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Orthoptic parameters and asthenopic symptoms analysis after 3D viewing at varying distances

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不同距离观看 3D 影像后视光学参数和视力疲劳症状分析

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摘要

目的:不同距离观看 3D 影像后调节幅度、集合近点(NPC)及近隐斜视和视力疲劳的症状分析。

方法:前瞻性研究,包括 30 例青年。每人每天三次分别在特定距离和不同距离观看 3D 影像,并连续三天进行观察,每一距离使用相同视频,相同的时间和不同的屏幕大小。使用 K-multimedia player 3D 播放器。观看 3D 影响后立即记录立体视觉、调节幅度、调节近点及近隐斜视和视力疲劳症状等相关变量。分别使用 TNO 测量视功能,RAF 尺测量调节幅度和集合近点,棱镜杆测量近隐斜视,封闭式问卷调查视力疲劳症状的发生情况。用描述性统计和配对 t 检验进行数据分析,定性数据采用卡方检测。

结果:在 40 cm,3 m 和 6 m 处调节幅度分别减少了 0.66 D,1.12 D 和 1.44 D,集合近点显著降低了 0.63 cm,0.93 cm 和 1.23 cm,近隐斜视分别增加了 0.87,2.74 和 2.2 棱镜度。结果发现,大多数受试者在每一距离处都出现眼周疼痛,头痛和刺激等反应。在家庭环境中,头痛、盗汗、疲劳、刺激和恶心等症状会显著增加,此外,通过使用笔记本电脑观看 3D 可能会引起头痛和盗汗等相关不适症状。

结论:观看 3D 前后、在三种不同距离处,调节幅度、集合近点及近隐斜视和视力疲劳的症状显著不同。在不同距离观看 3D 影像后,视力疲劳为主要症状。

关键词:调节幅度;集合近点;近隐斜视;视疲劳;3D 视频与立体视觉

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Abstract

• AIM: To analyse visual modifications such as amplitude of accommodation, near point of convergence (NPC) reopsis and near phoria associated with asthenopic symptoms after 3D viewing at varying distances.

• METHODS: A prospective study. Thirty young adults were randomly selected. Each individual was exposed to 3D viewing thrice in a day for a fixed distance and the distance was varied on three consecutive days. Same video of equal duration and different screen sizes were used for every distance. Cyclic 3D mode of K-multimedia (KM) player was used for projecting the 3D video. Different variables like stereopsis, amplitude of accommodation, near point of accommodation, near phoria and asthenopic symptoms were recorded immediately after 3D video viewing. Stereopsis was measured with "Toegepast Natuurwetenschappelijk Onderzoek" or "Netherlands Organisation for Applied Scientific Research" (TNO test), amplitude of accommodation and NPC were measured using RAF ruler, near phoria was measured using prism bar and a closed ended sample questionnaire was used to know the occurrence of asthenopic symptoms. Statistical analyses were performed using descriptive statistics, paired t-test *etc.* Qualitative data was analyzed using Chi-square test.

• RESULTS: For every distance of 40 cm, 3 m and 6 m, amplitude of accommodation was significantly reduced by 0.66 D, 1.12 D and 1.44 D. NPC got significantly receded by 0.63 cm, 0.93 cm and 1.23 cm, and the near phoria was significantly increased by 0.87, and 2.2 prism dioptres (PD) base-in respectively. It was found that most of the subjects got pain around the eyes, headache and irritation for each viewing distance. This study also revealed that 3D video viewing in theaters may increase the symptoms of headache, watering and irritation. Symptoms like headache, watering, fatigue, irritation and nausea may increase considerably at home environment and symptoms such as headache and watering may cause significant discomfort by 3D viewing using a laptop.

• CONCLUSION: There was a significant difference in amplitude of accommodation, NPC, near phoria and asthenopic symptoms before and after viewing a 3D video and also at three viewing distances. There was a predominant occurrence of asthenopic symptoms after 3D video viewing at different distances.

