A QUANTITATIVE EVALUATION OF THE VISUAL COMFORT AND DISCOMFORT INDUCED BY STRIPE AND GRID PATTERNS

A COMPARISON BETWEEN MIGRAINE PATIENTS AND NORMAL CONTROLS

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ABSTRACT

Migraine, a chronic headache disorder, is known to induce certain characteristic symptoms and perceptions in patients. Previous studies have reported that geometrical patterns cause visual discomfort and pattern glare; such effects are especially strong in migraine patients. On the other hand, when artists and designers use similar geometrical patterns in their works, the patterns induce good feelings. However, the comfort and discomfort caused by geometrical patterns have not been analyzed quantitatively and systematically. In the present study, we measured the comfort and discomfort induced by stripe and grid patterns in migraine patients and headache-free controls. We used two pattern components (square waves and sine waves) to examine the effect of contours on the patients. In the experiment, participants subjectively evaluated discomfort, brightness, fatigue, flicker, motion, and beauty. The results showed that all the evaluation values, except for the one for beauty, increased in both groups as the grid size decreased; moreover, the value for brightness given by the migraine patients increased by a substantial amount. Interestingly, the square waves composed of the smallest grids induced both beauty and discomfort in both participant groups. The results imply that although geometrical patterns may look beautiful, they can at the same time induce discomfort particularly in migraine patients.

Keywords: *vision, migraine, geometrical pattern, comfort, discomfort*

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1. INTRODUCTION

1.1. Comfort and discomfort from geometrical patterns

There is little doubt that geometrical patterns such as stripes or checkerboard patterns are found in abundance in our living environments (e.g., patterns on clothes, zebra crossings, designs on window blinds, and wallpaper designs). In addition, such patterns are also used to cause optical illusions of color and movement in abstract paintings called "op art." In such cases, we appreciate the artistic value of such patterns, and on occasion, even feel comfortable looking at them. However, there are some noteworthy problems. In previous studies, it was reported that geometrical patterns and more complex abstract paintings with a certain luminance profile are capable of inducing discomfort in people [1-3]. Furthermore, high-contrast striped patterns can induce seizures in patients with photosensitive epilepsy [4,5] and perceptions of discomfort and brightness in patients with migraine headaches [6,7]. In addition, such patterns can trigger migraine attacks [8].

1.2. Migraine

Migraine is a chronic headache disorder and has a low but measurable prevalence. In a previous study, Sakai and Igarashi [9] reported that 8.4% of the Japanese population had migraine. Patients with migraine have certain characteristic symptoms and perceptions, although they may differ among individuals. Migraine attacks occur intermittently on a daily basis, and cause pulsating pain on one side of the patient's head. For some patients, the attack is accompanied by photosensitivity and/or hyperacusia (i.e., sensitive auditory perception).

2. PURPOSE

In previous studies, the comfort and discomfort induced by geometrical patterns have not been studied quantitatively and systematically. In the present study, we attempted to quantitatively and systematically examine this comfort and discomfort by using geometrical patterns. We conducted an experiment with migraine patients and normal controls.

3. METHODS

3.1. Participants

Seventeen patients (11 females and 6 males aged 10-40 years) and 38 controls (17 females and 21 males aged 10-30 years) participated in the following experiment. To classify the participants into migraine patients and normal controls, a questionnaire was designed using the systematized diagnostic criteria obtained from the International Classification of Headache Disorders [10]. This questionnaire included items about the occurrence of chronic headaches, their characteristics, their duration, their frequency, their triggers, and so on. All the patients fulfilled the required criteria for a diagnosis of migraine. None of the participants were visually impaired.

We asked 58 participants to complete the questionnaire. However, for a clearer distinction between the migraine patients and the controls, 3 participants classified as "probable migraine" did not participate in the experiment. Further, 2 patients were classified as "migraine with visual aura" (i.e., a migraine attack occurred after the fortification spectra in the visual field faded), but they participated in the experiment because the presence or absence of visual aura did not affect patients' visual discomfort [6].

