ARTICLE

Test-Retest Reliability of the Brain Injury Vision Symptom Survey

Amber Weimer, BS[1]

Cory Jensen, BS[1]

Hannu Laukkanen, OD, MEd, FAAO, FCOVD-A[1]

John R. Hayes, PhD, FAAO[1]

Michael Saxerud, OD[1]

[1]*Pacific University College of Optometry, Forest Grove, Oregon*

ABSTRACT

Background: Assessment of the test-retest reliability of the Brain Injury Vision Symptom Survey (BIVSS), a self-administered survey for visual symptoms following mild to moderate traumatic brain injury (TBI).

Methods: Subjects (n=130, mean age 37 +/- 17.6, range 19 to 55) with mild-to-moderate TBI completed the 28-item BIVSS questionnaire two times (1-hr to 4-month separation interval). 25 subjects reported a history of medically diagnosed TBI, 5 an undiagnosed TBI, and 14 no history of injury. 87 subjects did not select a type of TBI diagnosis and were analyzed in the 'not specified' group. A scoring algorithm was developed for the BIVSS,[1] and Rasch and Likert analyses performed. Bland-Altman charts illustrating methods of analyses were created and limits of agreement calculated.

Results: A one sample t-test performed on both analyses for each patient group revealed no significant bias in scoring higher or lower on retest for any group with the exception of the 'not specified' group and Rasch analysis (n=87, t=3.41, p=0.01). When time between survey administrations is restricted to two weeks or less however, we see no significant difference for any group. Bland-Altman charts with 95% limits of agreement (+/- 0.40) revealed no significant change in direction of bias (Likert: p=0.92; Rasch: p=0.52) and consistency in distribution of values on retest (Likert: r=0.91; Rasch: r=0.25); the first administration accounting for 82.6% (r2) of variance at the second administration.

Conclusions: The BIVSS has very good test-retest reliability, and can serve as a suitable tool for assessing and quantifying visual symptoms associated with mild to moderate TBI. There is no significant bias in total BIVSS score between test administrations for either patients who have experienced TBI or non-injured patients. Future analysis of change in BIVSS subset scores concurrent with intervention could potentially reveal relationships between improvement in objective measurements and specific subjective subset scores.

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INTRODUCTION

The Center for Disease Control (CDC) estimates that 2.5 million Americans suffer a traumatic brain injury (TBI) annually.[2] This estimate is based on prevalence of brain injury resulting in emergency department visit, hospitalization, or death; the CDC recognizes that the actual prevalence of TBI in the United States is likely much higher. The

World Health Organization (WHO) classifies TBIs as profound, severe, moderate, or mild, based upon: the severity of injury, loss of consciousness and duration of post-traumatic amnesia.[3] Amongst reported TBIs, 75 percent are classified as mild TBI (mTBI), featuring: loss of consciousness lasting less than 30 minutes and post-traumatic amnesia of less than 24 hours following injury.[4] Although mTBIs are the most prevalent category of TBI, they often prove challenging to diagnose due to an absence of abnormalities apparent on conventional neuroimaging yet paradoxically disabling functional physical, cognitive, and behavioral effects.[5] Unemployment rates following mTBI are as high as 34 percent at 3 months post injury, with an estimated 30 to 85% suffering at least 1 visual problem after their injury.[6,7] Common visual symptoms effect visual comfort, clarity, light sensitivity, peripheral awareness, motion sensitivity, depth perception, and reading ability.[8-10]

There is an identified need for a validated, reliable, and comprehensive symptom survey for assessing the diverse array of visual symptoms following brain injury. Such a survey would be a boon to the teams of healthcare professionals currently managing the care of millions of patients with brain injury and would assist non-optometric health care practitioners in determining when visual symptoms merit referral for further optometric assessment and care. The Brain Injury Vision Symptom Survey (BIVSS), a 28-item scaled questionnaire, queries 8 visual symptom categories including: eyesight clarity, visual comfort, doubling, light sensitivity, depth perception, peripheral vision complaints, and reading related symptoms associated with mild to moderate brain injury. The validity of the BIVSS has been previously established (sensitivity 82.2% for predicting TBI).[1]

METHODS

The BIVSS was registered with the IRB and approval granted to gather de-identified data for this study. Anonymous surveys were collected from 130 adult subjects who self-identified as having mild to moderate TBI and had completed the BIVSS at two time points.

