Effects of Long-Term Exposure on Sensitivity and Comfort with Stereoscopic Displays

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Stereoscopic 3D media has recently increased in appreciation and availability. This popularity has led to concerns over the health effects of habitual viewing of stereoscopic 3D content; concerns that are largely hypothetical. Here we examine the effects of repeated, long-term exposure to stereoscopic 3D in the workplace on several measures of stereoscopic sensitivity (discrimination, depth matching, and fusion limits) along with reported negative symptoms associated with viewing stereoscopic 3D. We recruited a group of adult stereoscopic 3D industry experts and compared their performance with observers who were (i) inexperienced with stereoscopic 3D, (ii) researchers who study stereopsis, and (iii) vision researchers with little or no experimental stereoscopic experience. Unexpectedly, we found very little difference between the four groups on all but the depth discrimination task, and the differences that did occur appear to reflect task-specific training or experience. Thus, we found no positive or negative consequences of repeated and extended exposure to stereoscopic 3D in these populations.

Categories and Subject Descriptors: H.1.2 [**Models and Principles**]: User/Machine Systems—*Human factors*; I.2.10 [**Artificial Intelligence**]: Vision and Scene Understanding—*3D/Stereo scene analysis*; I.4.8 [**Image Processing and Computer Vision**]: Scene Analysis—*Stereo*

General Terms: Experimentation, Human Factors

Additional Key Words and Phrases: Stereoscopic 3D, S3D, stereopsis, stereo displays, depth discrimination

ACM Reference Format:

Debi Stransky, Laurie M. Wilcox, and Robert S. Allison. 2014. Effects of long-term exposure on sensitivity and comfort with stereoscopic displays. ACM Trans. Appl. Percept. 11, 1, Article 2 (March 2014), 13 pages.
DOI: http://dx.doi.org/10.1145/2536810

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1. INTRODUCTION

Current interest in stereoscopic 3D (S3D) media on the part of content creators and the viewing public has fostered substantial growth in the S3D film industry. Thus, not only do movie goers have the opportunity to view more S3D, but those working in the film industry are also exposed to multiple, extended sessions of S3D viewing, over relatively long spans of time. It stands to reason that the negative (e.g., discomfort) or positive (e.g., improved stereoscopic depth perception) effects of viewing S3D would be seen in those who work in the S3D film industry.

This study was funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) to D.S. and L.W. and by the Ontario Media Development Corporation and the Ontario Centres of Excellence funding to R.A. and L.W. as part of the 3D Film Innovation Consortium.

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DOI: http://dx.doi.org/10.1145/2536810

Discomfort as a result of distortions due to camera convergence [Kooi and Toet 2004; Allison 2007; Held and Banks 2008], and the vergence-accommodation conflict [Hoffman et al. 2008; Ukai and Howarth 2008; Lambooij et al. 2009, 2011; Shibata et al. 2011] have been well documented. Stereopsis can be achieved without discomfort when disparities fall within one-third the width of the zone of clear binocular vision, called *Percival's zone of comfort* [Percival 1920; Howard and Rogers 2002]. However, stimuli often fall outside of this zone when displayed on S3D displays, and the observer must decouple vergence and accommodation to fixate these stimuli. This dissociation of accommodation and vergence has been linked to symptoms such as headaches, visual fatigue, and eyestrain [Wann and Mon-Williams 1997; Hoffman et al. 2008; Lambooij et al. 2009, 2011].

There is evidence that the link between vergence and accommodation can be modified by experience. Judge and Miles [1985] investigated the effects of adaptation on the vergence accommodation ratio (AC/A). In their study, subjects wore lateral periscopic spectacles and were asked to change fixation every few seconds between objects at different distances (30cm to 50m). The AC/A ratio was measured using the Maddox rod technique. The gain in accommodative vergence increased, on average, from 0.82 before adaption to 1.13 after adaptation, a significant 37% increase in gain. Although different from the effects of long-term or repeated exposure, the susceptibility of the AC/A ratio to adaptation is evidence that it can be modified by experience.

More recently, Hoffman et al. [2008] used a multiplane volumetric display to evaluate the effects of mismatched accommodation and vergence on visual comfort. They found that when observers were presented with correct, or nearly correct, focus cues, they experienced less visual fatigue and fewer distortions in perceived depth. These authors did not directly evaluate the role that experience or training had on their results.

