Displays xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Displays

journal homepage: www.elsevier.com/locate/displa

The influence of polarized 3D display on autonomic nervous activities

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A R T I C L E I N F O

Article history:
Received 29 February 2012
Received in revised form 1 May 2014
Accepted 4 May 2014
Available online xxxx

Keywords:
Heart Rate Variability (HRV)
3D display
Visual fatigue

A B S T R A C T

The spectral analysis of Heart Rate Variability (HRV) can be used for assessing the autonomic nervous activities and further the physiological conditions of subjects. This study intended to explore whether or not people would have fatigue, faintness and other kinds of uncomfortable conditions after watching a 3D film by using HRV measures as the objective physiological indices, in addition to other subjective physiological indices.

Twenty men aged 22 ± 2 experienced watching 3D films and 2D films and were served as the controls of themselves. As the controls, the subjects had to rest at the same place. All subjects were are randomized for taking different experiences, and the electrocardiographic (ECG) signals were recorded during the whole process. The researchers could obtain the indices of the autonomic nervous activities before and after experiencing 3D and 2D movies with the help of spectral HRV analyses, along with the objective physiological information. The subjects were requested to fill out the questionnaire for the subjective feelings after the movie experiences.

It was found that the subjects' high-frequency power (HFP) representing parasympathetic nervous activities decreases after watching a 3D film. The sympathetic and parasympathetic nerve activities before and after watching a 2D film were not significantly different. The subjects complained that they felt dizzy, had headaches, and got visual fatigue while watching a 3D film.

This study found that the subjects' parasympathetic nerve activities were reduced after watching a 3D film, indicating that watching a 3D film would make people uncomfortable and tired. This result was the same as that of the questionnaire. Thus, HRV analyses could be an objective physiological index for discomfort as viewing 3D films.

1. Introduction

People have been making stereo pictures since the 17th century and have achieved a historical breakthrough in the development of 3D display technologies in the past 20 years. Although one of the main research directions is watching 3D displays without glasses at present [1–4], watching 3D displays with glasses recently is still the main trend. Regarding 3D displays with glasses, polarized glasses and shutter glasses are two commonest ways [5]. The polarized glasses are commonly used in theaters, as they are lighter, cheaper, no electronics and no radiation by comparison. The polarized 3D display technology is easy to implement in the theaters. In addition, people do not have to worry about wrong images caused by the different speed of glasses switches from that of screen displays.

At present, 3D display technologies are mainly used for both eyes watching images with different angles at the same time. The images can be transferred to the brain through retinal nerves and create pictures with different depths. Wickens et al. [6] suggested that the main physiological factors in the sense of depth were binocular parallax, convergence and accommodation.

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http://dx.doi.org/10.1016/j.displa.2014.05.001
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With the trend of 3D films, more people have paid attention to ergonomic study on 3D displays to see whether people are comfortable and safe while watching a 3D film.

The methods of 3D ergonomic study are visual fatigue measurement, survey assessment, blood pressure measurement, and other kinds of physiological signal measurements [1]. The majority of which are visual fatigue measurement and survey assessment. Kooi and Toet [7] found that binocular parallax was the main factor in people feeling uncomfortable while watching a 3D film. In addition to binocular parallax, Lambooij and IJsselsteijn [8] also pointed out that other factors could make people uncomfortable, such as different speeds of making images, images information (insufficient depth information in the incoming data signal yielding spatial and temporal inconsistencies), nonsymmetrical stereoscopic images, and unnatural blur. Ntuen et al. [9] asked the subjects to do the same experiments with 2D and 3D displays and compared these two results. The subjects were asked to correctly point out the ball randomly shown on the screen being close to the target and the color of the target. It was shown that the 3D group subjects had greater accuracy as compared with the 2D group. Thus, watching 3D films was easier for people getting visual fatigue by comparison.

On the other hand, it was stated that people would have faintness, fatigue and other uncomfortable situations when sympathetic and parasympathetic nerve systems were not balanced [10]. Kim et al. [11] investigated the psychophysiological effects of 3D artifacts included changes not only in subjective symptoms of visual fatigue and the depth sensation, but also to heart and brain activity. Therefore, we used HRV analysis to confirm the influence of watching the 3D film. HRV is a non-invasive index and can refer to the balance between autonomic nerves and the cardiovascular system as HRV is highly sensitive, measurable, and repetitive.