Subjects

Patients were recruited from ODs around the nation through the College of Optometrists in Vision Development (COVD) and Neuro-Optometric Rehabilitation Association (NORA). The BIVSS was administered to 130 adult subjects (mean age 37 +/-17.6, range 19 to 55), 25 of whom reported a medically diagnosed traumatic brain injury, 5 of whom reported an undiagnosed traumatic brain injury, 14 reporting no history of injury, and 87 categorized as unknown who did not self-report any of the aforementioned histories. Of the 130 subjects included, 100 had a total BIVSS score greater than 45, the previously established cut-off score for visually significant TBI.[1] To be included in the study, patients had to be at least 18 years old. History of medically diagnosed brain injury was not an inclusion criterion.

Materials

The BIVSS is a 28 item self-administered survey assessing post-TBI vision-related symptoms (eyesight clarity, visual comfort, diplopia, depth perception, dry eye, peripheral vision, light sensitivity, and reading skills) using a five point Likert scale (Figure 1). The frequency of symptoms in these categories are reported on the five-point scale ranging from never to always (never, seldom, occasionally, frequently, always) with never being given a value of zero and always a value of four. Total possible scores range from 0 to 112.

Statistical Methods

These data were analyzed by both Rasch and Likert analysis, utilizing a scoring algorithm previously developed for the BIVSS.[1] 25 of the 28 items were included in the Rasch analysis and all 28 items in the Likert analysis.[11,12] Data were illustrated with Bland-Altman charts, and limits of agreement calculated. Factor analysis

☐ I have had a medical diagnosis of brain injury (check box if true). My brain injury was: ____ years ago
☐ I suffered a brain injury without medical diagnosis (check box if true)
☐ I have NOT had a previous brain injury (check box if true)
your age _____ today's date: _____ your zip code: _____

Please check the most appropriate box, or circle the item number that best matches your observations. All information will be held in confidence. Thank you for your help!

SYMPTOM CHECKLIST ***Circle a number below:***

Please rate each behavior. **How often does each behavior occur?** (circle a number)	Never	Seldom	Occasionally	Frequently	Always
EYESIGHT CLARITY					
Distance vision blurred and not clear -- even with lenses	0	1	2	3	4
Near vision blurred and not clear -- even with lenses	0	1	2	3	4
Clarity of vision changes or fluctuates during the day	0	1	2	3	4
Poor night vision / can't see well to drive at night	0	1	2	3	4
VISUAL COMFORT					
Eye discomfort / sore eyes / eyestrain	0	1	2	3	4
Headaches or dizziness after using eyes	0	1	2	3	4
Eye fatigue / very tired after using eyes all day	0	1	2	3	4
Feel "pulling" around the eyes	0	1	2	3	4
DOUBLING					
Double vision -- especially when tired	0	1	2	3	4
Have to close or cover one eye to see clearly	0	1	2	3	4
Print moves in and out of focus when reading	0	1	2	3	4
LIGHT SENSITIVITY					
Normal indoor lighting is uncomfortable – too much glare	0	1	2	3	4
Outdoor light too bright – have to use sunglasses	0	1	2	3	4
Indoors fluorescent lighting is bothersome or annoying	0	1	2	3	4
DRY EYES					
Eyes feel "dry" and sting	0	1	2	3	4
"Stare" into space without blinking	0	1	2	3	4
Have to rub the eyes a lot	0	1	2	3	4
DEPTH PERCEPTION					
Clumsiness / misjudge where objects really are	0	1	2	3	4
Lack of confidence walking / missing steps / stumbling	0	1	2	3	4
Poor handwriting (spacing, size, legibility)	0	1	2	3	4
PERIPHERAL VISION					
Side vision distorted / objects move or change position	0	1	2	3	4
What looks straight ahead--isn't always straight ahead	0	1	2	3	4
Avoid crowds / can't tolerate "visually-busy" places	0	1	2	3	4
READING					
Short attention span / easily distracted when reading	0	1	2	3	4
Difficulty / slowness with reading and writing	0	1	2	3	4
Poor reading comprehension / can't remember what was read	0	1	2	3	4
Confusion of words / skip words during reading	0	1	2	3	4
Lose place / have to use finger not to lose place when reading	0	1	2	3	4

Figure 1. BIVSS Questionnaire sent to practitioners participating in this study.