Possibly because there has been little objective assessment of the long-term effects of S3D on adult viewers, manufacturers of 3D displays, handheld devices, and video cards have erred on the side of extreme caution and have issued sweeping warnings regarding S3D. For example, on their website's Health and Safety Precautions section, Nintendo [2013] warns that viewing S3D material may cause seizures (even if the individual does not have a history of epilepsy or seizures). They also list a number of potential symptoms that may arise from watching S3D material such as light-headedness, altered vision, convulsions, disorientation, nausea, and eye or muscle twitching. In addition to these warnings, Samsung [2013] includes a warning that "pregnant women, the elderly, sufferers of serious medical conditions, those who are sleep deprived or under the influence of alcohol should avoid utilizing the unit's 3D functionality." Again, these concerns have little or no grounding in empirical research and, in fact, the American Optometric Association has spoken strongly about the potential *benefits* of viewing S3D. In their publication "3D Vision and Eye Health" [2013], they point out that there is no evidence that viewing S3D can harm the normally developing visual system. In addition, they point to the potential for improved attention and visual learning when S3D is used in educational settings. These benefits may be augmented by improvements in sensitivity to or the ability to fuse large binocular disparities (binocular parallax). However, to date, there is no scientific evidence either for potential benefits or for these extreme negative consequences, nor have there been any long-term studies examining the effects of experience over many days, or even years, on viewer's sensitivity to or comfort with S3D. Thus, the goal of this study was to serve as a first step toward understanding the effects of extended, long-term experience with S3D content on (1) stereoscopic abilities in adults and (2) on the negative symptoms associated with such viewing.

The difference between conventional 2D nonstereoscopic content and S3D is the addition of binocular disparity; the difference in the lateral position of the image of an object on one retina compared to its position on the other. Stereoscopic ability can be quantified in several ways, most commonly by measuring stereoacuity, the smallest discernable disparity that an observer can reliably detect. Many factors affect stereoacuity, including viewing time, level of detail, and movement. Like many other visuospatial abilities, stereoacuity has been shown to depend on both the underlying physiology [Richards 1970] and experience [Foley and Richards 1974; McKee and Taylor 2010; Fendick and Westheimer 1983]. Motivated by early electrophysiological studies of stereopsis that showed distinct populations of disparity tuned neurons [Poggio 1995], Richards [1970] evaluated stereoanomalies in human observers. He reported that patterns of stereo-deficits were consistent with the existence of distinct neural populations, which encode (among other attributes) disparity sign, and magnitude. Subsequently, Foley and Richards [1974] reported that some stereoanomalous individuals could achieve normal stereoacuity with practice. Also, Patterson and Fox [1984] showed that observers who previously were classified as stereoanomalous performed normally when given long exposure durations. Investigators have recently shown that extensive training on stereoscopic tasks under specific conditions, such as equalized contrast in the two eyes and additional monocular cues, can lead to improved stereopsis in individuals with amblyopia or “lazy eye” [Hess et al. 2010; Ding and Levi 2011].

It is also well established that stereoscopic experience, or stereoscopic training, can improve stereoacuity in visually normal observers [Fendick and Westheimer 1983; O’Toole and Kersten 1992; Sowden et al. 1996; Gantz et al. 2007; McKee and Taylor 2010]. For example, Fendick and Westheimer [1983] examined the amount and the rate of improvement in stereoacuity for two inexperienced observers with stimuli viewed foveally and peripherally (2.5–5 degrees from fixation). Both observers showed substantial improvement, but by different amounts (73% and 23%), which is consistent with a later study by Schmitt et al. [2002] who demonstrated that the degree of improvement varies significantly across observers. In a more recent study, McKee and Taylor [2010] showed that unpracticed observers’ stereoscopic thresholds were initially significantly higher than those of practiced observers, but with practice (50 trials for real objects and 1,500 to 2,000 trials when using a stereoscope), naïve subjects reached “expert” level. The compelling evidence that stereopsis can improve with substantial practice suggests that there may be advantages to long-term, extended viewing of S3D content. There are two important factors that make it difficult to relate this body of work to S3D media. First, apart from McKee and Taylor [2010], all experiments used simple, isolated, reduced cue stimuli, which is very different from most film footage. Second, it is not clear whether the observed improvements were due to task-specific learning rather than improvement in stereopsis per se. One of the advantages of the approach used here is that we will be able to distinguish between these two effects.

