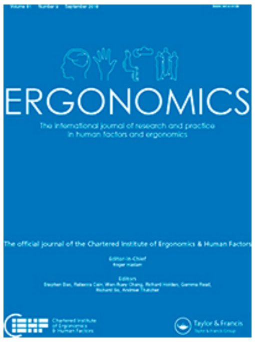

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Abstract

The widespread use of virtual reality head-mounted-displays (HMDs) calls for a reexamination of the impact of prolonged exposure to fixed visual displays at close ocular proximity. The purpose of this study is to validate the Virtual Reality Symptoms Questionnaire (VRSQ), created to understand symptoms of prolonged HMDs use (Ames, Wolffsohn, & McBrian, 2005), and Computer Use Survey (CUS), created to assess general physical and visual discomfort symptoms (Hayes, Sheedy, Stelmack, & Heaney, 2007). Participants (N=100) recorded their general discomfort symptoms using the CUS, performed an interactive task using a HMD for thirty minutes, and then answered the CUS again along with the VRSQ. VRSQ, analyzed using an exploratory factor analysis, indicated a clear two-factor solution, and demonstrated very good internal consistency (α = .873). The CUS, also analyzed using an exploratory factor analysis, indicated a four-factor solution, and demonstrated good internal consistency (α = .838). *Key words:* virtual reality, head-mounted-displays, visual discomfort, motion sickness, exploratory factory analysis

Practitioner Summary: A quantitative-experimental study was conducted to explore the factor structure and validate both the Virtual Reality Symptoms Questionnaire (VRSQ), and the Computer Use Survey (CUS). Findings indicate the VRSQ and CUS are precise and accurate survey instruments for evaluating discomfort after VR-HMD use and the latter for computer use.

Exploratory Factor Analysis and Validity of the Virtual Reality Symptom Questionnaire and Computer Use Survey

New technological innovations in computer processing and visual displays have resulted in the widespread use of virtual reality (VR) technology in fields, such as education (Jensen & Konradsen, 2017; Bellani, & Fornasari, Chittaro, & Brambilla 2011), entertainment, mental health (Maples-Keller, Price, Rauch, Gerardi, & Rothbaum 2017; Pallavicini, Argenton, Toniazzi, Aceti, & Mantovani 2016; Krijn, Emmelkamp, Olafsson, & Biemond 2004; Reger et al., 2011), and medical applications (Forester, Poth, Behler, Botsch, & Schneider 2016; Palter, 2003; Palter, Sobko-Koziupa, Gilhuly, & Pyer 2001; Lerner, Ayalew, Peine, & Sundaram 2010; Rajanbabu et al., 2013; Hoffman et al., 2014; Turnbull, & Phillips, 2017). Recently, the development of VR Head-Mounted-Displays (HMDs) have provided users with immersive experiences in three-dimensional (3D) computer generated space, where users are able interact with an environment that mimics real life experiences. The vast potential of VR-HMD technology calls for a deeper examination into the impact of prolonged viewing of binocular displays presenting varied stereoscopic depth cues at a static focal distance. The use of VR-HMD technology has been associated with deleterious side effects related to both ocular (e.g., visual fatigue, blurry eyes) and non-ocular (e.g., dizziness, body discomfort) discomfort symptoms (Magyari, 2016; Sharples, Cobb, Moody, & Wilson 2008). For example, several studies have reported that increased duration and exposure to VR-HMDs leads to higher reports of both ocular and body discomfort symptoms (Amenós & Knox, 2014; Kennedy, Stannney, & Dunlap, 2000; Moss & Muth, 2011).

The terminology and the measurements used to describe and assess the negative health outcomes related to post-VR immersion evolved with the advancement of computer processing and visual displays. For example, the Simulator Sickness Questionnaire (SSQ), one of the most popular survey instruments, studied the adverse side effects related to VR immersion (Kennedy et al., 1993). The SSQ was originally developed to replace the aging Pensacola Motion Symptom Questionnaire (MSQ) to more accurately assess discomfort caused by aviation simulators (Kellogg, Kennedy, & Graybiel, 1965). Despite the popularity of the SSQ to assess discomfort due to the use of VR, VR technology has changed dramatically with advances in visual displays, graphical fidelity, motion detection, and motion controllers. Motion controllers for example are designed to allow the user to have a more concrete experience when interacting in VR environments (Hinckley, Pausch, Proffitt, & Kassell 1998).