Table 1. T-test for each patient categories with Rasch and Likert analysis

Diagnostic Category	Analysis Method	N	Mean Difference	f	p
Not Specified	Rasch	87	0.08	3.41	0.001
	Likert	87	2.33	1.78	0.079
No TBI	Rasch	14	0.05	0.66	0.524
	Likert	13	0.77	0.32	0.757
Undiagnosed TBI	Rasch	5	0.11	1.19	0.302
	Likert	5	5.28	1.60	0.184
Medically Diagnosed TBI	Rasch	25	-0.05	-1.27	0.215
	Likert	25	-2.53	-1.23	0.233

was performed for the 8 symptom categories included on the survey. A paired t-test used to assess the difference in results between an unrestricted dataset including all 130 subjects and a restricted data set of 87 who had completed the BIVSS at two time points less than or equal to 2 weeks apart.

Rasch & Likert Analysis: Rasch analyses are often used in statistical analysis of survey response because they allow for a straight-forward method of item analysis. Rasch analysis also allows for the creation of a ranking system for the items included.[11] This enables the determination of which items are most predictive. However, Rasch makes the assumption that there is a single underlying factor that motivates all patient responses to the questionnaire, in this case: that all patients have received a TBI. This assumption allows for unidimensional analysis, which is useful for item analysis, but does not illustrate the breadth of factors contributing to patient responses when completing a questionnaire such as the BIVSS.

Likert analyses use a multidimensional approach to answer questions about the factors motivating patient response.[12] For example, Likert analysis was used to establish the eight symptom categories included in the BIVSS. However, Likert analyses do require that there is a linear relationship between the Likert scale being used and the responses given. This assumption can be tested with a z-score comparing the Likert scale used to the cumulative normal. For the BIVSS, this assumption had been previously tested.[1] When the results of a Rasch analysis are paired with a Likert analysis a more complete depiction of the factors motivating patient responses can be constructed.

Bland-Altman Charts

Bland-Altman charts are difference plots used to analyze the difference in score between two survey administrations. These charts are useful in the identification of bias and outliers in a data set, and for our purposes indicate whether or not there was significant change in BIVSS score on retest.

RESULTS

The results of Likert and Rasch analysis reveal that there was no significant difference in score on re-test for any group or method of analysis with the exception of the Rasch analysis for the 'not specified' patient group (p=0.01). The results of a one sample t-test performed on both Rasch and Likert analyses for each patient category are summarized in Table 1. Table 1 reveals that none of the patient groups showed a significant bias in either scoring higher or lower at the second versus first survey administration, with the exception of the not specified patient group and Rasch method of analysis (n=87, mean difference=0.08, t=3.41, p=0.01). Restricting the data set to a two week administration interval provides 63 patients for analysis. Of those 63 patients, 18 self-reported a medically diagnosed TBI, 7 reported no history of injury, 5 no history of diagnosed TBI, and 33

Table 2. Data subgroup total and 2 week restriction

Patient Subgroup	Total Dataset (n=130)	2 Week Dataset (n=63)
Medically Dx	25	18
No Dx	5	5
No Injury	13	7
Unspecified	87	33

did not specify a cause of TBI (Table 2). Analyses of these data provides no significant difference between first and second administrations with either analysis method for any of the patient categories.

A paired t-test was used to compare population means between the unrestricted and two week restricted data sets for both methods of analysis. The results indicate that for the unrestricted dataset there was no significant difference in total BIVSS score on retest using the Rasch method of analysis (mean=-0.02394, sd=0.63731, r=0.685), but a significant difference was found using the Likert method (mean=2.69583, sd=11.80038, r=0.014). When the restricted dataset is used, there was no significant difference on re-test for either method of analysis, Rasch: mean=0.0508, sd=0.5889, r=0.517; Likert: mean=0.16102, sd=12.129, r=0.919 (Table 3).