In the experiment reported here, we used a novel cross-sectional approach to evaluate the positive and negative consequences of S3D exposure. This paradigm allowed us to distinguish between the effects of stereoscopic-specific training and those due to familiarization with the experimental paradigm and task. To this end, we tested four groups of adult observers on a set of tasks outlined in the following section, and we also assessed their S3D symptoms and recorded their overall exposure to S3D content. The groups consisted of industry stereo experts, academic stereo experts, naïve observers, and academic vision science experts with no experience participating in stereoscopic experiments.

2. METHODS

2.1 Participants

Participants included individuals who work in the S3D industry as well as undergraduate and graduate students at York University. Industry participants were recruited through email postings targeted to a large pool of individuals affiliated with the S3D industry. A total of 44 people participated in this study, and their ages ranged from 18 to 60 years. All observers were first assessed using the Adult Randot Stereotest, and they were excluded from the study if their thresholds were greater than 60arcsec. Only five individuals did not meet this criterion and were excluded from this study. This study adhered to the tenets of the Declaration of Helsinki and was approved by the York University Ethics Board.

Subjects were classified (a priori) into four groups. The Stereo Expert group (n = 11) consisted of scientists who study stereoscopic vision in humans and consistently participate in a variety of stereoscopic experiments. The average age of participants in the Stereo Expert group was 25 (s.d. = 7.3), and the age range was 20 to 46 years. The S3D Industry Expert group (n = 11) consisted of individuals who work full-time in the S3D field as stereographers, or in postproduction, 3D animation, or 3D software development. The average age of participants in the Industry Expert group was 32 (s.d. = 8.6), and the age range was 20 to 51 years. The Industry Expert group had a basic understanding of human stereopsis (and typically a thorough understanding of S3D media), and spent many hours per week (and often many hours per day) viewing stereoscopic content. As part of their occupation, these experts may spend many consecutive hours viewing S3D images on computer displays searching for and correcting compositing artifacts (see Table I in Appendix 1). These errors may be quite small, near the stereoacuity threshold, or large, thus giving the industry experts experience with a wide range of binocular parallax. Our Naïve group (n = 11) consisted of undergraduate students who were not experienced in stereopsis or with psychophysical methods. The average age of participants in the Naïve group was 27 (s.d. = 6.9), and the age range was 18 to 40 years. We also tested a Vision Scientists group (n = 11), which consisted of graduate students from the Centre from Vision Research at York University who were very experienced in performing psychophysical tasks, but not ones which assessed stereopsis. The average age of participants in the Vision Scientists group was 32 (s.d. = 9.9), and the age range was 22 to 58 years.

It is important to note that an unavoidable self-selection bias may be present in our Stereo and Industry Expert groups. That is, it is possible that individuals with poor stereopsis or negative experience such as discomfort, may have avoided working in these fields, and as a result will not be represented in these categories. Because of this we are careful to acknowledge that the results apply to adults with typical stereoscopic function and presumably no serious prior discomfort. Our selection criteria, a score of 60arcsec or lower on the Randot Stereotest, ensured that the groups were comparable in terms of their stereoacuity.

2.2 Apparatus and Materials

During testing, participants sat with their head in a chin rest positioned 60cm from a Viewsonic G225f CRT 120Hz monitor (1,024 × 768 resolution). Participants viewed time-sequential stereoscopic stimuli using a shutter glasses system (Crystal Eyes, model CE-3), synchronized with the monitor's refresh rate. A wireless game-pad (Logitech cordless) was used to make responses. The white stimuli were visible on a midgrey background and were well above detection threshold, but the contrast was moderate (29% Michelson) to help minimize crosstalk. Prior testing revealed that under these conditions there was no detectable crosstalk.

Following testing, a questionnaire was completed by all observers (Appendix 2). Here participants indicated the stereoscopic nature of their employment (relevant for the Industry Expert), prevalence of headaches, ocular problems, and finally were asked to retrospectively indicate which of 10 common symptoms they associated with their experience of viewing S3D material. The questionnaire was specifically created for the Vision Scientist group. Two modifications were made when assessing the other groups. For the Stereo Expert and the Industry Expert groups, the first question asked how long they had worked in the S3D Industry (number of years), and the second question asked how many hours per day they spend viewing S3D material. Industry Experts were also asked an additional question regarding the nature of their job. For the Vision Scientists group, these questions were modified to inquire about the number of years they worked in the field of vision research, and the number of