Thus, we opted to utilize the Virtual Reality Symptom Questionnaire (VRSQ), which was developed to precisely measure both non-ocular and ocular symptoms associated with exposure to VR-HMD (Ames, Wolffsohn, & McBrien, 2005). In the pilot phase of scale development, the authors pooled 47 symptoms from previous virtual reality research, including motion sickness and simulator sickness symptoms. After evaluating cutoff values in frequency of endorsement, only 13-items were retained. Currently, the VRSQ is the only scale developed to specifically assess VR related discomfort symptoms from using HMDs. To date, the VRSQ has been cited 77 times in a Google Scholar search. Notwithstanding, the lacuna of information regarding the validity and factor structure of the VRSQ demands a deeper investigation among adults in the United States (Stone, 2017; Pesudovs, 2005). Researchers in this field have proposed anywhere between two to three categories underlying the types of discomfort symptoms experienced after VR immersion (Kennedy et al., 1993; Bouchard, Robillardet, & Renaud 2007). However, empirically there is no clear consensus on the underlying factor structure of the discomfort caused by VR-HMD technology. Additionally, the generalizability of the VRSQ has not been examined in contemporary VR-HMD platforms, which utilize real-time head tracking, hand tracking, and postural tracking in room-scale environments. Finally, the Computer Use Survey (CUS) developed by Hayes, Sheedy, Stelmack, & Heaney (2007) created to measure the general visual and body discomfort experienced by office workers who regularly use computers for their work. Our study utilized the CUS in order to test the convergent validity of the Virtual Reality Symptom Questionnaire. This was to ensure that the items of the Virtual Reality Symptom Questionnaire were accurately providing a reliable measure of the underlying construct (e.g., ocular and motor discomfort symptoms). In addition, the CUS validity was further examined in the present study by assessing its degree of relation with other existing symptom measures. Despite the development of a new instrument by Gonzalez-Perez et al. (2013) based off of earlier work by Hayes et al. 2007, no further work has been done to address the lack of validity and accuracy data of the original scoring system, particularly in the context of a virtual reality experience.

Thus, the purpose of this study is to examine the factor structure and validity of the VRSQ, as well as to expand on existing validity evidence for the Computer Use Survey, with a diverse sample of adults in Southern California. Although each measure has been used in previous work, the present study adds to this body of literature in two ways. First, it provides evidence of the as yet undetermined factor structure of each measure. Second, it provides new convergent validity evidence for each measure by examining the correlations between them, as they have not previously been used in the same study, following the same virtual reality task.

Method

Participants

The current sample was near gender balanced with 48 females, 51 males, and one participant whom identified as agender. A diverse sample was recruited, with participants between the ages of 18-57 (M = 24.77, SD = 7.81), identifying as 32% = White, 23% = Hispanic or Latinx, 17% = Two or more races, 13% = Asian or Asian American, and 3% = Black or African American. Participants reported having spent between 3 hours (12%), 8 hours (20%), 13 hours (11%), 18 hours (13%), and 23+ hours (54%) doing near work (e.g., computer work, texting, reading) within the past week.

Procedures

Subjects completed a VR session, and pre/post self-reported surveys, and optometric measurements (accommodative facility). Subjects were recruited from a Southern California University via flyers which included information about the study; incentives offered, eligibility criteria, and contact information. Before arrival, participants were sent a tutorial video containing information on VR-HMD use, applicable controls, and an overview of the task. Upon arrival, participants completed a pre-test questionnaire and were asked to provide consent. Participants were then tasked to interact and play within a rock climbing simulator (Crytek, 2016) for thirty minutes on a VR-HMD platform, Oculus Rift CV1 with Oculus Touch motion tracking controllers (Binstock, 2015). Post-VR immersion participants were asked to fill out a questionnaire and a debrief was given to all participants. Finally, a ($20) amazon gift card was provided to all participants who attempted the VR session.

Virtual reality platform. The Oculus Rift CV1 offers a room-scale VR experience in a 1.5 m x 1.5 m play area and allows freedom of movement via a Constellation IR camera tracking system, and a 3-axis gyroscope accelerometer (Orland, 2016; Binstock, 2015). The HMD utilizes dual, organic light-emitting diode (OLED) panels with a total resolution of 2160 x 1200 pixels (1080x1200 per eye), a refresh rate of 90Hz, and a 110° field of view.

Motion controls. To interact with the VR environment participants were given two handheld motion tracking controllers. Each controller is equipped with 5 buttons, an analog joystick, and haptic feedback through vibration. This allowed the participants to navigate through in-game menus and manipulate objects in VR space.

Virtual reality experience. The Climb, a rock climbingrock-climbing simulator places participants in lifelike scenarios such as climbing a frozen mountain. The CRYENGINE was developed for low latency motion tracking with high framerate and high fidelityhigh-fidelity graphics which increased immersion and controller feedback.

Measures

For each scale, scale scores were created by summation. Endorsement of higher scores indicated increased levels of the construct being assessed.

Virtual reality discomfort symptoms. Participant's virtual reality visual discomfort symptoms were assessed through the 13-item VRSQ (Ames, Wolffsohn, & Mcbrien, 2005). Participants were prompted with the statement, "Please rate your symptoms when using a VR head-mounted display." Two sample items follow: "*Tired eyes*" and "*Eyestrain.*" Respondents were given 7-unipolar categories to choose from with four descriptors: 0 = *None*, 1-2 = S*light*, 3-4 = M*oderate*, and 5-6 = *Severe*.

General discomfort symptoms. To assess acute symptoms related to ocular motor and general body discomfort, the Computer Use Survey (CUS) was utilized for its ability to measure similar constructs: *physical and visual discomfort symptoms* (Hayes et al., 2007). The Computer

Use Survey consists of 21-items separated into two parts: 11 vision and 10 body symptoms. The following prompts were presented: "We would like to know about any discomfort that you may generally experience. "To what extent do you experience..?," and "To what extent do you generally experience discomfort in your..?" Two sample items follow: "*Dry eyes"* and "Neck.*"* A Likert scale rating system was employed with the following response choices: 0 = *None*, 1 = S*light*, 2 = *Mild*, 3 = *Moderate*, 4 = *Somewhat Bad*, 5 = *Bad*, 6 = *Severe*.

