourse and pragmatics or social communication).	4.5	16
I think this test evaluates *verbal reasoning and problem-solving*.	4.8	16
I think the S-FAVRES evaluates some aspects of *executive functioning*.	4.8	16
I think the S-FAVRES *evaluates some aspects of social perception* (i.e. interpretation of listener's perspective).	4.6	16
The *administration* of the S-FAVRES is straightforward.	4.4	16
The *scoring* of S-FAVRES is straightforward.	3.7	15
The S-FAVRES takes a reasonable amount of *time* relative to the amount of information it provides.	4.3	16
In clients where I have been able to observe daily functioning in natural contexts, the S-FAVRES performance was *consistent with or predictive of their real life functioning*.	4.4	8

Respondents evaluated 13 questions about the S-FAVRES on a scale of 1–5, where 5 is Strongly Agree; 4 is Agree; 3 is Agree Somewhat; 2 is Disagree; 1 is Strongly Disagree. Respondents by question refers to the number of individuals who answered the question. The Weighted Mean evaluation was calculated from the total number of responses provided per question.

Construct validity

Construct validity is determined by demonstrating that the test relates to a defined construct or concept of the behaviour to be examined, by statistical evidence of the relationships among components of the test, by internal consistency of the test or by relationships between test scores and other variables on which the groups differ [114,115]. Construct validity was evaluated by formulating and testing a number of empirically driven hypotheses about the test and the target population.

Construct premise #1: Accuracy and rationale scores

It was hypothesized that students with ABI would obtain lower S-FAVRES Accuracy and Rationale scores and these hypotheses were supported. On average, individuals in the ABI group achieved significantly lower ($p < 0.001$) Total Accuracy scores ($M = 16.2$; SD = 3.2) than students in the TD group ($M = 19.0$; SD = 1.5) and significantly lower ($p < 0.001$) Total Rationale scores ($M = 15.2$; SD = 3.9) than TD students ($M = 18.7$; SD = 1.6). The results for Accuracy and Rationale are presented in Table VII.

Construct premise #2: Age

It was hypothesized that S-FAVRES Accuracy and Rationale scores would differentiate those with ABI from TD peers throughout the span of ages 12–19. A Wilcoxon two sample test was used to compare the performance of TD students to that of students with ABI within each of the following age groups: 12–13; 14–15; 16–17; 18–19. Accuracy and Rationale scores were significantly different for the ABI and TD groups at all age levels. There were statistically significant differences in accuracy and rationale scores between those with acquired brain injuries and typically-developing controls in each age group. This trend was also observed for Reasoning sub-skills scores. Also Reasoning sub-skills scores increased significantly with age in the TD group (Wilcoxon two-sample test, 2-sided; $p \leq 0.001$), but not in the ABI group ($p = 0.34$). These findings suggest that developmental

Table VII. Comparison of S-FAVRES total accuracy and rationale scores between acquired brain injury (ABI) and typically-developing (TD) individuals.

	ABI ($n = 57$)			TD ($n = 182$)			
Scores, Max = 20	Mean (SD)	Median (IQR)	Range	Mean (SD)	Median (IQR)*	Range	p
Accuracy	16.2 (3.2)	17 (14–18)	6–20	19.0 (1.5)	20 (19–20)	13–20	≤ 0.001*
Rationale	15.2 (3.9)	15 (13–19)	4–20	18.7 (1.6)	19 (18–20)	9–20	≤ 0.001*

Wilcoxon two sample test, 2-sided.
* Significant group difference.
IQR, Interquartile range represents the middle 50% of the data between the 25th and 75th percentiles.

improvements in reasoning performance are disrupted in adolescents with ABI. These data are presented in Table VIII.

Construct premise #3: Time

It was hypothesized that students with ABI would require more time to complete the test than their TD peers due to evidence of impairments of speed of processing in ABI [3,17,26,27,41,90,97,116]. The S-FAVRES Time scores were not significantly different for any of the age groups. Although time scores differentiated FAVRES performance for adults with and without ABI [90], this was not the case for adolescents. There was substantial variability in time scores for both groups, but greater variability in the ABI group whose time scores spanned from 20–113 minutes overall.