The HRV measures and the survey are normally used as the physiological indices for virtual reality experiments. It is found that visual-vestibular conflict resulting from visual reality would affect autonomic nervous modulation [12]. Chao et al. [13] compared with 3 kinds of 3D displays by visual acuity, binocular diopter, pupil size, binocular intraocular pressure, binocular High-Frequency Components of accommodative micro fluctuations, contrast sensitivity and critical flicker fusion frequency and a questionnaire. The result showed sympathetic and parasympathetic nerve systems appropriately control the physiological feedbacks by varying the ratio of the signals from the sympathetic and parasympathetic nervous systems when viewing 3D displays. Li et al. [14] found that the subjects' heart rates decreased after participating in visual car racing experiments. Ohyama et al. [15] used a polarized filter system to establish a visual reality and move visual subjects randomly to induce carsickness. They pointed out the decreasing index of sympathetic and vagal activities, low frequency power, after the experiment. In the Japanese event, Pokemon shock, many children were sent to hospitals after watching a certain explosion scene. This scene was displayed by multi-color flashes to create the persistence of vision. It was found that only five to ten percents of the children sent to hospitals were the patients with photosensitive epilepsy [16]. Yamb et al. [17] analyzed HRV, with personality survey and visual reality as the research methods, to explore the relationship between personality and visual stimulation. The subjects had to wear head mount systems and played games in the visual reality made by shooting game programs. It was discovered that there was consistency between autonomic nerve changes and mental tendency. The results could find the ones with sensitive visual stimulation beforehand and further decrease the risk of photogenic epilepsy because of visual-reality images.

In this study, we investigated the influence of polarized 3D display on autonomic nervous activity for long time by using HRV analysis. It is a direct way to detect the variation of parasympathetic and sympathetic nervous systems. This study planned to explore HRV by recording ECG and then analyze HRV parameters [18,19] to understand the changes in sympathetic and parasympathetic nerve activities.

This study proposed not only HRV analyses as the objective indices but also the questionnaire survey as subjective physiological indices. As a result, this study suggested that the subjects' parasympathetic nerve activities significantly decrease while watching 3D film and the subjects feel uncomfortable and fatigued. This study also suggested that the influence of 3D films on patients with cardiovascular diseases should be a research-worthy issue.

2. Materials and methods

2.1. Subjects

The subjects recruited were 20 healthy men with the mean age of 22 ± 2 (see Table 1), lest the HRV parameters [20,21] were affected by different genders and ages. All subjects did not have any medical illnesses for at least one year, had no alcoholism or drug abuse, and did not receive medical treatments for acute myocardial infarction, diabetes, chronic renal failure, congestive heart failure, etc. They also did not take antidepressant or other medicines which would affect autonomic nervous activities [22–26]. The study followed Declaration of Helsinki in 1975 and was approved by Institution's Human Research Committee. All subjects knew all relevant procedures, and did not have any food or drink with caffeine or alcohol 8 h before the experiment. Subjects should not have lack sleeping time at the night before doing the experiment. All subjects had slept well and the sleeping time was more than 8 h in this experiment.

The visual acuity of all subjects were recorded and checked their visual acuity with their glasses were corrective before implementing the experiment. And the binocular vision tested was implemented with a Randot Stereo test (shown as Fig. 1) before the experiment for confirming subjects can see 3D image well. The Graded circle test is from 400 to 20 s of arc (shown as Table 2).

2.2. Experimental environment

According some HRV researches which are useful for the method of experiment design, the place for the study was a dark room which looked like a mock theatre with the room temperature 25 ± 2 °C [25]. The polarized filter system of 3D display technologies was used, and the 3D film was projected onto a 60-in. screen. All subjects wore polarized glasses during the whole process. The researchers clipped a 10-min film from a computer game, METAL GEAR SOLID IV, as the experiment film. It is an action-adventure video. The depth perception of the 3D video was consistent during all time and the depth perception was limited for avoiding people feeling uncomfortable temporarily. The distance between the subject and the screen was 2 m [26].

Table 1
Baseline characteristics of the subjects.

Item	Average
Age (years)	22.7 ± 1.9
Body height (m)	1.72 ± 0.06
Body weight (kg)	66.2 ± 11.1
BMI (kg/m^2)	22.3 ± 3.2