• KEYWORDS: amplitude of accommodation; near point of convergence; near phoria; asthenopia; 3D video and stereopsis

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INTRODUCTION

There is a huge market expansion of movies filmed with three dimensional technology and television with 3D displays for the home entertainment, leading to an increased concern about possible side effects on viewers. It was suggested earlier that the viewing of 3D stereoscopic stimuli can cause vision disorders to manifest in previously asymptomatic individuals[1]. Popularity of 3D stereoscopic displays has made the 3D stereoscopic content to be distributed widely through various types of media, such as 3D movies in theatres, 3D televisions, laptops with 3D options and 3D mobile devices. Currently available 3D stereoscopic displays require the user to wear anaglyph, passive or active shutter glasses[2-4]. In spite of the maturity of 3D eyeglass displays, eyestrain from viewing them remains to continue.

3D imaging is one of the powerful tools to help the viewers to understand the spatial relationship of objects. 3D films like Avatar, trick our brains by bringing images projected onto a flat cinema screen to life in full three dimensional glories. When an object is viewed at a nearer distance, by occluding the right and left eye alternatively, the appearance of the world varies marginally. The right visual field is observed by the right eye and the left visual field is by the left eye[5]. The three dimensional viewing of the eyes are a sensory adaptation at the level of visual cortex. This is known as stereoscopic vision[6]. To create a similar effect, 3D videos are captured using two lenses placed side by side, similar to human eyes or by producing computer generated images to replicate the same effect. In old fashioned 3D films, footage for the left eye would be filmed using a blue filter, resulting in a blue image, footage for the right eye would be filmed using a red lens filter, producing a red image. These two images were superimposed on the cinema screen causing a 3D effect.

3D glasses with red and blue filters ensured viewer's left and right eyes saw the two images separately, where in the red filter would allow only red light to the left eye, and the blue filter would allow only blue light to the right eye. The brain would then combine these two slightly different images to create the illusion of 3D. This indicated that old fashioned 3D films couldn't make full use of colors. To overcome this problem, modern 3D films use polarized light instead of blue and red light[7]. The visual stimulus provided by a stereoscopic display differs from that of the real world because the image provided to each eye is produced on a flat surface. The distance from the flat surface to the eye remains constant, providing a single focal distance, but the introduction of disparity between the images allows objects to be located geometrically behind or in front of the screen. In the case of 3D stereoscopic display the stimulus to accommodate and the stimulus to converge do not match. A number of authors have suggested that it could negatively lead to the development of asthenopic symptoms[8]. So fatigue may be caused by the discrepancy between accommodative and convergence stimuli[9-10].

For stereoscopic displays, visual discomfort is one of the major impending issues. Visual discomfort may be used interchangeably with visual fatigue. Visual fatigue is the decrease in performance of the human visual system, which can be measured objectively. But visual discomfort is measured subjectively[11]. Perceived visual discomfort determined by subjective measurements is expected to provide an indication of the objectively measurable visual fatigue.

The diagnostic term for both visual fatigue and visual discomfort is asthenopia, which literally means "eye without strength"[12]. Asthenopia may be a diffuse general headache, or a concentrated ache around the eyes, or may be present in the shoulders and neck. In most cases, the term eyestrain may be used instead of asthenopia. Eyestrain is defined as "the symptoms experienced in the conscious striving of the visual apparatus to clarify vision by ineffectual adjustments"[13-14]. Visual fatigue is considered as any visual dysfunction resulting from the use of one's eyes or physiological strain or stress resulting from exertion of the visual system[12].

In Europe, an advisory board set up by the Italian Ministry of Health concluded that the national or international literature shows no evidence is present that the vision of three dimensional movies force eyes or brain to elaborate visual information in a non - natural way. Nevertheless, the prevalence of health outcomes on 3D movie spectators appears to be increasing in domestic environments[2]. Previous research showed that the occurrence of self-reported symptoms in young healthy adults during or immediately after watching a 3D movie may be high[15-17], though it often quickly disappears once the viewing was completed. More recently the specific disturbance derived from viewing 3D movies has been named "3D vision syndrome" but the relative occurrence of different symptoms in spectators and the individual characteristics that make some individuals more susceptible than others still remains to be validated[11,16].

This study was designed to assess the effect of 3D videos viewing for various distances on self reported symptoms by means of questionnaires and by the measurement of stereopsis, amplitude of accommodation, near point of convergence and near phoria.