Construct premise #4: Reasoning sub-skills

The Reasoning sub-skills score was calculated by scoring responses to a set of post-hoc interview questions asked after completion of each reasoning task. The questions are designed to analyse whether the individual was able to Get the Facts, Eliminate Irrelevant Information, Weigh the Facts, Flexibly change a response based on new conditions, Predict Consequences or Generate Alternatives. It was hypothesized that the Reasoning sub-skills score would reflect areas of difficulty for those with ABI. Due to time constraints, some test site clinicians did not proceed with the Reasoning sub-skills questions. Reasoning sub-skills data were available for 137 TD and 53 ABI individuals. On average, individuals with ABI obtained significantly lower Reasoning sub-skills scores than TD controls. All Reasoning sub-skills yielded statistically significant differences including: Getting the Facts, Eliminating Irrelevant Facts, Weighing the Facts, Flexibility, Predicting consequences, Generating alternatives and Total Reasoning sub-skills. These findings are summarized in Table IX.

The differences between the ABI and TD groups on Reasoning sub-skills were significant ($p \leq 0.001$) for each of the four S-FAVRES tasks.

Construct premise #5: Generation

As hypothesized, S-FAVRES Generation tasks differentiated the performance of adolescents with and without ABI. These tasks required individuals to generate as many ideas or examples as they could on a particular theme within 1 minute. Statistical analysis of S-FAVRES Generation scores revealed significantly lower scores for generating alternatives in the ABI group and this was a consistent trend in all four tasks. These data are presented in Table X.

Construct premise #6: Sensitivity and specificity

It was hypothesized that S-FAVRES Accuracy, Rationale and Reasoning sub-skills scores would discriminate performance of students with ABI from the TD group.

Table VIII. Comparison of S-FAVRES total reasoning sub-skills score by age group between acquired brain injury (ABI) and typically-developing (TD) individuals.

Age (years)	ABI (n = 53)			TD (n = 137)			
	Mean (SD)	Median (IQR)	Range	Mean (SD)	Median (IQR)	Range	p-value
12-13	82.3 (18.9)	90 (66–98.5)	48–105	94.1 (15.2)	90.5 (84–104)	67–128	0.182
14-15	85.5 (20.7)	86 (68–103)	47–120	100.2 (14.5)	98.5 (89–111)	78–130	0.019*
16-17	84.8 (18.0)	79 (74–101)	50–117	108.7 (17.0)	105.5 (95–123)	77–142	< 0.001*
18-19	92.4 (8.2)	91 (88–95)	83–109	112.9 (11.2)	112 (108–123)	87–127	0.016*

Wilcoxon two sample test, 2-sided.
* Significant group difference.
IQR, Interquartile range represents the middle 50% of the data between the 25th and 75th percentiles.

Table IX. Comparison of reasoning sub-skills for tasks 1–4 combined between acquired brain injury (ABI) and typically-developing (TD) individuals.

Reasoning sub-skills	ABI (n = 53)			TD (n = 137)			
	Mean (SD)	Median (IQR)	Range	Mean (SD)	Median (IQR)	Range	p-value
Getting the facts	14.7 (3.6)	15 (12–17)	7–20	17.6 (2.4)	18 (16–20)	8–20	< 0.001*
Eliminating irrelevant facts	2.3 (1.1)	2 (2–3)	0–4	3.1 (0.9)	3 (2–4)	1–4	< 0.001*
Weighing the facts	2.9 (1.0)	2 (2–4)	0–4	3.8 (0.5)	4 (4–4)	2–4	< 0.001*
Flexibility	3.0 (0.8)	3 (2–4)	1–4	3.3 (0.9)	4 (3–4)	0–4	0.008*
Predicting consequences	13.8 (2.6)	15 (13–16)	6–16	15.2 (1.4)	16 (15–16)	8–16	< 0.001*
Generating alternatives	48.7 (13.9)	48 (40–59)	23–77	58.7 (14.2)	57 (46–69)	32–96	< 0.001*
Total	85.4 (17.9)	89 (72–99)	47–120	101.7 (16.4)	101 (89–113)	67–142	< 0.001*

Wilcoxon two sample test, 2-sided.
* Significant group difference.
IQR, Interquartile range represents the middle 50% of the data between the 25th and 75th percentiles.

Table X. Comparison of S-FAVRES total generation score across tasks 1–4 between acquired brain injury (ABI) and typically-developing (TD) individuals.

