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Brain Injury Vision Symptom Survey (BIVSS) Questionnaire

Hannu Laukkanen*, Mitchell Scheiman†, and John R. Hayes‡

ABSTRACT

Purpose. Validation of the Brain Injury Vision Symptom Survey (BIVSS), a self-administered survey for vision symptoms related to traumatic brain injury (TBI).

Methods. A 28-item vision symptom questionnaire was completed by 107 adult subjects (mean age 42.1, 16.2 SD, range 18–75) who self-reported as having sustained mild-to-moderate TBI and two groups of reference adult subjects (first-year optometry students: mean age 23.2, 2.8 SD, range 20–39; and 71 third-year optometry students: mean age 26.0, 2.9 SD, range 22–42) without TBI. Both a Likert-style method of analysis with factor analysis and a Rasch analysis were used. Logistic regression was used to determine sensitivity and specificity.

Results. At least 27 of 28 questions were completed by 93.5% of TBI subjects, and all 28 items were completed by all of the 157 reference subjects. BIVSS sensitivity was 82.2% for correctly predicting TBI and 90.4% for correctly predicting the optometry students. Factor analysis identified eight latent variables; six factors were positive in their risk for TBI. Other than dry eye and double vision, the TBI patients were significantly more symptomatic than either cohort of optometry students by at least one standard deviation ($p < 0.001$). Twenty-five of 28 questions were within limits for creating a single-dimension Rasch scale.

Conclusions. Nearly all of the adult TBI subjects were able to self-complete the BIVSS, and there was significant mean score separation between TBI and non-TBI groups. The Rasch analysis revealed a single dimension associated with TBI. Using the Likert method with the BIVSS, it may be possible to identify different vision symptom profiles with TBI patients. The BIVSS seems to be a promising tool for better understanding the complex and diverse nature of vision symptoms that are associated with brain injury.

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Key Words: mTBI (mild traumatic brain injury), symptoms, survey, questionnaire, BIVSS (Brain Injury Vision Symptom Survey), Rasch, Likert scale

Traumatic brain injury (TBI) is not only relatively common but also a significant public health and socioeconomic burden in the U.S., resulting in suffering, lost days from work, and incurred medical costs.[1] According to hospital visit data reported to Centers for Disease Control and Prevention, more than 1.7 million individuals a year in the U.S. sustain brain injury.[2] This is likely an underestimate of incidence because many who incur "mild" traumatic brain injury (mTBI) do not report to the hospital. Many of those who do not report to the hospital immediately after the brain insult may only first seek help for persistent and troubling symptoms days, weeks, or even months after the trauma. TBI can be categorized from mild to severe, but according to a CDC report, 75% fall into the mild category.[3] A hospitalization study documented 80% of presenting TBI as "mild and uncomplicated".[4] Despite a classification of mTBI, the effect on the individual's function can be anything but mild. mTBI can affect many different brain structures and functions with symptoms related to physical, cognitive, or behavioral function.[5] The occurrence of specific visual consequences secondary to brain injury has been well documented[6–8] with an estimated frequency of sensorimotor vision symptoms after TBI ranging between 30 and 85%, depending upon the specific criteria used.[9] Among these consequences are complaints related to different aspects of vision such as comfort, clarity, light sensitivity, peripheral awareness, motion sensitivity, and visual functions such as spatial localization, two-eyed depth perception, and reading vision.[10]

*OD, MEd, FAAO
†OD, FAAO
‡PhD
Pacific University College of Optometry, Forest Grove, Oregon (HL, JRH); and Pennsylvania College of Optometry at Salus University, Philadelphia, Pennsylvania (MS).

A symptom questionnaire, the Brain Injury Vision Symptom Survey (BIVSS, Appendix 1, available at http://links.lww.com/OPX/A248), was developed to assist health care providers document vision complaints secondary to mild-to-moderate brain injury with adults. The purpose of this study was to validate the instrument on a sample of adult TBI against a reference cohort of optometry students (Students). Our underlying hypotheses were that symptom severity would differ between the groups (as measured by Rasch analysis) and/or that groups would have different symptom profiles (factor analysis of Likert data).

METHODS

The Brain Injury Vision Symptom Survey (BIVSS) was registered with the IRB and approval granted to gather de-identified BIVSS data for this study.