SUBJECTS AND METHODS

A convenience sample of 30 healthy young adult volunteers, of which 6 were males and 24 were females, having age between 20 and 30 were selected for this prospective study. The evaluation procedure include measurement of stereopsis by TNO test, measurement of amplitude of accommodation by Royal Air Force (RAF) ruler, measurement of NPC by pencil

Table 1 Asthenopic symptoms questionnaire

No.	Question
1	Have you developed a head ache during or after watching 3D video?
2	Was there any irritation during or after watching 3D video?
3	Did you have watering from the eye while watching 3D video?
4	Was there any feeling of tiredness in your eyes?
5	Did you develop nausea during or after watching 3D video?
6	Was there any double vision while or after watching 3D video?
7	Did you feel pain around the eyes during or after watching 3D video?
8	Was blurred vision noted during or after watching 3D video?

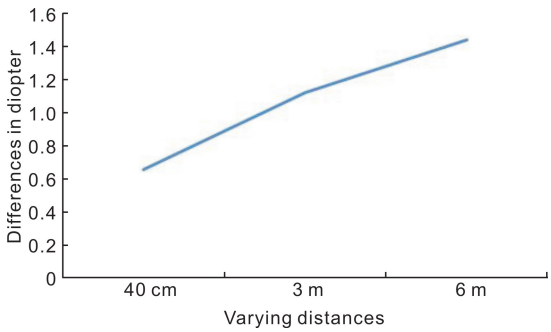

Figure 1 Difference in amplitude of accommodation at varying distances.

Table 2 Mean stereopsis before and after watching 3D video

Distance	Pre mean value (arc sec)	Post mean value (arc sec)
40 cm	62.5±1.77	60.5±2.32
3 m	62.5±1.77	60.5±2.32
6 m	62.5±1.77	60.5±2.32

push up test with RAF ruler, measurement of near phoria by using prism bar cover test and evaluation of asthenopic symptoms by means of questionnaires after showing the 3D videos. The tenets of the Declaration of Helsinki were followed and all procedures were approved by the ethics committee of the institute. Informed consent was obtained from all the subjects.

Each individual was tested for their baseline values of stereopsis, amplitude of accommodation, NPC and near phoria along with asthenopic symptoms questionnaire before showing the 3D videos. The procedure for measuring all the tests are mentioned elsewhere[17]. Each subject underwent three examinations at a fixed distance and these distances were varied on three consecutive days. On the first day, 3D video was projected at a distance greater than 6 m with a big screen size of 1.7 m×1.2 m, to simulate a 3D theatre viewing environment. On the second day, video was displayed at a distance of 3 m and a screen size of a regular television (32 inch) was used to simulate a 3D viewing at home. On the third day, video was presented at a distance of 40 cm on a laptop with screen size of 13.3 inch to simulate a computer based 3D viewing. On these three consecutive days, the subject was made to view the 3D videos thrice daily for duration of 10min with an interval of 120min. After presenting the first 10min of video, stereopsis was measured. Post second interval viewing, amplitude of accommodation and NPC were measured. Display after the third interval, near phoria was measured. After each interval, it was ascertained that the subjects were free of any symptoms before commencing the next procedure.

After completing the tests, asthenopic symptoms questionnaire was given to all subjects. A closed ended sample questionnaire was used and is given in Table 1. These steps were repeated for each day. For each test, same video of same duration was used and 'cycle 3D mode of KM player' was used to project the 3D video at varying distances.

All the data collected were entered in the Microsoft Excel. Statistical analyses were performed using descriptive statistics, paired t-test *etc.* Qualitative data was analyzed using Chi-square test. The P value less than 0.05 was considered to be statistically significant.

RESULTS

A total of 30 subjects were included in the study. The mean age of the sample was 21±0.32y with mean age of males and female were found to be 21±0.52y and 21±0.38y respectively. The mean and standard deviation of baseline stereopsis reading was found to be 62.5±1.77 arc sec for all three distances of 40 cm, 3 m and 6 m. The post 3D viewing stereopsis values were reduced and found to be 60.5±2.32 arc sec for all three distances as given in Table 2. There was no statistically significant difference in stereopsis between pre and post 3D viewing for all distances(P>0.05).

The mean amplitude of accommodation before viewing 3D for 40 cm, 3 m and 6 m were found to be 9.64±1.14 D, whereas post mean values were found to be 8.98±1.23 D, 8.52±1.48 D and 8.20±1.55 D respectively. A paired t-test was performed between pre and post 3D viewing at 40 cm, 3 m and 6 m, which revealed statistical significance for all distances with P<0.05. For all the three distances of 40 cm, 3 m and 6 m, amplitude of accommodation was significantly reduced after 3D viewing for 10min by 0.66 D, 1.12 D, and 1.44 D respectively as shown in Table 3. The differences in the reduction of amplitude of accommodation after 3D viewing from the base line values for 40 cm, 3 m and 6 m is represented in Figure 1.