	ABI (n = 53)			TD (n = 137)			
S-FAVRES tasks	Mean (SD)	Median (IQR)	Range	Mean (SD)	Median (IQR)	Range	p-value
Task 1	10.2 (4.0)	9 (8–13)	1–20	12.7 (4.4)	12 (9–15)	5–25	< 0.001*
Task 2	13.7 (4.4)	14 (10–16)	4–26	15.8 (4.0)	15 (13–18)	7–29	< 0.001*
Task 3	12.1 (5.2)	11 (9–15)	0–24	14.7 (5.0)	14 (11–18)	2–28	< 0.001*
Task 4	12.8 (4.4)	12 (9–15)	5–24	15.6 (5.0)	14 (12–19)	6–32	< 0.001*
Total test	48.7 (13.9)	48 (40–59)	23–77	58.7 (14.2)	57 (46–69)	32–96	< 0.001*

Wilcoxon two sample test, 2-sided.
* Significant group difference.
IQR, Interquartile range represents the middle 50% of the data between the 25th and 75th percentiles.

This hypothesis was supported. S-FAVRES Total Accuracy and Total Rationale scores were highly discriminatory between the ABI and TD groups. The total Accuracy, Rationale and Reasoning sub-skills scores were analysed for their ability to identify the performance of those with and without brain injuries by using a Receiver Operating Characteristic (ROC) curve. This method analyses each type of score with respect to its ability to accurately classify impaired performance as brain injured (sensitivity) and non-impaired performance as typically-developing (specificity). A score under the ROC curve that is higher than 0.50 is considered to be acceptable and scores over 0.80 are considered to be highly discriminatory between the two groups. The combined Accuracy and Rationale scores on the S-FAVRES yielded a score of 0.85. Accuracy scores alone and Rationale scores alone yielded scores of 0.82 and 0.79, respectively. The Reasoning sub-skills scores across all tasks yielded a score of 0.67.

Construct premise #7: Internal consistency

Internal consistency reflects the degree to which a test measures a single construct or the constancy of results across items within a test [26,117]. The S-FAVRES construct maintains that a set of reasoning sub-skills is utilized when tackling higher level reasoning, problem-solving or communication tasks and these include the ability to: get the most important facts; eliminate irrelevant information; weigh the facts; think flexibly; predict consequences; and generate alternatives. It was anticipated that one's performance in these reasoning sub-skills would be consistent across the four S-FAVRES tasks, even if those tasks were very different. Therefore, it was hypothesized that S-FAVRES Reasoning sub-skills scores would have a high degree of internal consistency across the four S-FAVRES tasks. Cronbach's alpha [118] is a measure recommended to evaluate internal consistency in test design [26,119]. Cronbach's alpha scores for S-FAVRES were 0.85 for all subjects' Reasoning sub-skills across tasks, 0.81 for TD and 0.84 for individuals with ABI, indicating an acceptably high degree of consistency [117] for Reasoning sub-skills scores At the same time, there were low-to-moderate degrees of consistency in total Accuracy (0.50) and Rationale (0.61) scores across the four S-FAVRES tasks. This lends support to the idea that each of the S-FAVRES tasks provides a unique type of challenge. Across tasks there appears to be some consistency of approach in terms of Reasoning sub-skills or whether the individual was able to get the facts, weigh the facts and so on.

Construct premise #8: Discriminatory ability of reasoning sub-skills

The design of the S-FAVRES includes all six Reasoning sub-skills with the view that each may contribute some information to the individual's cognitive-communication profile. The discriminatory ability of the Reasoning sub-skills tasks to classify students with or without brain injury was measured by the area under the curve (AUC) for an ROC curve. Each of the Reasoning sub-skills rated in the moderate range (i.e. ≥ 0.60) in terms of sensitivity and specificity in discriminating the performance of individuals with ABI from their TD peers. The discriminating power for each Reasoning sub-skills were as follows: Getting the Facts (0.73); Eliminating Irrelevant information (0.69); Weighing the Facts (0.72); Flexibility (0.60); Predicting Consequences (0.70); and Generating Alternatives (0.64). No one reasoning sub-skill was substantially more or less sensitive than another.

Construct premise #9: Age and gender

It was hypothesized that S-FAVRES scores would be able to discriminate between ABI and TD, regardless of age and gender. Logistic regression was conducted to examine S-FAVRES scores in relation to age, gender and the presence of brain injury. The results presented in Table XI indicate that Accuracy, Rationale and Reasoning sub-skills scores alone accounted for 83%, 79% and 77% of the variance, respectively, and each of these analyses reached a level of significance of $p < 0.001$.