Pre/post acute virtual reality symptoms. Participants were asked to respond to four acute VR symptom related questions, before and after using the VR-HMD adapted from a series of pre/post acute vision discomfort questions (Drew et al., 2013). The pre/post test questions and sample answers were as follows: Both *"Please rate the discomfort you feel from overhead lights ……"* and "*Please rate how uncomfortable you feel (before/after) using virtual reality."* Respondent's response choices ranged 1 = *No discomfort* to 5 = *Too unpleasant to view*. For items, *"Please rate any distortions of movement you currently experience with your vision ….."* response choice ranged from 1 = *No distortion* to 5 = *Too distorted to view, and "Please rate if you experience a headache …."* answers ranged from 1 = *No headache* to 5 = *A severe headache.*

Results

VRSQ Supplemental Validation

Although the VRSQ has been previously published and used as evidence in several samples, it was subjected to an Exploratory Factor Analysis (EFA) and reliability testing to confirm its appropriateness for the present sample, as well as validation by the Computer Use Survey.

Exploratory factor analysis. An exploratory factor analysis was conducted on the 13

VRSQ items using principal axis factoring and promax oblique rotation. A clear two-factor solution was identified, consistent with prior published work and theoretical justifications. This solution explained 56.646% of the total variance, with the first factor explaining 41.234% of the variance (with an Eigenvalue of 5.360) and the second factor explaining 15.413% of the variance (with an Eigenvalue of 2.004). Although an additional third factor had an Eigenvalue above one (1.029), there was a significant drop off in variance explained, supported by visual inspection of the scree plot which displayed a clear elbow at three (Figure 1). Therefore, the two-factor solution was retained. The two factors were correlated $r = .490$, supporting the oblique solution.

The item loadings from the pattern matrix, reflecting the unique contribution of each item to each factor, are displayed in Table 1. These results revealed that items 1-3 and 5-8, all reflecting general body discomfort, loaded on factor 2 (with item 7, difficulty concentrating, cross loading on both factors). Items 9-14, reflecting eye-related symptoms, and item 4, drowsiness, loaded on factor 1. Given that the analytic results for item 4 did not match theoretical expectations, this item was dropped from further analysis.

Reliability and item frequencies. Factor 1, Eye-related Symptoms (5 items), demonstrated good internal consistency ($\alpha = .859$). Factor 2, General Body Discomfort (8 items), also demonstrated good internal consistency ($\alpha = .832$). Finally, the total VRSQ scale (with item 4 removed) demonstrated very good internal consistency ($\alpha = .873$). When examining item endorsement frequencies, only VRSQ item 3 (boredom) was endorsed by fewer than 15% of respondents (11% endorsed). However, given the enticing nature of the virtual reality task, this result was not surprising nor concerning regarding the measurement of general body discomfort.

Validity. The VRSQ subscales and total scale were assessed for their correlation with the set of discomfort questions asked of participants both before and after their use of the virtual reality system. All VRSQ scales were moderately to strongly significantly correlated with each of the post-use discomfort questions on the VR-HMD (*rs* .323 to .718, see Table 4), and were not correlated with any of the pre-use discomfort questions on the VR-HMD, as expected. The VRSQ subscales were also assessed for their correlation with participants accommodative functioning. As expected the VRSQ General Body Discomfort factor was not significantly correlated to differences between before and after accommodative functioning. VRSQ Eye Discomfort factor was not significantly correlated, although it did achieve near significance (r = - .197, p = .059).

Computer Use Survey Validation

Exploratory factor analysis. An EFA was conducted on the 21 Computer Use Survey items using principal axis factoring and promax oblique rotation. A four factor solution emerged from this analysis. This solution explained 55.067% of the variance. The first factor explained 24.936% of the variance (Eigenvalue = 5.236), the second factor explained 13.826% of the variance (Eigenvalue = 2.903), the third factor explained 8.794% (Eigenvalue = 1.847), and the fourth factor explained 7.511% (Eigenvalue = 1.577). Although two additional factors had Eigenvalues over one, the scree plot indicated a drop-off after four factors (Figure 2), and the four factor solution was interpretable, so the four factor solution was selected. The factor intercorrelations indicated that factor 1 was correlated with factors 3 and 4 at r > .300, as was factor 2 with factor 4. Therefore, the oblique solution was retained.

The item loadings from the pattern matrix are displayed in Table 2. Items 5-10 and 21 loaded on factor 1, which was identified as “Visual Discomfort.” Items 11, 12, 16, and 17 loaded on factor 2, which was identified as “Back Discomfort.” Items 1-4 loaded on factor 3, which was identified as “Vision Difficulties” (item 4 [difficulty or slowness refocusing eyes] cross loaded on factors 1 and 3, but was conceptually identified as pertaining most closely to factor 3, and was retained on this factor). Items 14, 15, 18, 19, and 20 loaded on factor 4, which was identified as "Extremity Discomfort." Item 13 (elbow/forearm discomfort) did not load above .300 on any factor and was removed from the remainder of analyses.