Table 3 Mean amplitude of accommodation before and after seeing 3D video at varying distances

3D Viewing distance	Pre mean value (dioptre)	Post mean value (dioptre)	Difference (dioptres)
40 cm	9.64±1.14	8.98±1.23	0.66
3 m	9.64±1.14	8.52±1.48	1.12
6 m	9.64±1.14	8.20±1.55	1.44

Table 4 Mean NPC before and after seeing 3D video

3D Viewing Distance	Pre mean value (cm)	Post mean value (cm)	Differences (cm)
40 cm	6.3±1.26	6.93±1.41	0.63
3 m	6.3±1.26	7.23±1.45	0.93
6 m	6.3±1.26	7.53±1.43	1.23

Table 5 Mean near phoria before and after seeing 3D video

3D Viewing distance	Pre mean value (PDBI)	Post mean value (PDBI)	Differences (PDBI)
40 cm	7.16±3.85	8.03±4.02	0.87
3 m	7.16±3.85	9.90±4.49	2.74
6 m	7.16±3.85	9.36±4.54	2.2

PDBI: Prism diopters base-in.

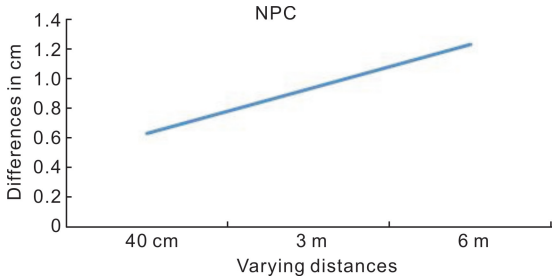

Figure 2 Differences in the NPC at varying distances.

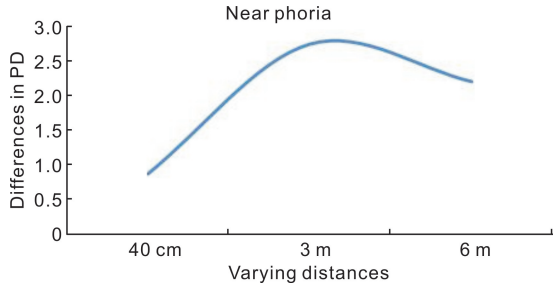

Figure 3 Differences in near phoria at varying distances.

The mean NPC before viewing 3D at 40 cm, 3 m and 6 m were found to be 6.3±1.26 cm, whereas post mean values were found to be 6.93±1.41 cm, 7.23±1.45 cm and 7.53±1.43 cm respectively as shown in Table 4. A paired *t*-test was performed between pre and post 3D viewing at 40 cm, 3 m and 6 m, which revealed statistical significance at all distances with $P<0.05$. Paired *t*-test performed between post 40 cm and 3 m, 40 cm and 6 m, 3 m and 6 m also showed statistical significance with $P<0.05$. The increase in the NPC after 3D viewing from the base line values to 40 cm, 3 m and 6 m is illustrated in Figure 2.

The mean near phoria before viewing 3D at 40 cm, 3 m and 6 m was found to be 7.16±3.85 prism diopters base-in (PDBI), whereas post 3D viewing mean values for 40 cm, 3 m and 6 m was found to be 8.03±4.02 PDBI, 9.90±4.49 PDBI and 9.36±4.54 PDBI respectively as given in Table 5. A paired *t*-test was performed between pre and post 3D viewing at 40 cm, 3 m and 6 m, which revealed statistically significant difference for all the distances with $P<0.05$. Paired *t*-test performed between post 3D viewing at 40 cm and 3 m, 40 cm and 6 m, 3 m and 6 m also gave a statistical significant difference with $P<0.05$. The difference in the increase of near phoria after 3D viewing from the base line values at 40 cm, 3 m and 6 m is plotted in Figure 3.