Table 3. T-Test analysis of whole data set and with 2 week restriction

T-Test of Whole Data Sheet					
Analysis Method	**Mean**	**Std. Dev.**	**t**	**df**	**p**
Rasch	-0.0239	0.637	-0.406	116	0.685
Likert	2.6958	11.80	2.503	119	**0.014***

T-Test Restricted to 2 Weeks					
Analysis Method	**Mean**	**Std. Dev.**	**t**	**df**	**p**
Rasch	0.0508	0.589	0.652	56	0.517
Likert	0.1610	12.129	0.102	58	0.919

The correlation coefficient for the relationship between total BIVSS score and method of analysis used was calculated (Rasch: 0.237; Likert: 0.909). The results reveal a higher correlation between scores on re-test using the Likert scale than the Rasch scale. Values of 1 indicate a perfect correlation and values of 0 no correlation.

Factor analysis for each of the 8 symptom categories included in the BIVSS (eyesight clarity, visual comfort, diplopia, depth perception, dry eye, peripheral vision, light sensitivity, and reading), revealed no significant difference in mean score on re-test for any symptom category with the exception of depth perception (p=0.01, effect size=0.18).

Bland-Altman charts with 95% limits of agreement calculated (Rasch:+0.48/-0.38, Likert: +23.9/-21.2) reveal no significant change in direction of bias between test administrations (Likert: p=0.92, Rasch: p=0.52). For both methods of analysis there is consistency in the distribution of the BIVSS values for all 130 patients on retest (Likert: r=0.91; Rasch: r=0.24). The first administration accounts for 82.6% (r2) of the variance of the second administration for the Likert analysis and 5% (r2) of the variance of the second administration for the Rasch analysis. Both Bland-Altman charts demonstrate stability across administrations with slope and y-intercept near zero: Likert (slope: -0.11, y-intercept: 6.87; Figure 2), Rash (slope: -0.121, y-intercept: 0.0285; Figure 3.).

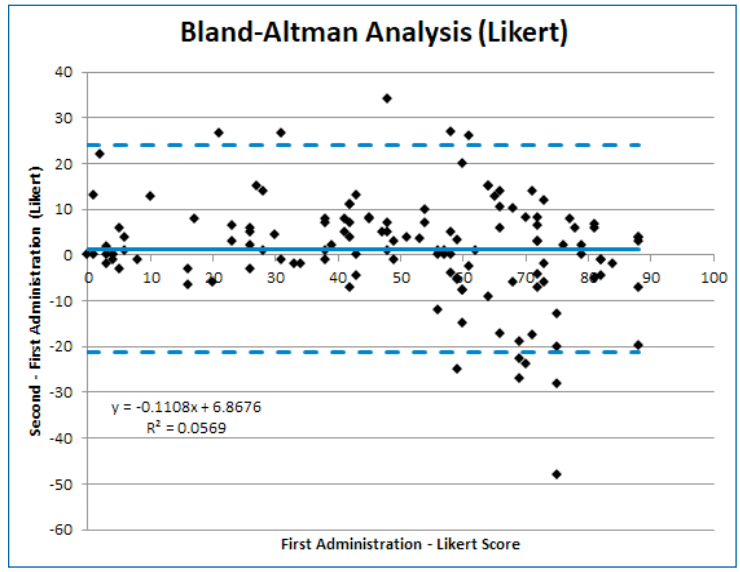

Figure 2: Bland-Altman analysis of whole Likert data set.