Reliability and item frequencies. Factor 1, Visual Discomfort (7 items), demonstrated good internal consistency ($\alpha = .836$). Factor 2, Back Discomfort (4 items), demonstrated adequate internal consistency ($\alpha = .789$). Factor 3, Vision Difficulties (4 items), also demonstrated adequate internal consistency ($\alpha = .760$). Factor 4, Extremity Discomfort (5 items), demonstrated borderline adequate internal consistency ($\alpha = .672$). Finally, the total Computer Use Survey scale (with item 13 removed) demonstrated good internal consistency ($\alpha = .838$). Only Computer Use Survey item 19 (lower leg discomfort) was endorsed by fewer than 15% of respondents (14% endorsed).

Validity. Correlations between the Computer Use Survey and the VRSQ (see Table 3) were expected to be moderate, given that similar symptoms were assessed but the frame of reference (general vs. current discomfort) was different. The distributions of each variable were sufficiently normal so as to meet assumptions for the analysis conducted (Afifi, Kotlerman, Ettner, & Cowan, 2007), with the exception of the Vision Difficulties subscale on which there was one outlier. Once this outlier was removed, the variable was also normally distributed. As expected, the total scores of the Computer Use Survey and the VRSQ were significantly, moderately correlated. In addition, the total score of the Computer Use Survey was moderately correlated with the eye and general discomfort subscales of the VRSQ. Furthermore, the visual discomfort scale of the Computer Use Survey was moderately to strongly correlated with both subscales and the total score of the VRSQ. In addition, the Extremity Discomfort subscale of the

Computer Use Survey demonstrated small to moderate correlations with all scales of the VRSQ. Finally, all four CUS subscales showed no significant correlations in the difference between accommodation functioning taken before and after using a VR-HMD. There were no significant correlations between the VRSQ and the Back Discomfort or Vision Difficulties subscales of the Computer Use Survey.

Additionally, the total score of the Computer Use Survey (see Table 4) was significantly correlated with VR-HMD pre-use feelings of uncomfortability and post-use feelings of uncomfortability, distortion of movement in vision, and discomfort from overhead lights. The Visual Discomfort scale of the Computer Use Survey was correlated with VR-HMD pre-use feelings of uncomfortability and discomfort from overhead lights, and post-use feelings of uncomfortability, discomfort from overhead lights, and headache. Finally, Back Discomfort on the Computer Use Survey was associated with VR-HMD pre-use feelings of uncomfortability and post-use distortions of movement in vision, and Extremity Discomfort on the Computer Use Survey was associated with VR-HMD post-use distortions of movement in vision.

Lastly, females experienced more Visual Discomfort ($p = .047$), Back Discomfort ($p = .013$), and total symptoms ($p = .005$) than males on the Computer Use Survey. There was also a significant correlation between older age and Vision Difficulties ($r = .399$, $p < .001$) and total symptoms ($r = .217$, $p = .030$), as well as between Vision Difficulties and having laser eye surgery ($r = -.354$, $p < .001$) and corrected vision ($r = -.309$, $p = .002$).

Among those who use virtual reality, more frequent use was associated with significantly fewer problems on every Computer Use Survey subscale (*rs* -.323 to -.612), and less VRSQ General Body Discomfort ($r = -.305$, $p = .049$).

Discussion

This study was exploratory in nature and no hypothesis was established. The VRSQ was created to address the lack of precise and accurate survey instruments for evaluating discomfort after VR-HMD use (Ames et al., 2005). However, until the present study, there has been no attempt made to explore its factor structure. Additionally, the factor structure of the Computer Use Survey (Hayes et al., 2007) was also explored. Thus, we conducted two separate EFAs to determine whether relevant factor structures exist in the aforementioned measures and to simplify their structures. In our study, we assumed that since both the VRSQ and CUS measured varying types of physical discomfort and their underlying factors were correlated, thus the factors were rotated using promax an oblique rotation method.

The EFA indicated a solution with two factors, which were identified and retained for the VRSQ; eye-related symptoms and general body discomfort. In line with previously established symptom categories for virtual reality related sickness/discomfort (Bouchard, Robillardet, & Renaud 2007; Kennedy et al., 1993). Our factor analysis revealed that eye-related symptoms in the VRSQ accounted for 41.23% of the variance, this suggests that visual/ocular symptoms within this category are most commonly present when utilizing VR-HMDs. However, the refinement of the two factors identified may be possible through rewriting weak primary loading items and the synthesis of new question. Of particular interest in this arena is VRSQ question 7, which indexes difficulty concentrating. This item cross-loaded on both the Body (.474) and Eye (.352) subscales. This may be due, at least in-part, to contextual ambiguity in the phrasing of "difficulty concentrating," as some participants may have interpreted this as cognitive ability to maintain sustained attention, whereas others may have assumed that this item was referring to the ability to focus one's eyes. Future research might explore whether this cross-loading may be reduced by creating two separate items, including one for each interpretation of the phrase. Furthermore, an EFA conducted on the CUS indicated a four factor structure; visual discomfort, back discomfort, visual difficulties, and extremity discomfort. Again, as with the VRSQ, visual discomfort was the most commonly reported category of symptoms. These findings suggest that for both the VRSQ and CUS, eye-related/visual discomfort factors consist of the most common underlying symptoms that are reported from participants after VR-HMD use. Our results demonstrate and support that the VRSQ is both reliable and valid instrument in testing for discomfort due to VR-HMD use.