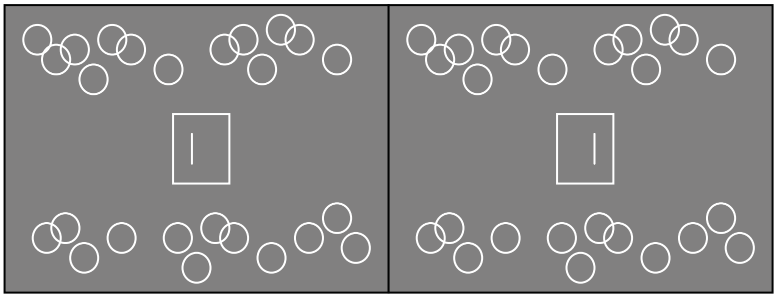

Fig. 1. Stereogram illustrating the depth discrimination task. When crossed-fused the line appears in front of the rectangle (fusion using divergence results in the line appearing behind the rectangle).

hours per week that they spend participating in psychophysical experiments. Both of these questions were omitted in the questionnaire completed by Naïve subjects.

2.3 Tasks and Stimuli

2.3.1 *Depth Discrimination.* As outlined in the Introduction, previous experiments have shown that practice on S3D tasks improves performance on tasks designed to assess disparity thresholds. We employed a two-alternative forced choice (2AFC) depth discrimination task to determine if such improvements result from general exposure to binocular disparity (Industry Experts) or if they are specific to exposure to psychophysical tasks (Vision Scientists) or to both (Stereo Experts). When required, antialiasing was used to achieve subpixel displacements, so the minimum effective disparity was 0.1 arc min (where 1 pixel equals 2.1 arc min). The participant was asked to judge the relative position of a thin line (20 × 3 arcmin) that was set inside a rectangle (1.84 × 4.52 degrees, Figure 1). The upper and lower portions of the screen were filled with an array of overlapping circles; the rectangle and circles were positioned at zero-disparity, which helped to maintain fixation at the screen plane. On each trial, observers were asked to fixate on the zero disparity rectangular frame, while the stimulus line was presented for 160ms and then to indicate whether the line was in front of or behind the reference frame. The brief exposure duration was used to avoid the initiation of vergence eye movements. Preliminary testing was conducted to determine an appropriate range of disparities for each participant. Nine disparities, which consisted of four evenly spaced disparities bracketing zero were shown in random order 30 times each. A Weibull function was subsequently fit to individual data sets to determine the slope and 64% threshold for each dataset.

2.3.2 *Disparity Matching.* Although there is evidence that stereoacuity improves with practice, little attention has been paid to improvement of suprathreshold disparity matching. It is possible that experience with manipulating and positioning a large range of disparities might give the Industry and Stereo Expert groups an advantage over those who did not have this training (i.e., Naïve and Vision Scientists). The second task involved disparity matching and used a method of adjustment. The stimulus configuration was similar to that used for the depth discrimination task, except a small dot (diameter = 21.3arcmin), originally set at zero disparity, was positioned below the line. Observers used the keypad to adjust the disparity of the dot until its apparent depth matched the apparent depth of the line. The disparities of the line were –8, –6, –4, –2, 0, 2, 4, 6 and 8arcmin; each disparity was tested 20 times in random order, and the settings for each disparity were averaged. Observers were given as much time as needed to complete this task but were encouraged not to spend too long scrutinizing the stimulus on each trial. Disparity matching responses were averaged and then plotted as a function of disparity.

2.3.3 *Fusion Limit.* Previous studies have shown that the fusion limit, the disparity at which an object no longer appears "single," is labile and is affected by interocular size differences [Heckmann and Schor 1989], spatial frequency [Schor and Wood 1983; Schor et al. 1984; Schor and Heckmann 1989], eccentricity [Ogle 1964; Crone and Leuridan 1973; Hampton and Kertesz 1983], and hysteresis [Fender and Julesz 1967; Diner and Fender 1987]. Since the fusion limit is flexible and is influenced by many different sources, it is likely also affected by experience, though this has not been studied to date. A staircase procedure was used to obtain each observer's sensory fusion limit. A box was presented in the center of the screen and observers fixated on a cross in the center of that box, both of these were positioned at zero-disparity. At the beginning of a trial, a dot (radius = 21arcmin) was presented in the center of the box, replacing the fixation cross for 160ms. Trials started either with the dot at zero disparity or at a large disparity (50arcmin) and on each trial the observer used the keypad to indicate if the dot appeared "single" or "double." Observers were instructed to judge the dot as being double only when the dot looked like two distinct images with no overlap. A single staircase proceeded as follows: Following a "single" response, the disparity was increased in 2arcmin steps until a "double" response was made. On the next trial in that staircase, the disparity was reduced and continued to be reduced on subsequent trials until their response reversed again. The reversal values (the disparity at which the response changed from "single" to "double," or "double" to "single") were recorded and a given staircase continued until 10 reversals were obtained (first reversal was discarded). To avoid hysteresis and bias effects, we interleaved the two staircases with different starting values. The diplopia point was taken as the average of the reversal values.