Although S-FAVRES scores varied as a function of age, age alone was not as predictive of group membership (ABI vs TD) as Accuracy, Rationale or Reasoning scores. Gender was not a significant predictor of performance. In each model of the analysis, the S-FAVRES scores (Accuracy, Rationale, Reasoning sub-skills) were significantly more predictive than age or gender. Use of a combined model that includes Accuracy, Rationale and Reasoning sub-skills scores predicted assignment to the ABI or TD groups with a high degree of accuracy (87%).

Table XI. Logistic regressions examining independent effect of S-FAVRES scores in predicting group membership, over and above age and gender.

	AOR of being in ABI group (95% CI)	*p*-value	AUC
Accuracy score only model			0.83
Accuracy	0.55 (0.46–0.66)	< 0.001	
Age at test	1.34 (1.11–1.63)	0.003	
Gender	0.73 (0.35–1.50)	0.385	
Rationale score only model			0.79
Rationale score	0.60 (0.52–0.71)	< 0.001	
Age at test	1.22 (1.01–1.47)	0.035	
Gender	0.81 (0.39–1.68)	1.68	
Reasoning score only model			0.77
Reasoning score	0.93 (0.91–0.96)	< 0.001	
Age at test	1.37 (1.13–1.68)	0.002	
Gender	0.57 (0.27–1.18)	0.131	
Combined model			0.87
Accuracy score	0.67 (0.53–0.85)	0.001	
Rationale score	0.76 (0.63–0.92)	0.005	
Reasoning score	0.96 (0.93–0.99)	0.014	
Age at test	1.46 (1.15–1.84)	0.002	
Gender	0.74 (0.32–1.74)	0.488	

AOR, Adjusted odds ratio; AUC, Area under the curve.

Construct premise #10: Scoring system

It was hypothesized that with the S-FAVRES scoring system it would be possible to establish cut-off scores that would reflect a high degree of sensitivity (identifying those with brain injuries) and specificity (identifying those without brain injuries) for the total test. This hypothesis was supported. The discriminatory ability of the Reasoning, Accuracy, Rationale and Reasoning sub-skills scoring systems to classify students with or without brain injury was measured by the area under the curve for an ROC curve. The ROC curves for Accuracy, Rationale and Reasoning sub-skills are 0.81, 0.79 and 0.73, respectively. A model that combines the Accuracy, Rationale and Reasoning sub-skills scores increases sensitivity and specificity with an Area Under the Curve of 0.85. In summary, the scoring system for the S-FAVRES provides three types of scores that each contributes valuable clinical information and that act in a combined manner to improve overall test sensitivity and specificity.

Concurrent validity

Concurrent validity refers to the relationship between the test and another independent criterion considered to be the current gold standard in measurement for a particular domain [114,115]. The Behaviour Rating Inventory of Executive Function (BRIEF) [120] evaluates executive functions in daily activities, such as the home and school environment [41]. It is a questionnaire with separate forms for parents and teachers of school age children aged 5–18 years. The BRIEF examines eight aspects of behaviour and analyses scores within two factors determined by factor analysis: Behaviour Rating Index (inhibit, shift, emotional control) and Metacognition Index (initiate, working memory, plan/organize, organization of materials and monitor). The BRIEF has been found to have a high level of internal consistency, appropriate inter-rater and test–re-test reliability and there is evidence to support its validity for paediatric brain injury populations [120,121]. S-FAVRES total Accuracy, Rationale and Reasoning sub-skills scores were not significantly correlated with any of the three indexes of the BRIEF, Behavioural Regulation, Metacognition or Global Executive scores (all Spearman correlation coefficients < 0.12, all p-values > 0.71) in a sample of 10 individuals with ABI. These findings suggest that the S-FAVRES is measuring aspects of cognitive-communication functioning that are unique from the behavioural observations measured by the BRIEF. The difference between the two measures could be attributed to the fact that the S-FAVRES is a measure of productive performance in complex communication tasks, whereas the BRIEF is a measure of parent observations in a variety of daily activities. The S-FAVRES may measure the impact of executive functioning and reasoning on communication, separate from other daily behaviours. Teacher ratings on the BRIEF could correlate more highly with S-FAVRES performance, since teachers are more likely than parents to observe daily performance on complex cognitive-communication tasks. Another possibility is that the sample size for this study was too small to detect possible correlations. Further evaluation of concurrent validity with other paediatric measures is warranted.