Assessment of asthenopic symptoms like headache, irritation, watering, tiredness, nausea, diplopia, pain around eyes and blurred vision were done by means of questionnaire after viewing 3D video. A Chi-square test revealed that there is a statistical significant increase in symptoms with $P<0.05$ for headache, irritation and pain around the eyes after the 3D viewing at 40 cm and 6 m when compared with baseline readings. Symptoms like headache, irritation, tiredness and pain around the eyes were significantly increased after the 3D viewing at 3 m when compared with baseline readings. The symptom of dryness after 3D video viewing was not included in our questionnaire as it had been proven in an earlier study[18]. The odds ratio (*OR*) was calculated for all the asthenopic symptoms by using the methods mentioned in earlier works[19-20]. The odds of developing the symptoms of headache and watering with reduced amplitude of accommodation after 3D viewing at 40 cm quadrupled and tripled respectively. The odds of developing the symptoms of headache, irritation, watering and tiredness with reduced amplitude of accommodation after 3D viewing at 3 m increases 5, 8, 3 and 4 folds respectively. The odds of developing the symptoms of headache, irritation and watering with reduced amplitude of accommodation after 3D viewing at 6 m were 3, 2 and 6 times respectively. The odds of developing the symptoms of watering and nausea with increased near phoria after 3D viewing at 3 m is 3 times and 13 times respectively. There was no significant variation in odds ratio for other asthenopic symptoms at other distances.

DISCUSSION

In this prospective study, 30 young adults were tested to know

the possible effects of 3D videos on viewers at varying distances. It was found to cause significant changes in amplitude of accommodation, NPC, near phoria and also a significant occurrence of asthenopic symptoms. All these variables also had a significant change in respect to the change in distance of seeing the 3D videos. All the asthenopic symptoms reduced in 15min period after which the subjects became asymptomatic.

An earlier study revealed that viewing 3D movies can increase the symptoms of nausea, oculomotor disorientation and asthenopia[21]. Analogous to riding a roller coaster, for most individuals, the increase in symptoms is part of the 3D experience and enjoyment where these experiences are not necessarily an adverse health consequence. In their study, they compared motion sickness induced by 3D and 2D movies and found that 3D movies created more problems on the viewers. They also used a theatre to show the 3D and 2D films, but objective measurements were not performed. In our study, we used three distances to show the 3D video to simulate the effects of a theatre, at residence and computer based 3D viewing. It was found that there is a statistically significant increase in symptoms like headache, irritation, tiredness, watering, nausea and pain around the eyes after viewing 3D videos. It was also noted that there is a statistically significant decrease in amplitude of accommodation, recession in NPC and increase in near phoria after 3D viewing at varying distances.

A similar result was obtained in an earlier study that "3D video viewing will cause change in accommodative responses, which would increase the positive relative accommodation, increase the near exophoria and decrease the near negative relative accommodation"[22]. They used three different illuminations (complete dark, back illumination and front illumination) to find out which illumination was better. They found that subjective accommodative function exhibits greater stability when illumination is in front of a viewer. In our study, we found that accommodation and convergence were significantly reduced and near exophoria and asthenopic symptoms were significantly increased after viewing 3D video at three varying distances.

A similar result was obtained in other works, which showed that it causes decreased range of relative vergence, accommodative response, and a delay in the p100 latency of VECP after viewing 3D videos in a stereoscopic television[23-24]. Our study is in accordance with this work, where there is a decrease in accommodation, reduction in NPC and increase in near phoria immediately after seeing stereoscopic video in television.

Another study stated that huge eye strain is being induced by 3D videos and proposed a new method for measuring the degree of eyestrain based on eye blink rate, viewer's gaze position and edge information[25]. Our study is also in conjunction with the previous statement that an increased eye strain is being induced by 3D videos at varying distances.

This study reveals that asthenopic symptoms increase significantly after viewing 3D video at variable viewing distances. It was also noted that the amplitude of accommodation and NPC were more affected after seeing 3D video at 6 m when compared to 3 m and 40 cm. This indicates that watching 3D movies in a theatre may increase asthenopic symptoms which include more of watering associated with significant decrease in amplitude of accommodation. There was a significant increase in near phoria after seeing 3D video at 3 m when compared to 40 cm and 6 m. This indicates that asthenopic symptoms like nausea and irritation are more for people who watch 3D television in their house. On comparison with 3 m and 6 m, 3D video display at 40 cm resulted in reduced change in amplitude of accommodation, NPC and near phoria in spite of which the asthenopic symptom of headache was more predominant at 40 cm.

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