2.4 Data Analysis

For all three tasks, heteroscedasticity and normality were assessed using the Levene's test and the Shapiro-Wilk test, respectively. When each groups' datasets were found to be both homogeneous and normally distributed, we used an analysis of variance (ANOVA) with an alpha level of 0.05 to analyze our data. Post hoc tests were performed with a Bonferroni adjustment for multiple comparisons. When normality or homoscedasticity were violated, a nonparametric alternative was used.

3. RESULTS

3.1 Depth Discrimination

Results of the depth discrimination task are shown in Figure 2. The Levene's test indicated that groups in this comparison had unequal variances ($p = 0.035$); therefore, instead of using an ANOVA, a Kruskal-Wallis nonparametric analysis was applied. A statistically significant main group effect was found for our depth discrimination task, $\chi^2(3) = 13.242$, $p = 0.004$.

Mann-Whitney U tests were performed post hoc to identify where these differences lie. Association strength was assessed using Glass' rank biserial coefficient, r_g [Glass 1966]. Significant differences between the Stereo Experts group and the Industry Experts ($p = 0.004$, $r_g = 0.70$, large effect) and Naïve groups ($p = 0.001$, $r_g = 0.79$, large effect) were found. The Vision Scientists group also performed significantly better than the Naïve group ($p = 0.023$, $r_g = 0.57$, large effect). The Industry Expert group's performance was not significantly different from the Naïve group ($p = 0.401$) or the Vision Scientists group ($p = 0.101$), nor was the Stereo Experts performance different from the Vision Scientists group ($p = 0.847$).

3.2 Disparity Matching

As shown in Figure 3, the four groups performed similarly in the disparity matching task. This was confirmed by an ANOVA, which showed no significant group differences in depth matching. Across all

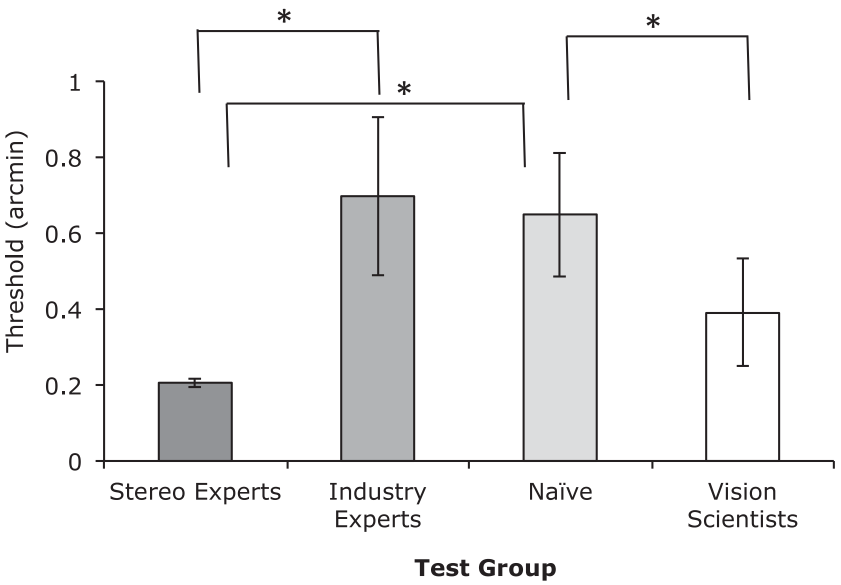

Fig. 2. Average depth discrimination thresholds are shown here for each group. Lower values correspond to better stereoacuity. Asterisks indicate significant group differences. Error bars represent the standard error of the mean.