Limitations

Although the sample collected in this study was large ($N = 100$) relative to other studies investigating VR-HMD discomfort, adequate sample sizes for EFA data sets have been previously been found to be between 50-300 (De Winter, Dodou, Wieringa, 2009; Tabachnick & Fidell 2013). However, MacCallum, Widaman, Zhang, and Hong (1999), provided evidence that these standards can be deceiving, such that determining the sufficiency of a sample size depends on the strength of communalities and whether each factor is defined by at least four items. Additionally, simulated heights experienced in the rock-climbing simulator, which includes virtual falls when losing grip of rock features, may have potentially induced disequilibrium or sickness in those with visual height intolerance (Brandt, & Huppert 2014).

Implications

Based on the results, a two-factor structure for the VRSQ shows promise as being reflective of the types of discomfort experienced after using VR-HMD’s. Regarding convergent validity, the Computer Use Survey offered ample evidence for the use of VRSQ to screen for uncomfortability after the use of HMDs. These findings can help researchers, VR developers, and consumers understand more about the risks associated with using VR-HMD technology.

Conclusions

To date, no surveys have been developed and validated for assessment of ocular and body symptoms associated with the use of contemporary immersive VR platforms, which offer an interactive experience incorporating low latency head tracking, postural tracking, and hand tracking in room-scale environments presented on high definition displays. HMDs used in earlier generations of VR typically offered a passive, scripted viewing experience of prerecorded video, such as those used in the development of the VRSQ. This study provides evidence of reliability (αs =.832 to 873) and validity (*rs* .323 to .718) of both VRSQ sub and total scales. The findings suggest body symptoms may differ in contemporary VR applications, due to mismatches between visual stimuli and vestibular input experienced in older generations of VR. This is mitigated in applications that utilize room-scale environments, which use head tracking to match the orientation of virtual environments with the user's orientation in real space. Nonetheless, based on our findings there is evidence that the VRSQ may have continued utility in the assessment of ocular and body symptoms associated with the use of immersive VR-HMDs used in room-scale environments.

Table 1

VRSQ Exploratory Factor Analysis Results: Pattern Matrix Item Loadings

Item:	(Eye-related Symptoms)	Loading on Factor 2 Body Discomfort)
1. General Discomfort	.007	**.752**
2. Fatigue	.080	**.549**
3. Boredom	-.165	**544**
4. Drowsiness	**.350**	.027
5. Headache	.155	**.510**
6. Dizziness	.009	**.809**
7. Difficulty Concentrating	.352	**.474**
8. Nausea	-.181	**.952**
9. Tired eyes	**.634**	-.105
10. Sore/aching eyes	**.854**	-.038
11. Eyestrain	**.989**	-.141
12. Hot/burning eyes	**.600**	-.095
13. Blurred vision	**.546**	.232
14. Difficulty focusing	**.584**	.257

Table 2

CUS Exploratory Factor Analysis Results: Pattern Matrix Item Loadings

Item:	Loading on Factor 1 (Visual Discomfort)	Loading on Factor 2 (Back Discomfort)	Loading on Factor 3 (Vision Difficulties)	Loading on Factor 4 (Extremity
1. Blurred vision at near distances (e.g., book or newspaper [with your usual glasses or contact lenses])	.210	-.016	**.580**	.041
2. Blurred vision at intermediate distances (e.g. computer screen [with your usual glasses or contact lenses])	-.119	.122	**.952**	-.043
3. Blurred vision at far distances (e.g. driving [with your usual glasses or contact lenses])	-.001	.013	**.630**	.133
4. Difficulty of slowness in refocusing my eyes from one distance to another	.365	-.100	**.358**	.095
5. Irritated or burning eyes	**.710**	-.095	.167	-.080
6. Dry eyes	**.710**	.014	-.060	-.104
7. Eyestrain	**.791**	.053	.092	-.181
8. Headache	**.410**	.084	-.102	.114
9. Tired eyes	**.653**	-.001	.002	.137
10. Sensitivity to bright lights	**.736**	-.113	-.039	.073
11. Discomfort in your neck	.023	**.825**	.004	-.039
12. Discomfort in your shoulder	-.089	**.894**	.076	-.026
13. Discomfort in your elbow/forearm	-.128	.198	-.003	.158
14. Discomfort in your hand/wrist	.149	.281	-.230	**.352**
15. Discomfort in your fingers	.123	.073	-.178	**.509**

16. Discomfort in your upper back	.076	**.746**	.051	-.023
17. Discomfort in your lower back	.242	**.313**	.048	.059
18. Discomfort in your thighs/knees	.103	-.054	.012	**.478**
19. Discomfort in your lower leg	-.057	-.087	.188	**.725**
20. Discomfort in your ankle/foot	-.158	.042	.129	**.705**
21. Discomfort in your eyes	**.578**	.150	-.030	.042