Subjects

Anonymous BIVSS data were obtained from 107 TBI (mean age 42.1, 16.2 SD, range 18–75). Forty-one (41) TBI fell in the age range 20 to 42 (mean age = 32.3, 6.8 SD). We did not collect gender and ethnicity information for the TBI patients. For this study, TBI diagnosis was not externally verified; subjects self-reported as having previously sustained a traumatic brain injury (either with or without a previous medical diagnosis). To be included, subjects needed to be at least 18 years or older, but duration of elapsed time since the first or most recent brain injury was not an exclusion criterion. Subjects whom had sustained brain injury were recruited from brain injury support groups (Portland, OR metro area) and via optometrists who attended the 2013 NORA or COVD meetings. Control subjects included 157 students from two different optometry classes (who self-reported as not having sustained a previous TBI). The reference group included 86 newly matriculated first-year students (mean age 23.2, 2.8 SD, range 20–39; 38.5/61.5% male/female; 48% White, 37% Asian, 2% Pacific Islander, 1% Hispanic, or "other") and 71 third-year students (mean age 26.0, 2.9SD, range 22 to 42; 37.5/62.5% male/female; 71.7% White, 20.2% Asian, 3.1% Hispanic, 1.1% Native American, 0.8% African-American, 0.3% Pacific Islander, or "other"). It is important to note that the two different reference groups completed the BIVSS questionnaires during different academic semesters and with differing academic loads. First-year students completed their questionnaires the first week of autumn semester after the undergraduate to graduate school transition summer semester (presumably with little or no academic load). In contrast, the third-year student group completed BIVSS questionnaires in the middle of spring semester, 1 week before having to sit for the Part I NBEO examination.

Materials

The BIVSS is a self-administered 28-item scaled survey designed to query multiple dimensions of vision-related behaviors (eyesight clarity, visual comfort, diplopia, depth perception, dry eye, peripheral vision, light sensitivity, and reading) in adults (Table 1). Participants responded to the frequency of symptoms on a five-point Likert scale (Never, Seldom, Occasionally, Frequently, Always).

The BIVSS measures a wide variety of symptoms that were chosen based on their association with TBI. It is a multidimensional model with only a few questions dedicated to each dimension. Symptoms create a profile that can be different between individuals.

Statistical Methods

The data were analyzed with two different methods. One method was to use Rasch analysis and compute the logits for each response category for each question.[11] The other method was to use Likert's analysis by treating the ordinal data as interval and applying standard parametric statistics.[12]

Likert Method of Analysis

Likert studied attitude scales. It was his contention that each question within the scale related to the same latent attitude. The assumption was that each range of rank ordered responses covered the entire range of the latent attitude. Multiple measurements, i.e. multiple questions, increased the reliability of the location for a particular individual on the underlying, unobservable scale.

Likert suggested that if the frequencies of rank ordered items were normally distributed, then the Likert scale questions would be proportional to the standard normal curve.[12] If they were proportional, then the relationship between the Likert scale and the cumulative normal scores (z-scores) obtained from the frequencies of responses for each question would be linear.[11] Figures for each of the eight latent variables and their corresponding questions are included in Appendix 2, available at http://links.lww.com/OPX/A249. Further, we looked at the standard deviation of the residuals divided by the slope of the regression line as a measure of fit of the proportionality of the data to a straight line (coefficient of determination).

Massof has pointed out that tails of the normal distribution at 0 and 100 percent frequency are not calculable because the values at those points are infinite.[11] This limits the ability to determine proportionality. We determined the cumulative frequency at each point along the five-point Likert scale then converted the percentage of observations at each point to a standard normal value. The underlying intensity of a symptom increases until the subject notices it. Before that point, the subject responds "Never" to the symptom. We assume that the unobservable intensity up to point of responding "Seldom" reflects the left hand portion of the normal curve. Close to 50% of the Students answered "Never" to each of the questions. The problem of the normal distribution's left tail value of zero percent at negative infinity was avoided by using the cumulative percent and starting with the frequency of "Never". However, there is still a problem calculating the standard score on the right-hand side of the distribution at 100%. We arbitrarily chose to use the standard normal value of the midpoint frequency between the last two scale values. For example, if the Students accumulate 100% of the responses by the fourth rank ("Frequently") and 95% were at the third rank ("Occasionally") or below, then the last point standard score was the midpoint between 100 and 95% = 97.5%, $z = 1.96$.

TABLE 1.
Likert profile analysis: principal components factor loadings using only optometry students