3.2. Stimuli

We used eight achromatic stripe and grid patterned images as visual stimuli in the experiment. The images were created using Adobe® Flash®, and four vertical grid sizes were used: stripes, 1/2 grids, 1/4 grids, and 1/32 grids (checkerboard pattern). To examine the differences between patterns with and without contours, the images were created with either square waves (clear-cut edges) or sine waves (fuzzy edges). All the patterns had the same spatial frequencies—0.5 cycles per degree—and the same mean luminance, approximately 42.5 cd/m2. Samples of visual stimuli are shown in Figure 1.

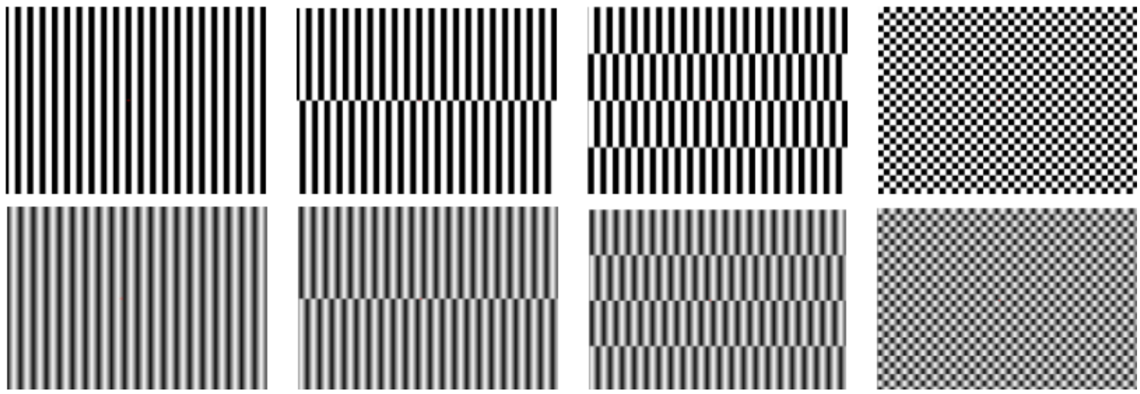

Figure 1: Samples of experimental stimuli. Four square-wave patterns are shown in the first row (from left: stripes, 1/2 grids, 1/4 grids, and 1/32 grids). Similarly, four sine-wave patterns are shown in the second row. The standard stimulus was the square-wave patterns with 1/4 grids.

3.3. Procedure

The experimental stimuli were presented on an Apple PowerBook G4 that had a 15.4 inch LCD display with a resolution of 1280 by 854 pixels. The monitor was set against a black background, and the participants were seated at an approximate distance of 57 cm from the monitor. The experiment was conducted in a laboratory with daylight fluorescent lamps, and the mean illuminance in the laboratory was approximately 500 lx.

In the experiment, the participants were asked to view each pattern and evaluate six types of perceptions. We chose "discomfort," "fatigue," "motion," "flicker," and "beauty" on the basis of the previous studies [2,11]. The perception of beauty was considered as that of comfort in this experiment. In addition, we chose "brightness" based on the previous clinical report on migraine [7]. The participants rated these perceptions on a 0-200 scale using magnitude estimation. The standard stimulus was the square-wave pattern with 1/4 grids, and its evaluated value was set at 100. A trial was carried out in the following order. The standard stimulus was presented on the monitor for 2 seconds with an interval of 3 seconds during which a black screen was presented; next, the comparison stimulus was presented in the same manner. Finally, the participants completed an evaluation form. The comparison stimuli were presented in a random order.