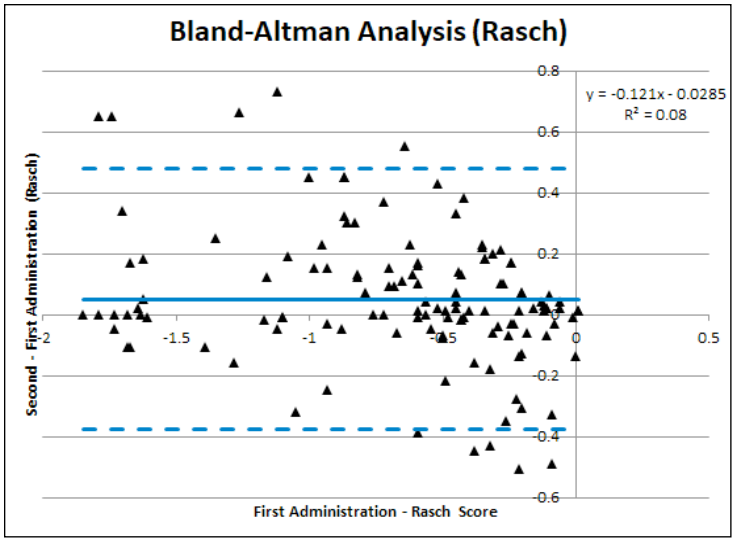

Figure 3: Bland-Altman analysis of whole Rasch data set.

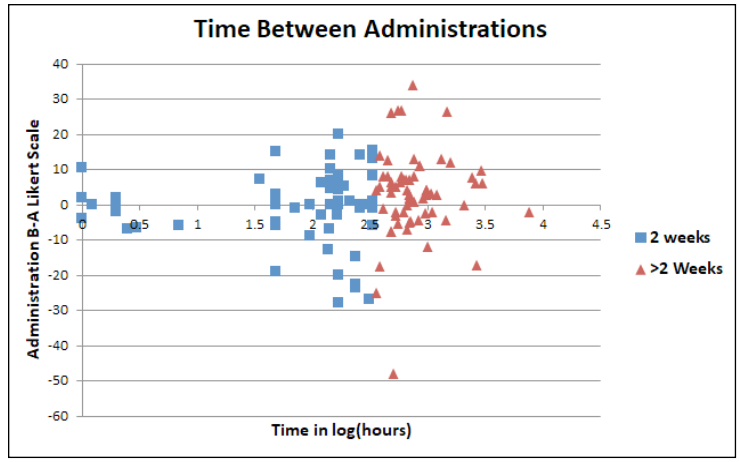

Figure 4: Time between administrations A and B showing greater variability outside 2 week restriction.

DISCUSSION

The BIVSS was designed to survey and quantify post-TBI vision-related symptoms (eyesight clarity, visual comfort, diplopia, depth perception, dry eye, peripheral vision, light sensitivity, and reading skills). An estimated 2.5 million Americans suffer a traumatic brain injury each year, the majority of whom will experience some period of visual sequelae following their incident.[2] There is an identifiable need for a valid, repeatable symptom survey that can identify the visual consequences of TBI and aid in guiding the co-management of these patients. The validity of the BIVSS for predicting visually significant TBI has been previously established.[1] This paper addresses repeatability of the BIVSS on re-administration.

When total BIVSS scores from all 130 subjects were examined, there was not a significant difference on retest using either method of analysis. When patients were subdivided into subgroups based on the type of TBI history they self-reported when filling out the BIVSS (not specified, no history of TBI, undiagnosed TBI, medically diagnosed TBI), we similarly found no significant difference on retest with either method of analysis for any subgroup, with the exception of 'not specified' category with only Rasch analysis. The not specified category was the largest patient subgroup (n=87) and contained the greatest time between administrations. Time between survey administrations and the initiation of therapy between administrations are variables that were not controlled for in this study. As time between administrations increases there is a higher likelihood of a change is symptomology reporting on the BIVSS upon re-administration. For these reasons we created a restricted dataset of subjects who had completed the BIVSS a second time less than or equal to two weeks after their initial survey completion (Figure 4). With this two week restriction in place there was no significant difference in any subgroup or with either method of analysis. These results indicate that the BIVSS is a reliable survey on retest, yielding similar total symptom scores.

Additionally, although the 'not specified' subgroup contained the most subjects it is important to note that all surveys analyzed were submitted by optometrists providing care to brain injured patients. We can make the assumption that even when a type of TBI history was not selected by the patient, there remains a high probability that these patients did have a history of TBI. Examining completed surveys, we found that ninety percent of individuals in the 'not specified' subgroup had included a written-in cause of injury or date of injury on their survey.