Factor	Question	Category	Question	F1	F2	F3	F4	F5	F6	F7	F8
1	24	Reading	Short attention span/easily distracted when reading	**0.80**	0.13	0.11	0.20	0.19	0.05	0.11	−0.09
1	25	Reading	Difficulty/slowness with reading and writing	**0.86**	−0.07	0.07	0.08	0.11	0.14	0.15	0.06
1	26	Reading	Poor reading comprehension/can't remember what was read	**0.81**	0.03	0.25	0.14	0.03	−0.07	0.22	−0.06
1	27	Reading	Confusion of words/skip words during reading	**0.79**	0.18	−0.07	0.07	−0.02	−0.07	−0.03	0.21
1	28	Reading	Lose place/have to use finger not to lose place when reading	**0.60**	0.00	0.21	−0.02	−0.11	0.09	−0.10	0.25
2	5	Comfort	Eye discomfort/sore eyes/eyestrain	−0.01	**0.76**	0.15	0.19	0.17	0.07	0.07	0.06
2	6	Comfort	Headaches or dizziness after using eyes	0.01	**0.80**	0.19	0.10	0.00	0.12	−0.04	−0.07
2	7	Comfort	Eye fatigue/very tired after using eyes all day	0.15	**0.73**	−0.02	0.23	0.22	0.16	0.06	−0.05
2	8	Comfort	Feel "pulling" around the eyes	0.07	**0.55**	−0.01	0.22	0.23	0.22	0.14	0.25
3	4	*Eyesight Clarity*	Poor night vision/can't see well to drive at night	0.00	0.12	**0.46**	0.22	0.28	0.27	0.12	0.02
3	18	Depth Perception	Clumsiness/misjudge where objects really are	0.08	0.19	**0.71**	0.03	0.08	0.28	0.24	0.08
3	19	Depth Perception	Lack of confidence walking/missing steps/stumbling	0.12	0.04	**0.75**	−0.04	0.00	0.08	0.07	0.33
3	20	Depth Perception	Poor handwriting (spacing, size, legibility)	0.19	0.10	**0.55**	0.01	−0.18	−0.12	−0.05	0.14
4	15	Dry Eye	Eyes feel "dry" and sting	0.11	0.18	−0.10	**0.80**	0.16	0.08	0.11	0.05
4	16	Dry Eye	"Stare" into space without blinking	0.06	0.18	0.03	**0.77**	0.02	0.15	0.17	0.09
4	17	Dry Eye	Have to rub the eyes a lot	0.14	0.17	0.18	**0.64**	0.27	0.07	−0.14	0.12
5	9	Doubling	Double vision—especially when tired	0.04	0.33	−0.09	0.03	**0.79**	0.03	0.02	0.17
5	10	Doubling	Have to close or cover one eye to see clearly	0.00	−0.12	0.44	0.22	**0.67**	0.05	0.17	−0.04
5	11	Doubling	Print moves in and out of focus when reading	0.05	0.19	−0.22	0.21	**0.64**	0.12	0.16	0.19
6	12	Light Sensitivity	Normal indoor lighting is uncomfortable—too much glare	0.02	0.05	−0.10	0.00	0.07	**0.81**	0.12	0.17
6	13	Light Sensitivity	Outdoor light too bright—have to use sunglasses	0.04	0.15	0.12	0.23	0.09	**0.53**	−0.10	−0.07
6	14	Light Sensitivity	Indoors fluorescent lighting is bothersome or annoying	−0.01	0.15	0.18	0.09	0.04	**0.83**	0.07	0.05
7	1	Eyesight Clarity	Distance vision blurred and not clear—even with lenses	0.12	−0.10	0.23	0.13	0.01	−0.07	**0.76**	0.00
7	2	Eyesight Clarity	Near vision blurred and not clear—even with lenses	0.09	0.16	−0.07	−0.08	0.11	0.09	**0.76**	0.14
7	3	Eyesight Clarity	Clarity of vision changes or fluctuates during the day	−0.02	0.11	0.14	0.33	0.35	0.22	**0.51**	−0.02
8	21	Peripheral Vision	Side vision distorted/objects move or change position	−0.03	−0.04	0.12	0.19	0.02	−0.13	0.23	**0.73**
8	22	Peripheral Vision	What looks straight ahead—isn't always straight ahead	0.05	0.02	0.11	−0.03	0.11	0.14	0.00	**0.77**
8	23	Peripheral Vision	Avoid crowds/can't tolerate "visually-busy" places	0.20	0.04	0.23	0.10	0.29	0.23	−0.31	**0.49**

The loadings are the correlations between the question and the underlying latent factor (bold-face numbers). All factors matched the assigned BIVSS category except #4 (*italics*).

Our sample included Students and TBI. However, for developing scales, only the Students were used to create a reference set of factors with principal-axis factor analysis. Factor coefficients were created for each question using Anderson-Rubin transformations that provided factor scores with a mean of zero and standard deviation of one.[13] First-year students' mean and standard deviations were used as a reference for calculating z-scores for the third-year students and TBI. The first-year students had a reference mean standard score (z) of zero.