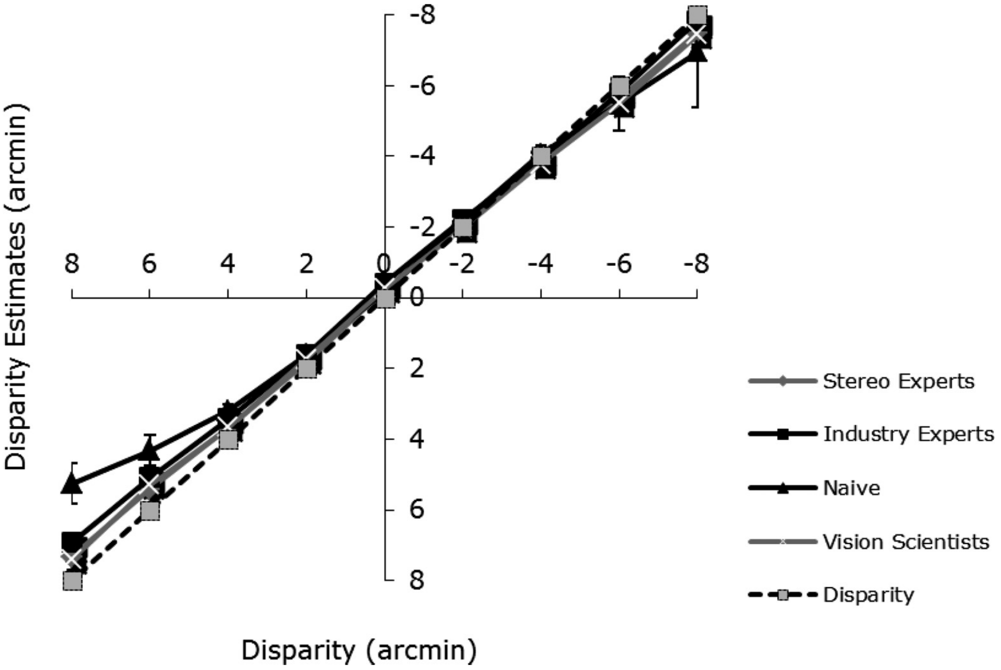

Fig. 3. Estimates of average matched disparity (arcmin) as a function of screen disparity for each group. Positive disparity values represent uncrossed (far) depth, and negative disparity values represent crossed (near) depth. The dashed black line with square markers represents the physical disparity. Error bars represent the standard error of the mean.

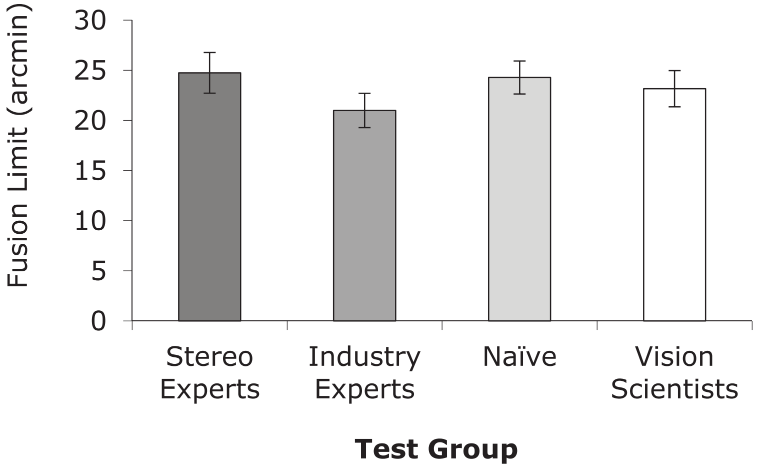

Fig. 4. Bar graph of the average fusion limits for each type of observer (see text for details). Error bars represent ± one standard error of the mean.

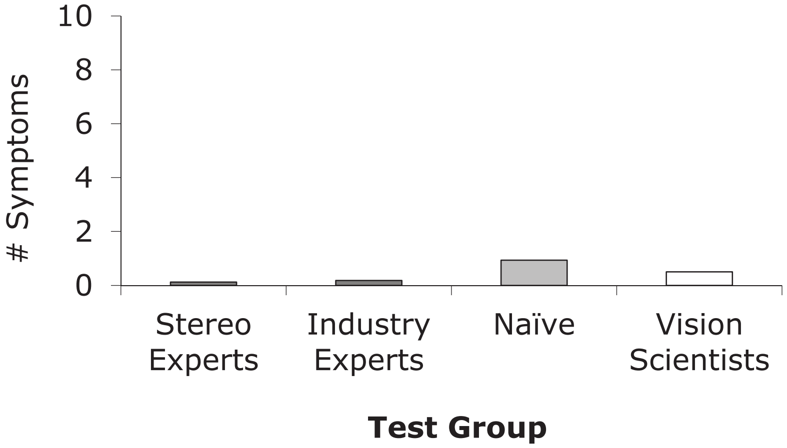

Fig. 5. Histograms show the average number of reported symptoms when viewing S3D material for each group of observers.

subjects, we found very little variability for most disparities. The only exception was for the Naïve subjects, where we found slightly higher intersubject variability for the larger (6 and 8arcmin) disparities in the uncrossed direction. Disparity estimates were very close to the real disparity, as indicated by the dashed line in Figure 3.