Predictive validity

The S-FAVRES and FAVRES were intended as tests that could differentiate functional performance of those with intact cognitive-communication abilities from those without and could predict real world functioning. The adult version of the FAVRES has shown promise in terms of prediction of everyday functioning such as return-to-work or return-to-school [90,107,110]. The Student FAVRES, as a new measure, will require ongoing examination of its predictive validity. Newsome et al. [46] utilized the research edition of the Student FAVRES tasks to evaluate 'everyday living executive function skills' in a functional MRI study of self-awareness and perspective taking that compared adolescents aged 12–19 with brain injury to typically-developing peers. The study found that, when thinking of the self from a third person perspective, adolescents with traumatic brain injury demonstrated greater activation in brain regions implicated in social cognition. Findings indicated that the adolescents with brain injuries performed significantly lower than the typically-developing group on all cognitive and social-cognitive measures, including measures of reading, working memory, social judgement and everyday executive function skills as measured by the S-FAVRES. Although the S-FAVRES appears to be an acceptable measure in terms of discriminating performance of those with and without brain injury, its ability to predict real world performance at school or work requires further examination.

Reliability

Inter-rater reliability was analysed by comparing the scoring of one speech-language pathologist and a research assistant on test results for 20 participants (10 ABI; 10 TD). The Spearman Correlation Coefficient was 0.98 for Accuracy, 0.74 for Rationale and 0.99 for Time, respectively indicating an acceptably high level of reliability [26,122].

Test–re-test reliability was evaluated on 10 participants in the TD control group who repeated the test 14–38 days from the first administration. Data were analysed using both Spearman correlation coefficients and Intra Class Correlation coefficients. Spearman correlation coefficients revealed moderate-to-high correlations between test and re-testfor Accuracy (0.58, $p \leq 0.079$); Rationale (0.60, $p \leq 0.068$), Time (0.65, $p \leq 0.044$) and Total Reasoning sub-skills (0.68, $p \leq 0.030$) and were either statistically significant or approached significance. Time score correlations were moderately high and significant. There was a trend toward faster time scores on the second administration and this was attributed to greater familiarity with the material. Intra Class Correlation coefficient scores comparing Time one to Time two results demonstrated fair agreement for Accuracy (0.28), moderate agreement for Rationale (0.56) and Time (0.51) and strong agreement for Reasoning sub-skills (0.80).

Discussion

The goal in developing the S-FAVRES was to create a test of sufficient challenge to detect subtle cognitive-communication deficits throughout the developmental stages of adolescence. As Ciccia et al. [3] indicate, many existing standardized tests evaluate language functions that have stabilized before later adolescence and sufficient challenge requires that tasks call on the type of integrative and decision-making functions that are continuing to develop at this stage. S-FAVRES tasks are challenging, contextually rich, relevant to adolescents' daily lives and similar to the complex communications of everyday interactions. At the same time, the goal was to develop tasks that could measure performance in a quantifiable, consistent and practical manner for clinical utility.

The results of the current study provide evidence to support the validity, reliability, sensitivity and specificity of the S-FAVRES. Face validity was established through focus groups and student evaluations of task relevance and difficulty. Content validity was supported by expert ratings regarding the aspects of cognitive-communication functioning the test measures. A set of hypotheses was tested to evaluate construct validity. Three aspects of S-FAVRES scoring, Accuracy, Rationale and Reasoning sub-skills, were able to differentiate students with and without brain injury with high levels of sensitivity and specificity. The S-FAVRES functional construct for verbal reasoning was established through statistical analysis of group differences as well as the discriminatory ability of each of the Reasoning sub-skills to correctly classify participants with ABI. Those with ABI were less likely to achieve optimal scores in terms of: Getting the Facts, Eliminating Irrelevant Information, Weighing the Facts, Flexibility, Predicting Consequences and Generating Alternatives. Detection of difficulties in these areas provides speech-language pathologists with a starting point for designing treatment protocols for communication interventions that will be relevant to real world participation.

A key consideration with any assessment measure is the purpose and timing of administration. The purpose of the S-FAVRES is to analyse adolescents' cognitive-communication strengths and weaknesses to assist with planning for intervention and for return to participation at school, work and community. Candidates for this evaluation are students who are about to be discharged from hospital, are attending outpatient rehabilitation or who are living in the community with concussion or acquired brain injury. The S-FAVRES is an activity level measure most suited to clinical questions that seek to predict how a student will perform in school or social settings or in returning to communications within the community. The S-FAVRES provides some indication of an individual's strengths and weaknesses in completing the complex communication tasks of daily life. Additional measures are required to evaluate impairments in specific communication domains such as comprehension and word retrieval. Therefore, S-FAVRES results should be interpreted by a speech-language pathologist within the context of a full cognitive-communication assessment profile that includes: pre-injury status, impairment level standardized testing, collateral interview, discourse and social communication analysis and evaluation of cognitive-communication functioning in a variety of contexts (i.e. teacher evaluation; observation, self and parent input).