Analysis of variance (ANOVA) was used to compare groups on each of the underlying factors. Bar charts were used to illustrate the results. Error bars were constructed so that non-overlapping bars were equivalent (84% confidence intervals) to Fisher's least significant difference test where significance is an unadjusted $p < 0.05$.[14]

Multiple logistic regression was used to evaluate the model on predicting TBI using the factors in the model. Sensitivity and specificity were reported based on the predicted probability of TBI assuming a 50% cutoff. All Likert statistical analyses were conducted using SPSS.[15]

Rasch Method of Analysis

Rasch analysis has been used to place people and questions along a single dimension of disability. The Likert method requires demonstrating that the frequency of responses is normally distributed, but then the actual ranks are used in parametric statistics. In Rasch analysis, the frequency of responses is used directly in the computation of the scale. A Rasch scale is created by fitting a logistic function to the difference between a person's response to a symptom question and the degree to which the question reflects the intensity of a symptom. The data were analyzed using Winsteps program (version 3.92, Chicago, IL).[16] Questions are selected based on their ability to consistently identify a location along a single scale using Infit statistics (the amount of inconsistency between the subject's responses and the item difficulty).[17] Each possible response from a question is a particular point along the Rasch dimension. Separate Rasch scales are created if there are multiple underlying dimensions.

Unlike the Likert analysis that based the multidimensional profiles on reference Students, the Rasch scale used all subjects so that responses of TBI are optimized to create a single scale. The Rasch analysis was created to be specific to TBI, whereas the Likert scale was employed as a multidimensional set of scales relative to Students.

A Rasch scale requires a single underlying unidimensional scale. We have proposed that the BIVSS is a collection of multidimensional scales. The Winsteps program includes diagnostics for unidimensionality. For Rasch analysis, a primary unidimensional latent variable is defined. Principal components analysis is applied to the remaining variance not accounted for by the initial primary factor. An eigenvalue is the amount of variance accounted for by additional underlying factors. One question is equivalent to one eigenvalue. All eigenvalues of unexplained variance greater than two defined new factors (i.e. that means a single factor has to account for the equivalence of two whole questions before it can be considered as potential variance). To determine if the lack of unidimensionality was sufficient to merit breaking BIVSS into separate Rasch scales, we looked at the attenuated correlations between item clusters within the new factors and the original primary factor. Small correlations indicate lack of unidimensionality ($r < 0.57$) because it suggests the new factors (created from the error variance) are separate from the primary factor. Linacre has suggested that correlations less than 0.57 demonstrate the need to break the BIVSS into separate subscales.[18] Rasch also uses Infit statistics to determine if items are kept in the model. Items were kept in the model if their Infit mean squared error (MSE) was between 0.7 and 1.3.[17] One of the strengths of Rasch analysis is eliminating questions that do not reliably connect symptom intensity to the specific population measured.

The age distribution was different between the groups. We conducted two analyses, one with the entire set of available data and one limited to TBI in the same age range as the students (22–40 years).

Missing data was handled through the maximum likelihood estimation procedure of the Rasch analysis that accounts for missing data. For the factor analysis method, individual questions missing responses were interpolated by taking the mean of the mean BIVSS score for the patient and the mean BIVSS score for the question. There was no missing data for the Students.

RESULTS

Self-administered BIVSS completion success was acceptable for both groups of subjects. At least 27 of 28 questions were completed by 93.5% of subjects who had sustained TBI. Out of the 2996 questions asked of the TBI, 29 were left blank. Three patients missed answering question (q8), one patient did not respond to six different questions, and one did not respond to five questions. Non-TBI completion success was 100%, in that each reference subject completed all 28 questions.

The Total BIVSS score as a function of time since most recent TBI yielded a small, nonsignificant trend (less than 6 months: mean = 60, 20.0 SD; 6 months to 1 year: mean = 59.1, 20.1 SD; 1 to 5 years: mean = 50.1, 23.3 SD; more than 5 years: mean = 45.5, 28.8 SD; $F = 1.91$, $p = 0.133$). Controlling for age did not alter the nonsignificant finding ($F = 1.189$, $p = 0.10$).

Likert Scale Profile Analysis

The assumption that the cumulative standard normal distribution was linearly related to the rating scales is illustrated in Appendix 2, available at http://links.lww.com/OPX/A249. The average slope for the reference group (all Students) was 0.52 (range 0.13–0.77). The cumulative normal distribution increased about one half standard deviation for each increase in one rank rating. The average standard deviation of the residuals was 0.29 (range 0.08–0.53). The average index of proportionality (coefficient of determination) was 0.58 (range 0.17–1.0). One question could not be tested because only 14 subjects responded with a symptom ranking of "Seldom" ("Side vision distorted/objects move or change position") whereas all others responded "Never".

The eigenvalues for the eight factors in factor analysis accounted for 65% of the variance. The factor loadings are presented in Table 1. Factor scores were computed for all subjects. Although one might expect age to be a confounder, our analysis showed that with TBI age was only confounded with Factor 8 (Peripheral Vision: $r = 0.23$, $p = 0.02$). None of the other factors were significantly correlated in the optometry student group (Students mean correlation $r = 0.008$, range -0.12 to 0.20; TBI mean $r = 0.08$, range = -0.10 to 0.23).