Bland-Altman charts for the Likert and Rasch methods of analysis reveal a slight

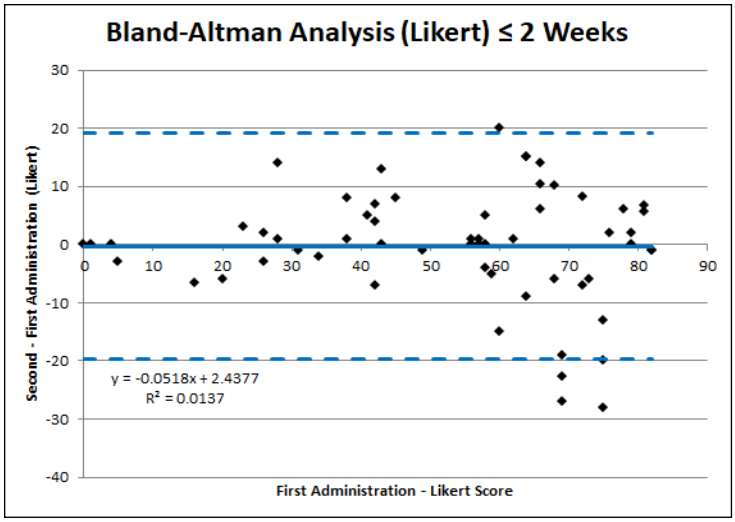

Figure 5: Bland-Altman analysis of 2 week Likert data set.

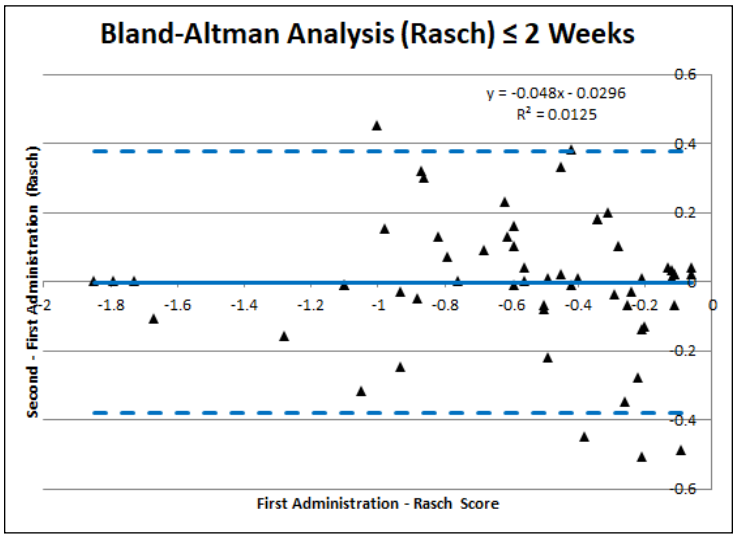

Figure 6: Bland-Altman analysis of 2 week Rasch data set.

regression toward the mean as symptom score increases. This indicates that patients who have experienced TBI with more visually significant symptoms had a tendency to score lower on the second versus first survey administration. Conversely, patients with lower initial BIVSS scores had a tendency towards higher scores on their second survey administration. The slight regression to the mean revealed in these analyses may be the result of treatment initiation between survey administrations, which was not controlled for. If the dataset is restricted to only those individuals who completed the BIVSS a second time less than or equal to two weeks after their initial administration however, we see that the slope of the trend line is near zero for either method of analysis (Rasch slope=-0.048: Likert slope=-0.052) (Figure 5, Figure 6). This indicates there is stability in total BIVSS score on retest when time between administrations is restricted to 14 days.