Table 3

Bivariate Correlations between VRSQ and CUS Scales

	VRSQ Total	VRSQ Eye-related Symptoms	VRSQ General Body Discomfort
CUS Total	.397***	.369***	.324**
CUS Visual Discomfort	.448***	.419***	.365***
CUS Back Discomfort	.151	.122	.142
CUS Vision Difficulties	.134	.130	.106
CUS Extremity Discomfort	.266**	.252*	.215*

# $p < .10$, *$p < .05$, **$p < .01$, *** $p < .001$

Table 4

Bivariate Correlations between VRSQ, CUS, and VR-HMD Pre/Post Scales

	Pre-Use Uncomfortability	Pre-Use Distortion of Movement in Vision	Pre-Use Discomfort from Overhead Lights	Pre-Use Headaches	Post-Use Uncomfortability	Post-Use Distortion of Movement in Vision	Post-Use Discomfort from Overhead Lights	Post-Use Headaches
VRSQ Total	.173#	-.071	-.024	.031	.729***	.623***	.428***	.577***
VRSQ Eye-related Symptoms	.131	-.111	.106	.025	.313**	.485***	.442***	.385***
VRSQ General Body Discomfort	.183#	-.103	.035	.034	.641***	.653***	.502***	.574***
CUS Total	.320**	-.007	.151	-.106	.252*	.278**	.215*	.115
CUS Visual Discomfort	.386***	-.039	.234*	-.033	.282**	.172#	.308**	.266**
CUS Back Discomfort	.247*	.016	.137	-.092	.096	.230*	.153	-.058
CUS Vision Difficulties	.048	.178#	.007	-.108	.033	.090	.022	-.024
CUS Extremity Discomfort	.155	-.138	-.031	-.057	.187#	.333**	.097	.157

# $p < .10$, *$p < .05$, **$p < .01$, *** $p < .001$

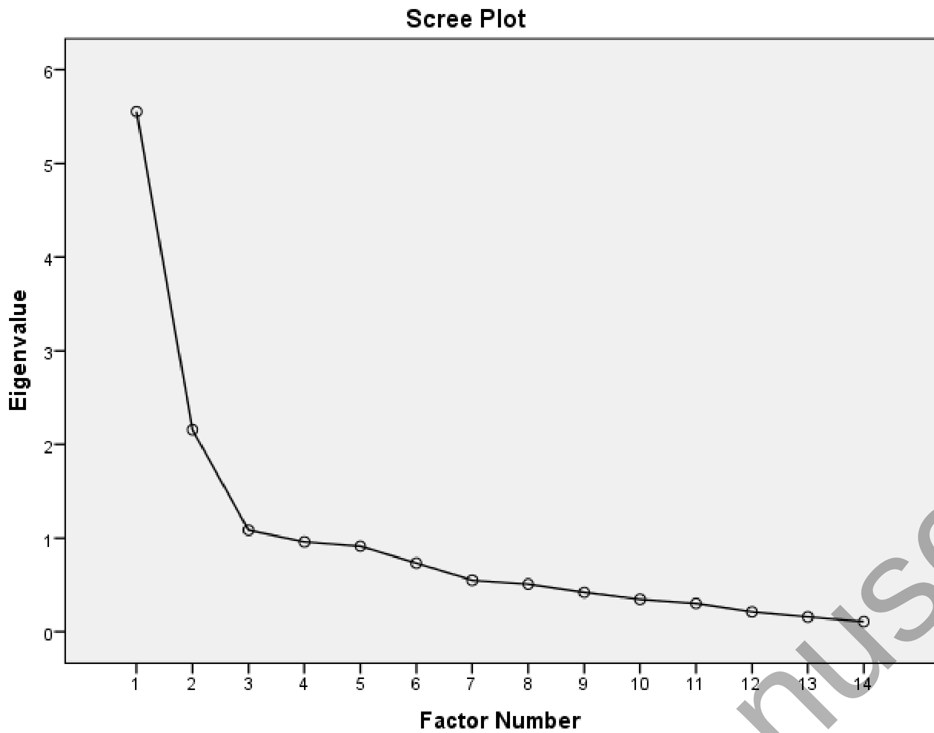

Figure 1 Caption: Scree plot of the VRSQ Exploratory Factor Analysis

Figure 1 Alt Text: A visual line graph referred to as a "scree plot" indicating a 2-factor solution. The title of the graph is displayed above the figure and labeled "Scree Plot" In the Graph the, Y axis represents 1 unit increase in eigenvalues starting at 0 up to 6 and the X axis represents number of possible factors starting at 1 up to 14.