4. RESULTS

For each evaluation item, the mean ratings given by the two participant groups were calculated (Figure 2). We conducted three-way analyses of variance (ANOVAs) for each evaluation item. Each analysis included 1 between-participants factor (group: migraine patients vs. normal controls), and 2 within-participants factors (grid size: stripes, 1/2 grids, 1/4 grids, and 1/32 grids; pattern type: square wave and sine wave).

The results indicated that in both migraine patients and controls, both pattern types induced increasing discomfort, brightness, fatigue, motion, and flicker as the grids became smaller. However, the perception of beauty increased relatively for the stripes of both square and sine waves. For all the evaluation items, the main effects of grid size were significant (discomfort: $F_{3, 159} = 47.4$, $p < .001$; brightness: $F_{3, 159} = 21.3$, $p < .001$; fatigue: $F_{3, 159} = 69.8$, $p < .001$; motion: $F_{3, 159} = 60.1$, $p < .001$; flicker: $F_{3, 159} = 68.6$, $p < .001$; beauty: $F_{3, 159} = 7.3$, $p < .001$). In addition, there were significant interactions between grid size and pattern type for brightness, fatigue, motion, and flicker (brightness: $F_{3, 159} = 3.6$, $p < .01$; fatigue: $F_{3, 159} = 2.7$, $p < .05$; motion: $F_{3, 159} = 7.7$, $p < .001$; flicker: $F_{3, 159} = 10.1$, $p < .001$).

We found several differences between the ratings of the patients and controls. For brightness, there was a significant interaction between grid size and group ($F_{3, 159} = 3.8$, $p < .01$). That is, the square-wave pattern with 1/32 grids significantly induced intense strong brightness for the patients, not for the controls (the mean evaluation values with the 95% confidence limits given in parentheses; patients: 135.6 [123.7 to 147.5]; controls: 112.0 [104.0 to 119.9]). In addition, although there was no significance, patients perceived more discomfort (patients: 131.2 [116.9 to 145.5]; controls: 114.1 [104.5 to 123.6]) and less beauty (patients: 108.2 [94.9 to 121.6]; controls: 123.0 [114.1 to 132.0]) for the square-wave pattern with 1/32 grids than did the controls.

Clearly, for both participant groups, the sine-wave patterns induced more discomfort, fatigue, motion, and flicker, and the square-wave patterns induced more beauty. There were also significant main effects of pattern type for discomfort, fatigue, motion, flicker, and beauty (discomfort: $F_{1, 53} = 35.8$, $p < .001$; fatigue: $F_{1, 53} = 25.6$, $p < .001$; motion: $F_{1, 53} = 14.9$, $p < .001$; flicker: $F_{1, 53} = 15.0$, $p < .001$; beauty: $F_{1, 53} = 42.0$, $p < .001$). However, when the grid size was 1/32, there was no significant difference in either participant group between the motion induced by square- and sine-wave patterns (patients/square wave: 133.5 [118.1 to 149.0]; patients/sine wave: 134.4 [119.0 to 149.8]; controls/square wave: 122.2 [111.9 to 132.6]; controls/sine wave: 125.3 [115.0 to 135.7]); this also applied to flicker (patients/square wave: 145.3 [130.6 to 160.0]; patients/sine wave: 142.9 [128.3 to 157.6]; controls/square wave: 139.1 [129.3 to 148.9]; controls/sine wave: 136.7 [126.9 to 146.5]).