Study limitations/further research

This is the first evaluation of the S-FAVRES and there are limitations and indications for continued research. Recruitment of participants was conducted using a two gate sampling strategy with test site clinicians selecting individuals with brain injuries from their caseloads and typically-developing adolescents from other locations in the community. A one gate sampling strategy would reduce the potential for sampling bias [123], but was not practical for the purposes of this initial standardization. This analysis indicated that group samples were equivalent on the basis of age and gender. Analysis of socioeconomic status, educational performance and other cognitive-communication performance measures would also be useful and further research into these factors is warranted. An attempt was made to reduce incorporation bias, which occurs when the same participants are used to develop a test and to determine its diagnostic accuracy [123]. The S-FAVRES tasks and scoring system were developed within pilot studies using a separate group of typically-developing individuals. The final version of the measure was administered to another group of participants in the standardization study. Blinding of examiners is another means of reducing bias that is recommended to improve diagnostic accuracy [123]. Although it was not possible to have the test administered by blinded examiners, steps were taken to separate those involved in subject selection and administration, scoring and data analysis. Examiners administered the S-FAVRES at test sites and sent in the participant's written responses to the research centre where they were scored by the first author and a research assistant in a scoring table that was separated from identifying information (i.e. ABI, TD, age, gender). Data analysis was conducted by a statistician at another research centre.

For the purposes of this initial standardization, the SFAVRES was administered to a broad sample of individuals with ABI ranging from mild-to-severe and with a range of stages of recovery from 2 months to 14 years post-injury. Administration of the SFAVRES to this broad sample helped to demonstrate that the S-FAVRES has some utility in identifying cognitive-communication deficits across a diverse range of characteristics within the ABI population. Future studies with more homogenous samples will be required to answer specific clinical questions about S-FAVRES performance with specific types of ABI (i.e. sport concussion, cardiac arrest), at specific times in the recovery process (i.e. acute recovery, lifelong functioning), for different types of assessment (i.e. goal planning, treatment outcomes, return to school) and for specific participant characteristics (i.e. cognitive or communication deficits in specific domains).

A study exploring the S-FAVRES ability to predict real world functioning was not conducted. However, feedback from clinicians, parents and students indicated the S-FAVRES' potential in terms of ecological and predictive validity. A test's ability to predict real world functioning must be evaluated over time and it is hoped there will be future studies to examine the predictive validity of the Student FAVRES. In terms of concurrent validity, additional research is required to determine how the S-FAVRES correlates with other measures of adolescent cognitive and communication performance. In the current study, correlations with the BRIEF were low. Studies indicate that correlations among measures of executive functioning have been found to be modest, possibly because each challenges a slightly different aspect of executive functioning and possibly because the construct of executive functioning requires better definition [123]. The S-FAVRES is proposed not as a specific measure of executive functioning, but rather as a measure of functional communication which is influenced by multiple cognitive processes. The complexities in defining reasoning, executive functioning, metacognition and problem-solving as separate constructs lend support to the utility of an activity level measurement of integrated communication activities in which they are all at play. The S-FAVRES approach to functional evaluation of performance in complex communication activities is unique in this regard and the current results appear to support the utility of this approach.

Conclusion

In summary, the S-FAVRES is a measure of higher-level cognitive-communication abilities that yields four types of scores that are sensitive to the difficulties experienced by adolescents with acquired brain injuries. It differentiates between the performance of adolescents with brain injury and their typically-developing peers. It reflects developmental changes in performance and provides sufficient challenge to differentiate the performance of older adolescents (18–19 years old). It provides clinicians with a framework for analysing strengths and weaknesses in performing cognitively and communicatively demanding tasks. Statistical analysis and expert evaluation have demonstrated acceptable levels of inter-rater, test–re-test reliability, face, content and construct validity. More research is required to evaluate concurrent and predictive validity. The S-FAVRES provides clinicians with a basis for evaluation of complex communication in integrated tasks that simulate the complex cognitive-communication requirements of daily academic, community and social life. The S-FAVRES shows promise as a contextually based measure of activity level performance.

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