Fig. 1 shows the relationship between the groups. The differences between the bars are effect sizes for the individual group

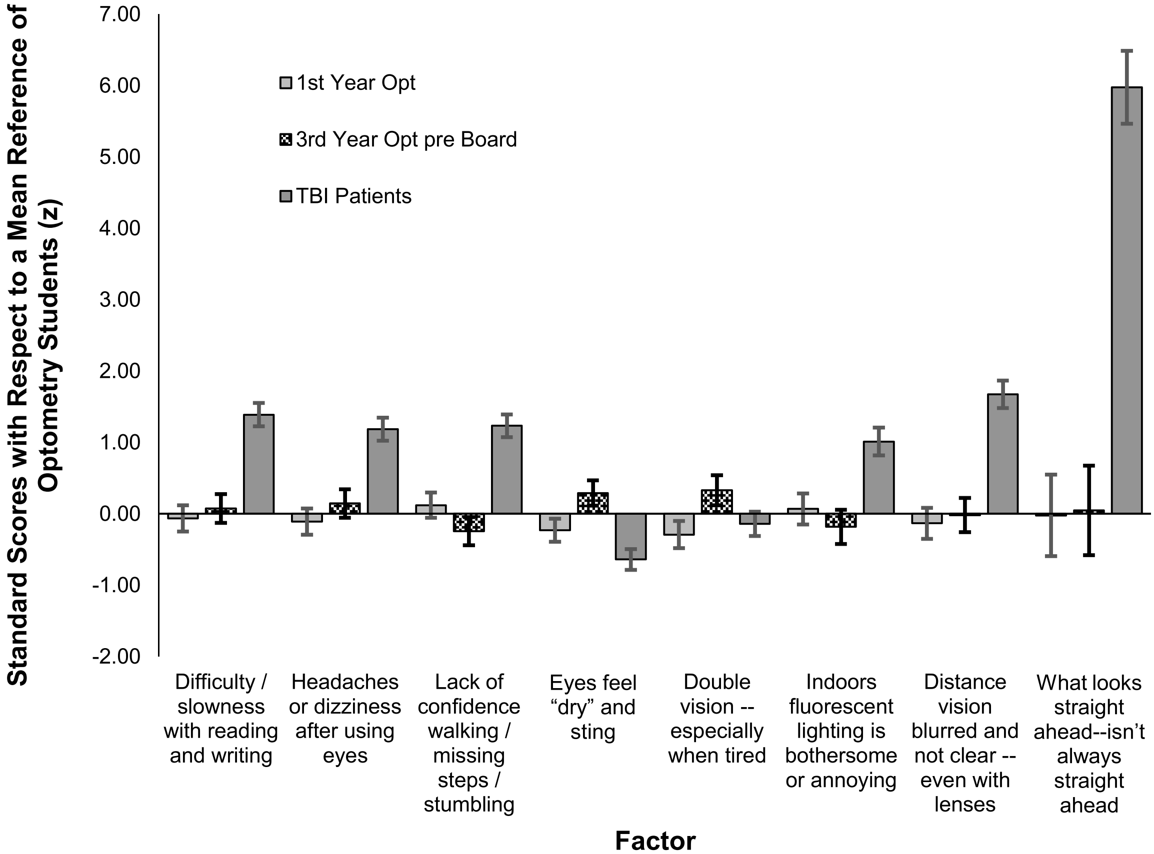

FIGURE 1.

Mean standard factor scores (SD) by group. The factors are represented by the question with highest loading on the factor. Both TBI age groups are included figures. Error bars are constructed so that non-overlapping bars are significant at an unadjusted p <0.05.

comparisons. Third-year symptom scores were greater on Factor 4 (Dry Eye: Effect size = 0.52 SD, $p = 0.002$) and Factor 5 (Doubling: Effect size = 0.62 SD, $p = 0.002$). The strongest loadings on those factors were questions about dry eye and double vision, respectively. Interestingly, the TBI were more symptomatic on every dimension except Factors 4 and 5. With respect to dry eye, they were significantly less symptomatic (Effect size = −0.40 SD, $p = 0.008$ and −0.93 SD, $p < 0.001$ for first- and third-year students, respectively). With respect to double vision, the TBI were significantly less symptomatic than third-year students (Effect size = −0.47 SD, $p = 0.14$), but not significantly less so than the first-year students (Effect size = 0.15, $p = 0.4$). TBI were significantly more symptomatic than either cohort of Students by at least one standard deviation ($p < 0.001$) for all the other factors.