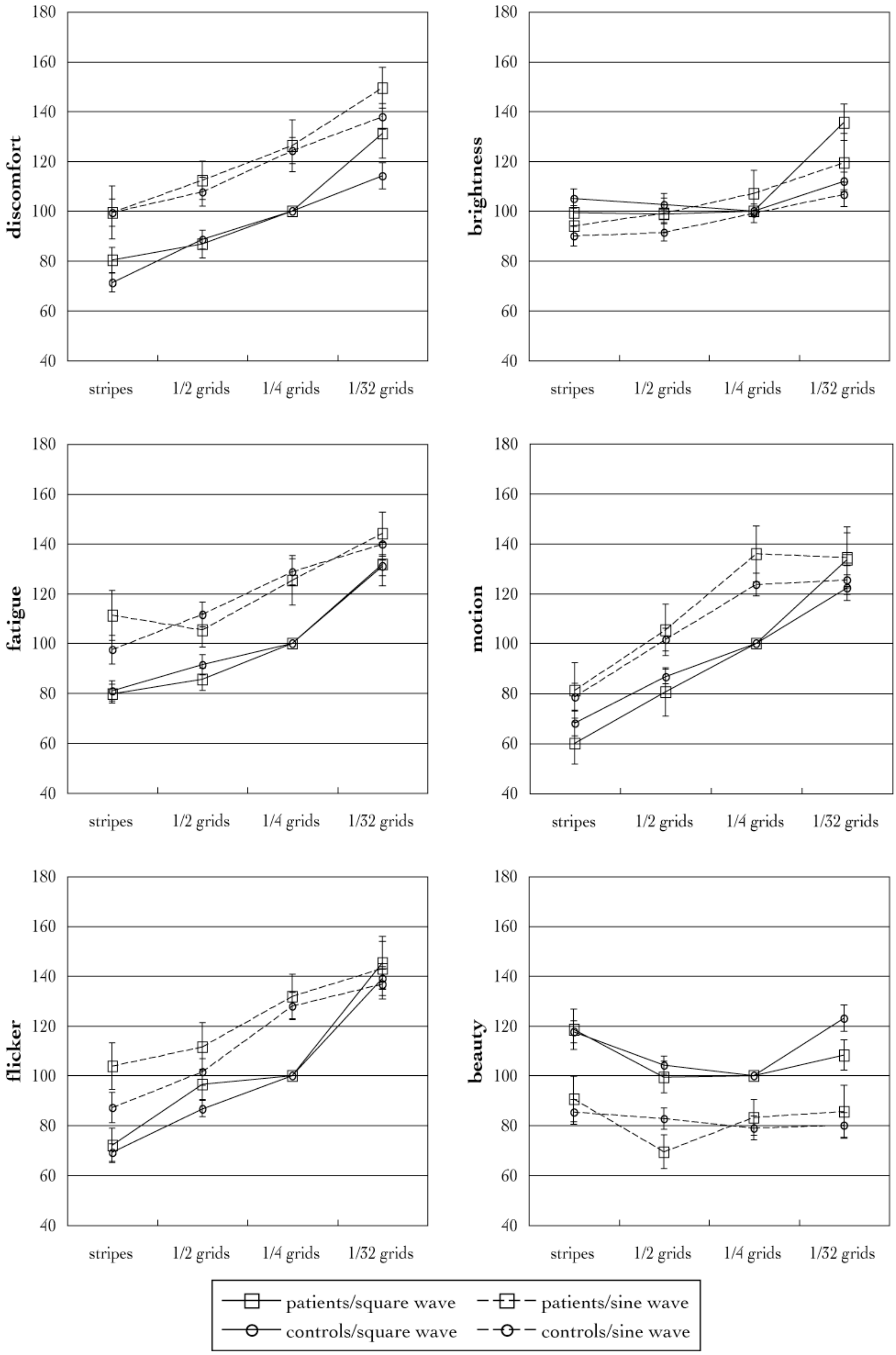

Figure 2: The mean ratings for the evaluation items in each of the four conditions, patients/controls by square wave/sine wave. Note that the y-axes only indicate evaluation values in the range 40-180 for the sake of simplicity. The x-axes show the four grid sizes used as the experimental stimuli. The error bars denote one standard error.

5. DISCUSSION

In the present study, we conducted an experiment to examine the comfort and discomfort induced by two types of geometrical patterns in migraine patients and controls. Three-way ANOVAs revealed differences in evaluations between the migraine patients and controls, affected by four pattern grid sizes and luminance profiles (square wave or sine wave).