3.3 Fusion Limit

As shown in Figure 4, fusion limits were similar for the four groups. Statistical analysis confirmed this, as there was no main effect of group: $F(3) = 0.1.290$, $p = 0.291$, partial $\eta^2 = 0.088$ (medium effect), and Observed Power = 0.318 (Figure 4).

3.4 Questionnaire

The number of symptoms reported by each subject was averaged for each of the four groups and is shown in Figure 5. Significantly unequal variances were indicated on the Levene's test ($p = 0.019$);

therefore, a Kruskal-Wallis nonparametric test was used. We did not find a significant main group effect, $\chi^2(3) = 7.769$, $p = 0.051$, for the number of reported symptoms. Also, the symptoms that were reported are summarized in Table II in Appendix 2. At least one symptom was reported by 16 of the 44 observers. Typically observers reported 0 or 1 symptom, although two Naïve observers reported 3 and 5 symptoms. Of the people who regularly use stereoscopic displays (Stereo Experts and Industry Experts), 3 out of 22 reported symptoms, whereas 13 of 22 of those who did not regularly use stereoscopic displays reported symptoms. Therefore, there is a trend toward fewer symptoms reported when individuals are highly experienced with S3D; however, this trend was not statistically significant and would require a larger number of subjects to evaluate fully.

4. DISCUSSION

Repeated exposure to S3D has been shown to increase sensitivity to disparity in the psychophysical literature [Fendick and Westheimer 1983; McKee and Taylor 2010]; therefore, we anticipated that the Stereo Experts and Industry Experts would outperform observers that did not have S3D experience. However, we found that the stereoacuity of the Industry Experts group was similar to the Naïve group who had little S3D experience. This suggests that their experience with S3D had no impact on their depth discrimination abilities (positive or negative). However, the Stereo Experts group performed significantly better than the Industry Experts and the Naïve group. This is likely due to the fact that the Stereo Experts are both experienced with S3D, and with the psychophysical tasks used to assess stereopsis. However, there was no significant difference between the Stereo Experts and the Vision Scientists groups, suggesting that this advantage is provided by familiarity with the task. However, a difference in variability was observed; smaller standard errors were obtained for the Stereo Expert group.

Results from our experiments suggest that stereoscopic perceptual learning is very specific and likely involves an attentional component [O'Toole and Kersten 1992; Bashinski and Bacharach 1980; Sowden et al. 1996]. That is, participants learn to attend to task relevant information in S3D, which is why the psychophysical experience of Vision Scientists provided an advantage when faced with an S3D psychophysical task. However, the extensive training and experience of the Industry Experts did not transfer to S3D psychophysical tasks. These results highlight an important consideration for the investigation of perceptual learning; it is essential to consider task-specific learning that may not reflect true changes in an observer's ability to perceive the dimension in question.

The disparity matching results were uniformly good, with all groups making near-veridical disparity estimates. It is possible then that the failure to find group differences here is a ceiling effect caused by our unlimited exposure duration. It is well established that stereoacuity for simple line stimuli improves with increasing exposure duration [Ogle and Weil 1958]. There is some suggestion that the Naïve group performed more variably at the largest disparity tested (Figure 3), and their data appears to start to flatten. However, this trend did not reach significance.

The fusion limit is influenced by changes in a number of properties including spatial frequency, eccentricity, and interocular size differences. Because this limit has been shown to be somewhat labile, we anticipated that experience might influence the maximum fusible disparity. Therefore, we expected that experienced observers (Stereo Experts and Industry Experts), who had extended experience viewing a large range of disparities, would have larger fusion limits, but no between-group differences were found on this task. This was unexpected, and given the wide spread of experience with S3D represented by these groups show for the first time that the fusion limit is relatively stable.