Table 4. Questionnaire subsection factor analysis for administration A and administration B

BIVSS Category	Correlation A:B	Mean A	Mean B	P
Eyesight Clarity	0.87	1.58	1.62	0.54
Visual Comfort	0.79	1.24	1.33	0.20
Diplopia	0.84	0.56	0.73	0.01
Depth Perception	0.83	0.83	0.92	0.25
Dry Eye	0.84	1.61	1.60	0.97
Peripheral Vision	0.74	0.57	0.69	0.13
Light Sensitivity	0.81	1.53	1.57	0.57
Reading Skills	0.75	0.47	0.55	0.14

Prior work establishing the validity of the BIVSS examined the eight visual symptom categories included in the survey (eyesight clarity, visual comfort, diplopia, depth perception, dry eye, peripheral vision, light sensitivity, and reading), and identified 'peripheral vision' as most predictive factor for TBI (r=0.23, p=0.02). In this reliability study, we found no significant difference for any factor on retest with the exception of 'depth perception' (p=0.01, Effect Size=0.18,), meaning that questions in the 'depth perception' category accounted for most of the variance in total BIVSS score. The difference in the other 7 factors on was not found to be significant on retest, including in the 'peripheral vision' category (p=0.14) (Table 4).

For the breadth of visual symptoms following TBI, there was not a significant difference in symptom score on retest except in the category of depth perception. This category queries the subject's frequency of: clumsiness, misjudging where objects really are, lack of confidence walking, missing steps, stumbling, and poor handwriting; including spacing, size, and legibility (Figure 1: BIVSS). The majority of individuals are less self-aware of the quality of their depth perception than they are many other aspects of their vision. Subjects may become more aware of such typically abstract

symptoms when they are specifically queried; for example, heightening a patient's sensitivity to their two-eyed depth perception.

A paired t-test was used to compare population means between the unrestricted and two week restricted data sets for both the Rasch and Likert methods of analysis. There was no significant difference on re-test for either method of analysis when examining the two-week restricted data set (Rasch: mean=0.0508, sd=0.5889, r=0.517; Likert: mean=0.16102, sd=12.129, r=0.919). When examining the unrestricted data set there was no significant difference on retest using the Rasch method of analysis (mean=-0.02394, sd=0.63731, r=0.685). However, when examining the unrestricted data with the Likert method of analysis we see a significant difference in total BIVSS score on re-test (mean=2.69583, sd=11.80038, r=0.014). (Table 3).

The correlation between the total BIVSS score and the method of analysis used was calculated (Rasch: 0.237; Likert: 0.909). These results indicate that the Likert scale is more correlated with test-retest scores on the BIVSS than the Rasch scale. Additionally, there is a significant difference in BIVSS score on retest when using the Likert method of analysis on the unrestricted data set but not when using the Rasch method of analysis. This finding is no longer true when the time between survey administrations is restricted to two weeks. Restricting the dataset controls for changes in visual symptoms associated with the initiation of treatment or with changes in the patient's overall condition that may be expected to occur over larger spans of time.

Limitations

A limitation of this study was that the initiation of treatment between survey administrations was not controlled for. As time between administrations increases, the likelihood of change in visual symptoms increases for a multitude of reasons, including initiation of vision therapy, spectacle prescriptions that include prism, and improvement of symptoms over time due to physiological repairs. If we restrict the dataset to only those patients who completed the survey a second time less than two weeks after the initial administration however, we can decrease the potential for these time-related changes in visual symptoms.

Future research should test the correlation between BIVSS subset scores and related objective measures of visual function via retrospective analysis of mTBI patients who have completed the BIVSS pre and post-treatment for their visual symptoms. Additionally, it would be interesting to test the effect of item-order on response behavior and if the presence of descriptive titles for symptom subsets influences patient response. Further analysis of change in BIVSS subset score concurrent with treatment of visual symptoms may reveal a correlation between improvement in objective measurements of visual performance and subset score.

CONCLUSIONS

The results suggest that the BIVSS has very good test-retest reliability and can serve as a valuable tool for assessing and quantifying visual symptoms associated with mild to moderate TBI. There is no significant bias in total BIVSS score between test administrations for either patients who have experienced TBI or non-injured patients.

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CORRESPONDING AUTHOR BIOGRAPHY: Amber Weimer, BS

Amber is a fourth-year Optometry student at Pacific University College of Optometry (PUCO) with anticipated graduation in the spring of 2019. She has a particular passion for ocular disease and rehabilitative optometry, and is actively pursuing clinical research and residency opportunities in the field.