Even though we did not see significant correlations between factors and age, we were still concerned about age as a confounder. We repeated the above ANOVA using only TBI within the same age range as the Students (age 20–42). Age-matched results were very similar to the full TBI sample (see Fig. 1). Age was not significantly correlated with any of the eight factors (Factor 8: $r = 0.203$, $p = 0.203$, $n = 41$).

The logistic regression is reported in Table 2. Six of the eight factors were positive risk factors for TBI (Odds Ratio > 1.0). Two of the six positive risk factors were not significant, but that may have been due to multicollinearity. As shown in Fig. 1, Factors 4 and 5 (Dry eye and Double Vision related questions) represented reduced risk relative to the reference group (i.e. odds ratio < 1). The lack of statistical significance for Double Vision may also have been due to multicollinearity. The sensitivity was 82.2% for correctly predicting TBI and 90.4% for correctly predicting non-TBI status with Students.

Rasch Analysis

The overall Rasch analysis yielded a person reliability of 0.91 with 3.18 separation. The Item reliability was 0.97 with 5.72 separation. There were three contrasts with eigenvalues greater than 2 (3.65, 2.62, and 2.34). Disattenuated correlations between the clusters were fairly strong. The smallest correlation was $r = 0.75$, which was not weak enough to justify separating the primary Rasch scale into separate scales (criteria $r < 0.57$). Table 3 provides the item diagnostics for the questions sorted by the question most related to TBI (the most related was: "What looks straight ahead—isn't always straight ahead") and the question at the other end of the scale most related to the reference Students was: "Eye fatigue/very tired after using eyes all day". Three questions were outside the Infit range of acceptable mean squared errors (questions 5, 15, and 16). The analysis was re-run without those three items. The new analysis had a person reliability of 0.90 with person separation = 3.05 and item reliability of 0.97 with item separation of 5.82. There were still three contrasts with eigenvalues greater than two, but also with the lowest correlation equal to 0.75. The strong correlation did not justify separating the scale into separate Rasch subscales.

TABLE 2.

Logistic regression model for the Likert method factors

Factor	B	SE	Wald	df	p	Odds Ratio Exp(B)
1. Difficulty/slowness with reading and writing	0.65	0.19	12.32	1	<0.001	1.92
2. Headaches or dizziness after using eyes	0.02	0.21	0.01	1	0.933	1.02
3. Lack of confidence walking/missing steps/stumbling	0.59	0.19	9.91	1	0.002	1.80
4. Eyes feel ''dry'' and sting	−0.84	0.27	9.62	1	0.002	0.43
5. Double vision—especially when tired	−0.07	0.21	0.10	1	0.750	0.94
6. Indoors fluorescent lighting is bothersome or annoying	0.34	0.19	3.11	1	0.078	1.40
7. Distance vision blurred and not clear—even with lenses	0.47	0.17	7.88	1	0.005	1.61
8. What looks straight ahead—isn't always straight ahead	0.63	0.15	18.99	1	<0.001	1.88
Constant	−2.34	0.33	49.55	1	<0.001	0.10

The dependent variable was TBI (yes or no). Full TBI sample was used.

B, regression coefficient; SE, the standard error of the coefficient; Wald is the statistical test, df, degrees of freedom; p, statistical significant (alpha = 0.05); Odds Ratio, exponentiation of the regression coefficient (e^B) where values greater than 1 reflect increased risk.

Fig. 2 compares the three groups on the single Rasch dimension. TBI were significantly more symptomatic than either optometry group ($p < 0.001$). However, the two optometry groups were not significantly different ($p = 0.284$). A logistic regression was run to determine the sensitivity (79% correctly predicting TBI) and specificity (91% correctly predicting optometry student status) of the Rasch scale with a 0.5 cutoff criteria (−intercept/coefficient = −1.42/2.348 = −0.605). The total raw score equivalent cutoff for the specified sensitivity and specificity was ≥32 on the revised 25-item scale.

DISCUSSION

The BIVSS questionnaire was originally developed to more fully assess symptoms of individuals who had sustained mild-to-moderate

TABLE 3.