In terms of the questionnaire, we predicted that experienced observers would report less discomfort when viewing S3D material because they would have likely adapted to a range of factors that contribute to discomfort (such as the vergence accommodation conflict) over time. For instance Yang et al. [2012] reported that older individuals experience less discomfort when viewing S3D media than younger observers because they have adapted to conflicts and are better able to decouple vergence and accommodation. We did not find a significant main effect for the number of symptoms reported in the questionnaire, which may be due to a floor effect. Nonetheless, the low incidence of symptoms overall is noteworthy. Consistent with our expectation, it was the Naïve subjects who had the least experience with S3D that report the most negative symptoms. Although the between-group difference was very small, it is possible that a greater amount of exposure to S3D can decrease observer's negative symptoms. Again, this may be due to adaptation to the vergence-accommodation conflict or to learning to ignore, or avoid, "bad stereo."

One limitation of our questionnaire was that it did not record the frequency of symptoms; it would be beneficial to know if observers experience their noted symptom(s) every time they viewed S3D or if they had only experienced it once. Also, observers were asked to reflect on the symptoms that they experience when viewing S3D movies or imagery in general and not at the moment, so there is a memory component to this data that may have skewed the responses [Shwarz 2009]. That is, individuals may selectively recall a particular negative experience and give it more weight than other experiences. Similarly, an observer may have recently had a very positive experience and weigh that more heavily. However, we would expect that this source of variability would at least be equivalent across the groups. Also, since the groups were assigned a priori, there is an unavoidable possibility of self-selection. For example, individuals that tend to experience more discomfort with S3D imagery may not choose to work in a stereo-related field, and individuals who inherently have better stereopsis might remain in the field.

5. CONCLUSION

This work lays the foundation for further research on the impact of viewing S3D media on comfort and on stereoscopic abilities. While it is important to bear in mind the limitations of studying preselected groups and the retrospective nature of the survey, our results suggest that there is little effect (either positive or negative) of extended exposure to S3D for these populations.

APPENDIX 1

Table I. Data from Questionnaire

This table lists the number of years observers have worked in their field, number of hours per week viewing S3D (or for Vision Scientists, participating in visual experiments).

Industry Experts			Stereo Experts			Vision Scientists		
SS	#yrs	# hrs/week	SS	#yrs	# hrs/week	SS	#yrs	# hrs/week
1	1	10	1	0	6	1	0	0
2	2	6	2	0	2	2	0	0
3	1	20	3	4	6	3	0	0
4	2	3	4	4	6	4	0	0
5	1	1	5	1	15	5	0	0
6	1	5	6	3	2	6	6	1
7	1	15	7	0	0	7	1.5	1
8	2	30	8	20	5	8	38	5
9	1	2	9	1	1	9	15	1
10	1	4	10	3	4	10	2	1
11	1	30	11	1	10	11	7	1
Average	**1**	**11**	**Average**	**4**	**5**	**Average**	**6**	**1**

Table II. Number of Symptoms That Each Subject Indicated Experiencing while Viewing S3D Imagery

Industry Expert		Stereo Expert		Naïve		Vision Scientists	
Subject	#symptoms	Subject	#symptoms	Subject	#symptoms	Subject	#symptoms
1	0	1	0	1	0	1	0
2	1	2	0	2	1	2	0
3	0	3	0	3	3	3	0
4	0	4	0	4	1	4	1
5	0	5	0	5	1	5	2
6	0	6	0	6	0	6	1
7	1	7	1	7	1	7	1
8	0	8	0	8	0	8	0
9	0	9	0	9	5	9	0
10	0	10	0	10	1	10	0
11	0	11	1	11	0	11	2
	average		**average**		**average**		**average**
	0.18		**0.18**		**1.18**		**0.64**

APPENDIX 2

STEREOSCOPIC EXPERIENCE QUESTIONNAIRE

Name: ________

Age: ________

Number of years working in vision research: ________

Estimated number of hours per week participating in psychophysical experiments: ______

Do you have any ocular problems (e.g., strabismus)? Please explain.

Do you get headaches when viewing S3D content? If so, please estimate the frequency (e.g., every day, 50% of the time).

Do you get headaches normally, that is when not viewing S3D? If so, please estimate the frequency (e.g., every day, 50% of the time).

Do you experience any of the following symptoms while viewing, or after viewing 3D movies or imagery?

☐ Blurry vision
☐ Double vision
☐ Visual fatigue
☐ General fatigue
☐ Eyestrain
☐ Nausea

☐ Headache
☐ Dizziness
☐ Eye dryness
☐ Tearing

Is there any other information that you think we should know with respect to your experience of S3D, or your participation in this study?

ACKNOWLEDGMENTS

We would like to thank our industry partners for giving their staff time to participate in this study, and to Arc Productions for allowing us to set up test equipment in their studio space.

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Received February 2013; revised October 2013; accepted October 2013