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Subjective evaluation of visual fatigue caused by motion images

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Abstract

A questionnaire was developed to subjectively assess visual fatigue caused by viewing various types of motion images. The questionnaire was evaluated using four types of moving images; playing a TV game using an HMD or a TV, viewing images with and without stabilization of camera shake, viewing a movie with and without colour break-up and viewing either a stereoscopic movie (anaglyph method) or a nonstereoscopic movie. Factor analysis revealed five factors: (1) Eye Strain, (2) General Discomfort, (3) Nausea, (4) Focusing Difficulty and (5) Headache, which were effective for classifying motion images.

Keywords: Visual fatigue; Subjective evaluation; Motion image

1. Introduction

In 1997, approximately 685 people were hospitalized because of uncomfortable symptoms and photosensitive seizures after watching a TV animation program called "Pokemon". Some studies [1–6] and follow up studies [7,8] concluded that it was the flickering TV images that caused this incident. In 2003, 36 (out of approximately 300) junior-high-school students experienced motion sickness while watching a homemade movie during class activity in their auditorium, and were sent to hospital. This was termed the "Matsue movie sickness incident", and one of the causes was thought to be severe camera shake [9]. It is important to use subjective methods for evaluating visual fatigue caused by viewing moving images such as the well known and established Simulator Sickness Questionnaire (SSQ) developed by Kennedy et al. [10]. As new technology arrives, it brings with it new effects of light and sound, dynamic movement of quasi-images and so forth and it was effects such as these that are thought to have accidentally caused the Pokemon incident in 1997 and the Matsue movie sickness incident in 2003. This paper aims to develop a new questionnaire for assessing visual fatigue from viewing movies, TV programs and video games.

Visual fatigue in this paper is defined as "eyestrain or asthenopia, caused by both two-dimensional (2-D) and stereoscopic (3-D) motion images" [11]. Visual fatigue has a wide range of visual symptoms, including tiredness, headaches and soreness of the eyes [11,12]. "Simulator sickness", "cinema or Cinerama sickness", "visually induced motion sickness" and "vehicle-induced sickness" show the same symptoms as visual fatigue [13]. However, though there is overlap in the "visual fatigue" of computer vision syndrome (CVS) [14], where eye complaints are caused by using visual display terminals (VDT) or visual display units (VDU), the definition of visual fatigue in this paper is not exactly the same.

The SSQ is the most established questionnaire using simulator sickness for assessing visual fatigue and was developed from the Pensacola Motion Sickness Questionnaire (MSQ). Usually, simulator sickness shows slighter symptoms than motion sickness. Many researchers use questionnaires referring to the SSQ, the MSQ, or a list of symptoms of visual fatigue; such as Howarth and Costello who adapted a version of the MSQ with their own questions [15], Ohno and Ukai [16] who developed their

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questionnaire from the SSQ and List of Symptoms of Visual Fatigue [12], and Ogata et al. who used the list of symptoms of visual fatigue as items of their questionnaire [17]. Other studies use one-item questionnaires to assess visual fatigue; such as Yano et al.'s five subjective ranking assessments [18–20] or Kooi's rating scale and comparison rating scale for visual comfort [21,22]. These one-item questionnaires often used with objective methods for studying visual fatigue [18–22], however fatigue is also a subjective experience and therefore this needs to be taken into account with a subjective measurement.

This paper will focus on the questionnaire developed by Ohno and Ukai [16]. Though it was originally designed to evaluate motion sickness arising from the use of head mounted display (HMD), it covers a wide range of symptoms including visual fatigue, physical fatigue and motion sickness. In the section analyzing visual fatigue arising from the use of an HMD and a TV, they found that their questionnaire results consisted of three factors, a visual fatigue related factor, a motion sickness factor and an ocular surface-related factor. The visual fatigue related factor contains items such as "difficulty focusing", "hazy", "gritty", "near vision difficulty" and "far vision difficulty"; which are all symptoms of eyestrain or asthenopia. The motion sickness factor contains items like "vomiting", "vertigo", "nausea", "dizzy" and "sleepy"; whereas the ocular surface-related factor contains items such as "watery eyes", "sting" and "eyeache".

The VRSQ (Visual Reality Symptom Questionnaire) was developed by Ames et al. [23], exclusively for the use of an HMD, and could be the standard questionnaire for symptoms induced through viewing virtual reality imagery with an HMD. The VRSQ contains 23 items, which are divided into two groups of symptoms: ocular symptoms and nonocular symptoms. Ocular symptoms on the VRSQ are similar to the items used by Ohno and Ukai, while there are fewer nonocular symptoms on the VRSQ.

Problems of motion sickness are not caused purely by HMD, some kinds of projectors and shaky cameras also cause them. It was such flickering images that caused the Pokemon incident and severe camera motion that contributed to the Matsue movie sickness incident; consequently, in this paper, data from five experiments shown in Table 1 are applied for new analysis.

2. Method

2.1. Subjects

In total, 104 subjects with normal vision participated in the experiment. All signed the informed consent form and then completed the whole experiment in two days.

Table 1 displays the number of subjects in each experiment. In Experiment 2, the 20 participants were undergraduate students (age range: 17–22). In Experiments 1 and 3 the participants were both undergraduate students and staff. In Experiment 1, one subject was in his 40's and other subjects' ages ranged from 19 to 22; in Experiment 3 one subject was in his 40's and other subjects' ages ranged from 21 to 25. In Experiment 4, the subjects consisted of 31 undergraduate students and vocational school students (age range: 20–32). In Experiment 5, the participants were 11 postgraduate students and undergraduate students (age range: 21–24). The subjects' ages differed between experiments, however most were in their 20's.

2.2. Experimental conditions

2.2.1. Experiment 1

Experiment 1 consisted of a TV shooting game on an HMD display and 14-in. TV monitor providing the element of moving images [16].

A 3-D shooting game, Panzer Dragoon (GS-9015, Sega Enterprises, Japan) was presented using a Sega Saturn HST-0001 (Sega Enterprises, Japan). The HMD display was Glasstron PLM-50 (Sony, Japan). The convergence and accommodation stimuli of the HMD were within 2 m with a 33.75° for diagonal visual angle. The TV monitor was a 14-in. TV monitor (14C-L 30, Sharp, Japan). The visual distance to the TV monitor was 60 cm with a diagonal visual angle of approximately 31°.

Subjects played the TV game for 20 min and their visual fatigue was evaluated before and after the game. Subjects participated in both HMD and TV conditions and each condition was counter-balanced.

2.2.2. Experiment 2

Experiment 2 also consisted of a TV action game presented on an HMD display and a TV monitor [24],

Table 1
Experimental conditions

Experiment	Conditions compared	Approximate time for task (min)	Number of subjects	Number of measurement	Number of data	Original paper
Experiment 1	HMD and TV monitor	20	30	2	60	Ohno and Ukai [16]
Experiment 2	HMD and TV monitor	30	20	3	80	Ukai et al. [24]
Experiment 3	Shaky video and stabilized video	20	12	3	48	Ukai [25]
Experiment 4	1-chip DLP projector and 3-LCD projector	140	31	2	62	Mori et al. [26]
Experiment 5	Stereoscopic movie (anaglyph method) and nonstereoscopic movie	85	11	2	22	