Rasch analysis item diagnosis table

	Question	Model Scale	Infit SE	Infit MSE	Infit ZSTD
22	What looks straight ahead—isn't always straight ahead	1.04	0.09	1.02	0.2
21	Side vision distorted/objects move or change position	0.66	0.08	1.09	0.9
10	Have to close or cover one eye to see clearly	0.51	0.08	1.16	1.6
9	Double vision—especially when tired	0.48	0.07	1.21	1.9
12	Normal indoor lighting is uncomfortable—too much glare	0.44	0.07	0.89	−1.1
20	Poor handwriting (spacing, size, legibility)	0.30	0.07	1.26	2.6
19	Lack of confidence walking/missing steps/stumbling	0.23	0.07	0.91	−0.9
11	Print moves in and out of focus when reading	0.18	0.07	0.96	−0.4
8	Feel ''pulling'' around the eyes	0.15	0.07	0.98	−0.1
2	Near vision blurred and not clear—even with lenses	0.14	0.07	1.13	1.3
23	Avoid crowds/can't tolerate ''visually-busy'' places	0.14	0.07	0.92	−0.8
16	*''Stare'' into space without blinking*	*0.12*	*0.07*	*1.38*	*3.7*
17	Have to rub the eyes a lot	0.03	0.07	1.16	1.7
18	Clumsiness/misjudge where objects really are	0.03	0.07	0.92	−0.9
28	Lose place/have to use finger not to lose place when reading	0.03	0.07	1.02	0.2
1	Distance vision blurred and not clear—even with lenses	−0.02	0.07	1.25	2.6
14	Indoors fluorescent lighting is bothersome or annoying	−0.03	0.07	1.06	0.6
27	Confusion of words/skip words during reading	−0.08	0.07	0.95	−0.5
3	Clarity of vision changes or fluctuates during the day	−0.09	0.07	0.82	−2.2
4	Poor night vision/can't see well to drive at night	−0.11	0.07	1.16	1.7
15	*Eyes feel ''dry'' and sting*	*−0.29*	*0.06*	*1.57*	*5.7*
6	Headaches or dizziness after using eyes	−0.37	0.06	0.84	−2
25	Difficulty/slowness with reading and writing	−0.42	0.06	1	0
26	Poor reading comprehension/can't remember what was read	−0.44	0.06	0.89	−1.3
5	*Eye discomfort/sore eyes/eyestrain*	*−0.59*	*0.06*	*0.6*	*−5.6*
24	Short attention span/easily distracted when reading	−0.63	0.06	0.84	−2.1
13	Outdoor light too bright—have to use sunglasses	−0.67	0.06	1.25	2.8
7	Eye fatigue/very tired after using eyes all day	−0.75	0.06	0.72	−3.8

Items are ranked from most serious symptom to least. Underlined items are those which are out of the acceptable range of fit (Infit MSE between 0.7 and 1.3). The analysis was rerun and subjects scored without those three items. Full TBI sample was used.

Model Scale, Rasch scale value; SE, standard error; ZSTD, standardized MSE value.

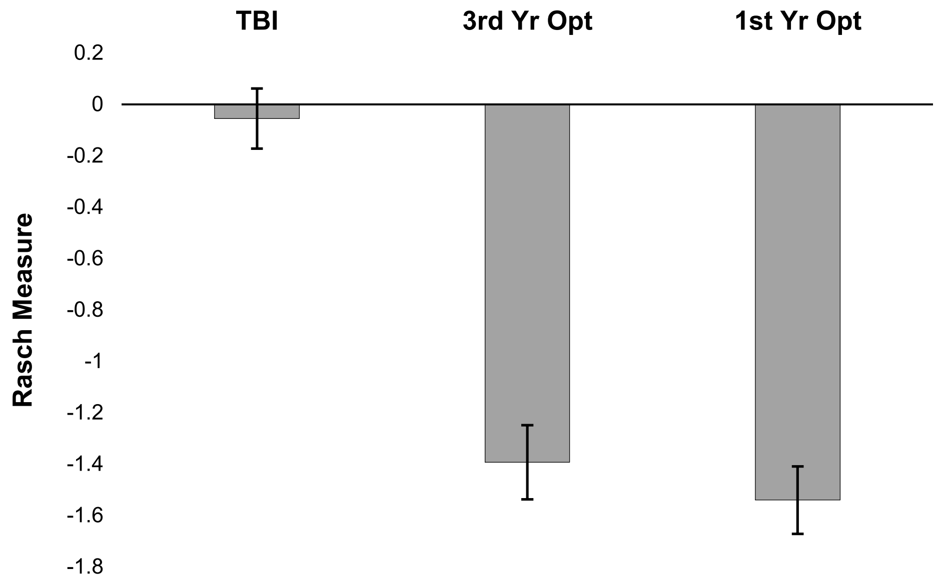

FIGURE 2.
Mean Rasch scores for 25-item scale. The full TBI sample is included in this analysis. Error bars are constructed so that non-overlapping bars are significant at an unadjusted $p < 0.05$.

brain injury. The author's clinical experience suggested that many of these individuals' visual needs were often underserved because eye care providers did not fully explore the complex symptomatology secondary to TBI.

Nearly all individuals who had sustained mild-to-moderate TBI were able to self-complete the BIVSS questionnaire. There was significant mean score separation between TBI and non-TBI groups.

We analyzed the data from both the perspective of Likert and Rasch. We could not make the blanket statement that our observed scales with the Likert method were proportional to the normal frequency distribution because there was clearly some systematic deviation from a straight line. However, we believe the deviation was relatively modest and did not affect the ability of the scale to accurately detect differences.