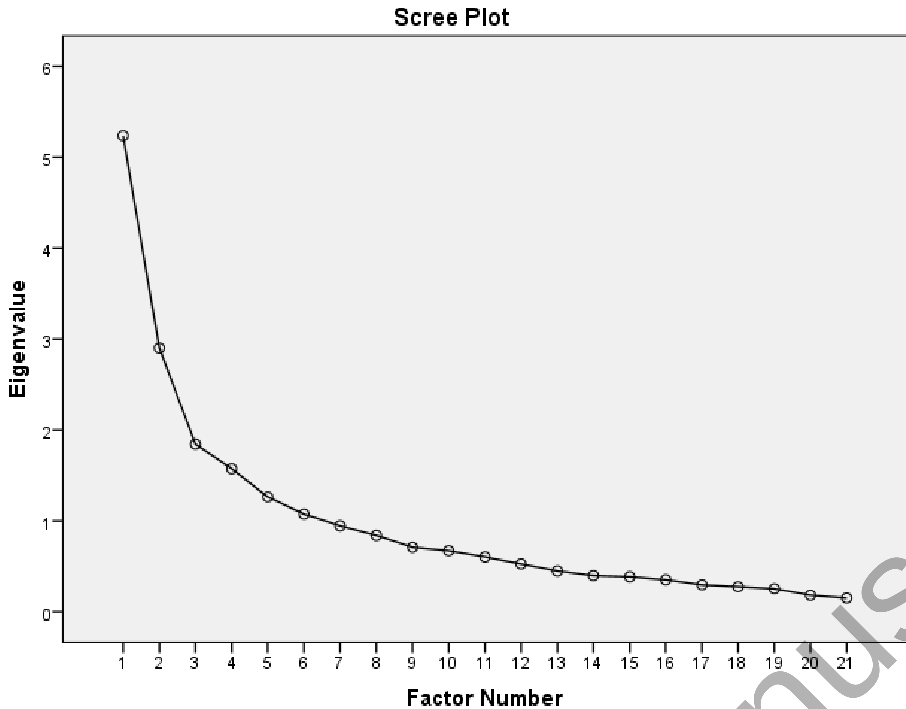

Figure 2 Caption: Scree plot for CUS Exploratory Factor Analysis

Figure 2 Alt Text: A visual line graph referred to as a “scree plot” indicating a 4-factor solution. The title of the graph is displayed above the figure and labeled “Scree Plot” In the Graph the, Y axis represents 1 unit increase in eigenvalues starting at 0 up to 6 and the X axis represents number of possible factors starting at 1 up to 21.

References

Afifi, A. A., Kotlerman, J. B., Ettner, S. L., & Cowan, M. (2007). Methods for improving regression analysis for skewed continuous or counted responses. Annual Review of Public Health, 28, 95–111. doi:10.1146/annurev.publhealth.28.082206.094100

Amenós, M. C., & Knox, P. C. (2014). The effect of a projected virtual reality training environment on vision symptoms in undergraduates. *British and Irish Orthoptic Journal*, *11*(0), 39. doi:10.22599/bioj.84

Ames, S. L., Wolffsohn, J. S., & Mcbrien, N. A. (2005). The Development of a Symptom Questionnaire for Assessing Virtual Reality Viewing Using a Head-Mounted Display. *Optometry and Vision Science*, *82*(3), 168–176. doi:10.1097/01.OPX.0000156307.95086.6

Bellani, M., Fornasari, L., Chittaro, L., & Brambilla, P. (2011). Virtual reality in autism: State of the art. *Epidemiology and Psychiatric Sciences*, *20*(3), 235–238. doi:10.1017/S2045796011000448

Binstock, A. (2015). Powering the Rift. Retrieved August 18, 2018, from https://www.oculus.com/blog/powering-the-rift/

Bouchard, S., Robillard, G., & Renaud, P. (2007). Revising the factor structure of the Simulator Sickness Questionnaire. *Annual review of cybertherapy and telemedicine*, *5*(Summer), 128-137.

Brandt, T., & Huppert, D. (2014). Fear of Heights and Visual Height Intolerance. *Current opinion in Neurology*, *27*(1), 111-117. doi:10.1097.wco.0000000000000057

Carnegie, K., & Rhee, T. (2015). Reducing Visual Discomfort with HMDs Using Dynamic Depth of Field. *IEEE Computer Graphics and Applications*, *35*(5), 34–41.

doi:10.1109/MCG.2015.98

Crytek. (2016). The Climb. Frankfurt: Crytek.

D. Magyari, “Virtual Reality: Are Health Risks Being Ignored?,” *CNBC*, 2016. [Online]. Available: http://www.cnbc.com/2016/01/08/virtual-reality-are-health-risksbeing-ignored-commentary.html. [Accessed: 01-Aug-2016].

De Winter*, J. C. F., Dodou*, D., & Wieringa, P. A. (2009). *Exploratory Factor Analysis With Small Sample Sizes. Multivariate Behavioral Research, 44(2), 147–181*. doi:10.1080/00273170902794206

Drexler, J. (2006). Identification of system design features that affect sickness in virtual environments.

Foerster, R. M., Poth, C. H., Behler, C., Botsch, M., & Schneider, W. X. (2016). Using the virtual reality device Oculus Rift for neuropsychological assessment of visual processing capabilities. *Scientific Reports, 6*(1), 37016. doi:10.1038/srep37016

Gonzalez-Perez, M., Susi, R., Antona, B., Barrio, A., Gonzalez, E. (2013). The Computer-Vision Symptom Scale (CVSS17) Development and Initial Validation. *Investigative Ophthalmology Vision Science.55*, 4504–4511. doi:10.1167/iovs.13-13818

Grzybowski, A., Schachar, R. A., Gaca-Wysocka, M., Schachar, I. H., & Pierscionek, B. K. (2018). Maximum human objectively measured pharmacologically stimulated accommodative amplitude. *Clinical Ophthalmology (Auckland, N.Z.), 12*, 201–205. doi:10.2147/OPTH.S154432