Both the participant groups perceived more discomfort, fatigue, motion, and flicker in the smaller grid patterns. The results can be explained by the number of contours in the visual stimuli: although all eight visual stimuli had the same mean luminance, the smaller grids had more contours. On the other hand, the sine-wave patterns had fuzzy contours. The migraine patients particularly perceived intense brightness in the square-wave pattern with the smallest grids. However, the controls did not perceive intense brightness in either pattern. In the experiment, some patients reported discomfort or pattern glare or gestured aversively as soon as they saw the patterns. These findings imply pattern sensitivity in migraine patients and are remarkably similar to the report by Koyama and Kawamura [7]. It can be said that the sensitivity to contours of pattern in migraine patients can be explained by hyperexcitability of the visual cortex [5]. However, since patients with mild or moderate migraine participated in the study, the significant differences in the results between the participant groups were evident only in evaluations of brightness, and in the perception of more discomfort and less beauty induced by the square-wave pattern with 1/32 grids as compared to those for controls. Taken together, our results supported the view that patients were hypersensitive and aversive to the clear-cut edges of square-wave patterns.

The sine-wave patterns induced more discomfort, fatigue, motion, and flicker in both participant groups. This may be explained by the peripheral drift illusion, where static images with a gradually changing luminance profile cause illusory motion perception in the peripheral vision [12]. An example of this is shown in Figure 3. Since the sine-wave patterns used in this experiment also have a gradually changing luminance profile, the "motion" values in the experiment should have shown a more substantial increase as compared to those from the square-wave patterns. This increased evaluation of motion may explain the similarly increased discomfort, fatigue, and flicker. Indeed, the evaluations of motion in sine-wave patterns positively and significantly correlated with discomfort, fatigue, and flicker (Pearson product-moment correlation coefficient [$N = 55$], with discomfort: $r = 0.38$, $p < .01$; fatigue: $r = 0.33$, $p < .05$; flicker: $r = 0.66$, $p < .001$).

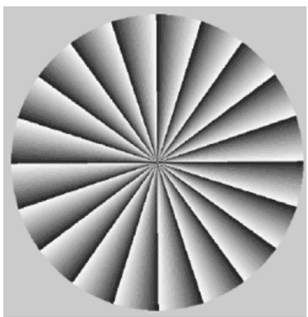

Figure 3: The peripheral drift illusion. When this image is seen in the peripheral vision, it appears to rotate clockwise [12].

With regard to beauty, the perceptions of both participant groups were relatively strong in the stripes and 1/32 grids of square waves. In contrast, the sine-wave patterns decreased the perception of beauty for both participant groups. It has been reported that the beauty of the patterns is positively correlated with the clearness of the patterns [2]. Therefore, our results suggest that the fuzziness of the sine-wave pattern decreased the perception of beauty. Further, the unfamiliarity of the sine-wave pattern could also have reduced the perception of beauty, unlike the stripe or grid square-wave patterns that we frequently come across in our living environments.

Interestingly, both the participant groups experienced both strong discomfort and relatively strong perceptions of beauty for the square-wave patterns with 1/32 grids. This finding implies that comfort and discomfort can occur at the same time. Therefore, square-wave patterns should be used carefully, particularly when they are likely to be viewed by people with migraine.

In the experiment, participants evaluated only "beauty" as a representative emotion of visual comfort. However, adding more positive evaluation items such as pleasantness and artistic merit could enable us more detailed examination. Besides, we used only achromatic geometrical patterns in the present study, and we cannot eliminate the possibility of an association between colored geometrical patterns and visual stress in migraine patients. Previous studies reported S-cone deficits (i.e., blue-yellow color blindness) in people with migraine [13] and a preference for colored filters such as blue or green [14]. Further studies are necessary to examine the relationships between the spatial and chromatic properties of geometrical patterns and pattern sensitivity in people with migraine.

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