The Likert method was suitable for developing a multidimensional profile using only Students. We believe our multiple questions for each factor were measuring the same underlying subdimension using a weighted factor loading average. The BIVSS questionnaire was physically organized in groups of overlapping questions under topical headings. The factor structure that was identified matched this structure in all cases but one. ''Poor night vision/can't see well to drive at night'' correlated better with the Depth Perception factor rather than Eyesight Clarity grouping.

Our reference population of Students was convenient but useful. The students were a sample of young adults with no visual diseases who came from a variety of backgrounds. They were not representative of a ''normal'' group of subjects and that is why we refer to them as a reference point. The characteristic nature of the student's daily activities results in much more near work than with the average non-student population. Perhaps this was why both reference groups had significantly more dry eye than the TBI who likely engaged in much less near work activity. Perhaps the dose effect of studying for Boards led to significantly more dry eye and led to an increase in double vision for the third-year students when compared to the first-year students. Regardless, the methodology was sensitive enough to detect these common sense differences. It is interesting to note that two of the three questions rejected by the Rasch analysis were those where the TBI group was less symptomatic (''Eyes feel dry and sting'' and ''Stare into space without blinking''). The other question rejected was on a different factor, but similar in concept (''Eye discomfort/sore eyes/eyestrain''). Rasch analysis included both Students and the TBI. The purpose of the unidimensional Rasch scale was to differentiate TBI from non-TBI participants rather than creating a set of comparative symptoms relative to the optometry student reference group.

Both the Likert multidimensional profile and the Rasch unidimensional scale proved useful. The former provided a multidimensional profile of symptoms that was capable of discriminating between people with different underlying problems. Likert illustrated that individual factors could provide a profile of symptoms based on effect sizes in standard deviation units. The advantage of Rasch analysis was the provision of a single scale with a threshold cut off score of 32; very useful for screening patients with TBI-like symptoms. It would be tempting to argue that this supports a diagnostic interpretation of the Rasch scale. This would not be advisable because there could be other conditions that would also meet this criterion. Finally, although the Likert method provided a set of factors, the logistic regression suggested they were not all independent. Some of the factors that individually showed a greater than one standard deviation effect (Fig. 1) were not significant in the logistic regression. The reason for this non-significance in the logistic regression was the correlation between the factors (multicollinearity).

Limitations

A limitation of this study was the dissimilarity in the demographics between the reference groups (Students) and subjects with TBI. It is also conceivable that the individuals in our TBI sample who sought out optometric care might have been more symptomatic than those who suffer TBI but do not seek out vision care. Students likely differ from the general population because they are a homogenous population that has more education with a more extensive history of near work. Students have greater exposure to eye care and are likely more aware of symptoms related to visual function. Taken together, this suggests the results of this study should be considered preliminary validation of the BIVSS. Future research will include a broader demographic referent group that more accurately reflects the general population.

A test-retest study with TBI is currently underway. Future research should test the potential effect of item-order on response behavior (whether responses change depending upon where in the questionnaire an item appears) and whether the presence of a descriptive label for a group of questions impacts responses.

This study suggests investigational follow-up for visual processing symptoms between different groups because the BIVSS was found to be sensitive in identifying differences in dry eye and doubling for students studying for examinations compared to newly matriculated students. Further, the strong response of peripheral vision symptoms from TBI suggests focusing on this in future studies, especially with those symptoms related to visual motion sensitivity.

Anecdotal evidence suggests that the BIVSS may also be useful with a broader severity range of brain injury, pediatric patients, and also nontraumatic acquired brain injuries such as stroke. Follow-up research will be needed to confirm this.

The BIVSS can contribute to future clinical care by helping vision care providers better understand the dimensions and patterns of visual symptoms after TBI. It may also help guide the diagnostic examination and serve as a biomarker for rehabilitation. Given the Rasch symptom cutoff score, the BIVSS could serve a vision referral screening function for allied health professionals. The BIVSS questionnaire is intended as a public document, without charge to all researchers and clinicians provided that the developmental paper(s) is cited. An Excel Scoring spreadsheet is available upon request.

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APPENDIX

Appendix 1, the Brain Injury Vision Symptom Survey, a 28-item vision symptom questionnaire, is available at http://links.lww.com/OPX/A248. Appendix 2, figures A2A-H: to treat Likert data with parametric statistics, there needs to be a linear relationship between the rank ordered scales and the cumulative normal distribution. Each of the eight Appendix 2 figures illustrates the degree to which this relationship was met (available at http://links.lww.com/OPX/A249).

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Hannu Laukkanen
Pacific University College of Optometry
2043 College Way
Forest Grove, OR 97116
e-mail: laukkanh@pacificu.edu