Hayes, J. R., Sheedy, J. E., Stelmack, J. A., Heaney, C. A. (2007) Computer Use, Symptoms, and Quality of Life. *Optometry and Vision Science, 84*(8), E739-E745 doi:10.1097/OPX.0b013e31812f7546

Hinckley, K., Pausch, R., Proffitt, D., & Kassell, N. F. (1998). Two-handed virtual manipulation. *ACM Transactions on Computer-Human Interaction*, *5*(3), 260–302. doi:10.1145/292834.292849

Hoffman, H. G., Meyer, W. J., Ramirez, M., Roberts, L., Seibel, E. J., Atzori, B., … Patterson, D. R. (2014). Feasibility of Articulated Arm Mounted Oculus Rift Virtual Reality Goggles for Adjunctive Pain Control During Occupational Therapy in Pediatric Burn Patients. *Cyberpsychology, Behavior, and Social Networking*, *17*(6), 397–401. doi:10.1089/cyber.2014.0058

Jensen, L., & Konradsen, F. (2017). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies*, 1–15. doi:10.1007/s10639-017-9676-0

Kellogg, R. S., Kennedy, R. S., & Graybiel, A. (1965). Motion sickness symptomatology of labyrinthine defective and normal subjects during zero gravity maneuvers. *Aerospace Medicine, 36*, 315-318.

Kennedy, R. S., Stanney, K. M., & Dunlap, W. P. (2000). Duration and exposure to virtual environments: sickness curves during and across sessions. *Presence: Teleoperators & Virtual Environments, 9(*5), 463-472.

Krijn, M., Emmelkamp, M. G. P., Ólafsson, P. R., & Biemond, R., (2010). Virtual reality exposure therapy in anxiety disorders: A systematic review of process-and-outcome studies. *Depression and Anxiety*, *27*(10), 933–944. doi:10.1002/da.20734

Lerner, M. A., Ayalew, M., Peine, W. J., & Sundaram, C. P. (2010). Does Training on a Virtual Reality Robotic Simulator Improve Performance on the da Vinci ® Surgical System? *Journal of Endourology*, *24*(3), 467–472. doi:10.1089/end.2009.0190

Maples-Keller, J. L., Price, M., Rauch, S., Gerardi, M., & Rothbaum, B. O. (2017). Investigating Relationships Between PTSD Symptom Clusters Within Virtual Reality Exposure Therapy for OEF/OIF Veterans. *Behavior Therapy*, *48*(2), 147–155. doi:10.1016/J.BETH.2016.02.011

McCauley, M. E., & Sharkey, T. J. (1992). Cybersickness: Perception of Self-Motion in Virtual Environments. Presence: Teleoperators and Virtual Environments, 1(3), 311–318. doi:10.1162/pres.1992.1.3.311

Meyerbröker, K., & Emmelkamp, P. M. G. (2010). Virtual reality exposure therapy in anxiety disorders: A systematic review of process-and-outcome studies. *Depression and Anxiety*, *27*(10), 933–944. doi:10.1002/da.20734

Morel, M., Bideau, B., Lardy, J., & Kulpa, R. (2015). Advantages and limitations of virtual reality for balance assessment and rehabilitation. *Neurophysiology Clinique/Clinical Neurophysiology*, *4*5(4–5), 315–326. doi:10.1016/J.NEUCLI.2015.09.007

Orland, K. (2016). The Ars review: Oculus Rift expands PC gaming past the monitor's edge | Ars Technica. Retrieved August 18, 2018, from https://arstechnica.com/gaming/2016/03/the-ars-review-oculus-rift-expands-pc-gaming-past-the-monitors-edge/

Pallavicini, F., Argenton, L., Toniazzi, N., Aceti, L., & Mantovani, F. (2016). Virtual Reality Applications for Stress Management Training in the Military. *Aerospace Medicine and Human Performance*, *87*(12), 1021–1030. doi:10.3357/AMHP.4596.2016

Palter, S. F. (2003). The Operating Room of the Future II. *Surgical Innovation*, *10*(3), 95–97. doi:10.1177/107155170301000301

Reger, G. M., Holloway, K. M., Candy, C., Rothbaum, B. O., Difede, J., Rizzo, A. A., & Gahm,

G. A. (2011). Effectiveness of virtual reality exposure therapy for active duty soldiers in a military mental health clinic. *Journal of Traumatic Stress*, *24*(1), 93–96. doi:10.1002/jts.20574

Sharples, S., Cobb, S., Moody, A., & Wilson, J. R. (2008). Virtual reality induced symptoms and effects (VRISE): Comparison of head mounted display (HMD), desktop and projection display systems. *Displays*, *29*(2), 58–69. doi:10.1016/j.displa.2007.09.005

Tabachnick, B. G., & Fidell, L. S. (2013). Using multivariate statistics, 6th edn Boston. *Ma: Pearson*.

Turnbull, P. R. K., & Phillips, J. R. (2017). Ocular effects of virtual reality headset wear in young adults. *Scientific Reports*, *7*(1), 16172. doi:10.1038/s41598-017-16320-6