A QUANTITATIVE EVALUATION OF STRIPE AND GRID PATTERNS BY MIGRAINE PATIENTS AND NORMAL CONTROLS

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Abstract: Geometrical patterns such as stripes and grids induce various types of visual perception including movement, fatigue, and discomfort. Although these patterns can induce discomfort, especially in migraine patients, they can also be used for art and design to induce good feelings. In the present study, we attempted to measure these perceptions quantitatively and systematically in migraineurs and headache-free controls. In the experiment, participants evaluated discomfort, brightness, fatigue, flicker, motion, and the beauty of square and sine wave patterns by using magnitude estimation. The results showed that all of the evaluation values, except for beauty, increased in both groups as the grids became smaller; moreover, brightness increased significantly by a greater amount in migraineurs than in controls. The square waves with the smallest grids induced both beauty and discomfort in both groups, and the sine-wave patterns induced stronger fatigue and motion perceptions than square-waves patterns in both groups.

Keywords: Vision, Geometrical pattern, Migraine, Comfort, Discomfort

1. Introduction
1.1. Comfort and Discomfort from Geometrical Patterns

Geometrical patterns such as stripes or checkerboard patterns are found in abundance in our living environments (e.g., zebra crossings, elevator steps, designs on window blinds, patterns on clothes, wallpaper designs, and so on. Examples are shown in Figure 1). In addition, such patterns are also used to cause optical illusions of color and movement in abstract paintings called “Op art” by several well-known artists such as Riley [1] (an example of Op art by Kitaoa [2] is shown in Figure 2). In such cases, we appreciate the beauty and artistic value of such patterns.

Geometrical patterns can also induce different kinds of perception. In previous studies, it was reported that geometrical patterns and more complex abstract art images with a certain luminance profile are capable of inducing visual discomfort [3-6], fatigue, motion [4], and beauty [7]. However, different kinds of perception simultaneously induced by geometrical patterns have not been studied quantitatively and systematically. Therefore, we sought to determine what and how much individuals perceive in geometrical patterns and how the perceptions differ among individuals.

1.2. Migraine

Previous studies have shown that patients with migraine headache are sensitive to geometrical patterns and perceive pattern glare from them (i.e., perceptions of discomfort and abnormal brightness) [8-10]. In addition, such patterns can even trigger migraine attacks [11, 12].

Migraine is a chronic headache disorder and has a low but measurable prevalence all over the world. While the prevalence of migraine differs from country to country in which epidemiological surveys have been conducted (e.g., 11.7% of the US population and 15.2% of the Brazilian population [13, 14]), a previous study reported that 8.4% of the Japanese population suffers from migraine headaches [15].

Patients with migraine have certain characteristic symptoms, although they may differ among individuals [16].
Migraine attacks occur intermittently on a daily basis and last for 3–72 hours. The attacks cause pulsating pain on one side of the patient’s head and can decrease the patients’ quality of life [17]. For some patients, the attack is accompanied by abnormal perceptions called visual aura, photosensitivity, sensitive auditory perception, and/or abnormal olfactory perception [16]. Studies have shown that some migraine patients have visual symptoms because their visual cortex is easily excitable during migraine attacks [18] and even in the interictal period [19].

2. Purpose

In the present study, we attempted to quantitatively and systematically examine perceptions induced by geometrical patterns, and to compare migraine patients with headache-free controls.

3. Method
3.1. Participants

Seventeen patients (11 female and 6 male patients aged 10–40 years) and 38 controls (17 female and 21 male controls aged 10–30 years) participated in the experiment. We classified the participants into migraine patients and normal controls by using a questionnaire based on the second edition of the International Classification of Headache Disorders [16]. This questionnaire included 18 items about the occurrence of chronic headaches as well as characteristics, duration, frequency, accompanying symptoms, and so on. Seventeen out of fifty-eight participants met the diagnostic criteria for migraine with or without aura. All participants had normal visual acuity, and none had visual deficits such as color blindness. Written informed consent was obtained from each participant. This study was approved by the Ethical Committee of Graduate School of Engineering, Chiba University.

3.2. Stimuli

We used 8 achromatic stripe and grid patterns as visual stimuli in the experiment. The images were created using Adobe® Flash®, and 4 vertical grid sizes were used: 0 grids (stripes), 2 grids, 4 grids, and 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, 42.5 cd/\(m^2\) (\(L_{max} = 85.0 \text{ cd/}m^2\), \(L_{min} = 0 \text{ cd/}m^2\)). Thus the Michelson contrast was 1.0 for all patterns. Examples of experimental stimuli are shown in Figure 3.

3.3. Experimental Setup

The visual stimuli were presented on an Apple PowerBook G4 that had a 15.4 inch LCD display with a resolution of 1280 × 854 pixels. The display was placed against a black background, and the participants were seated at a distance of 57 cm from the monitor with their heads fixed on a chin-rest. The experiment was conducted in a laboratory with daylight fluorescent lamps, and the mean illuminance in the laboratory was approximately 500 lx.

Figure 1. Geometrical patterns in our living environments

Figure 2. Example of Op art [2]
3. 4. Procedure

In the experiment, the participants were asked to binocularly view each pattern and evaluate 6 types of perceptions. We chose “discomfort,” “fatigue,” “motion,” “flicker,” and “beauty” on the basis of the previous studies [4, 7]. The perception of beauty was considered as that of comfort in this experiment. In addition, we chose “brightness” to measure the intensity of pattern glare induced by the stimuli based on the previous clinical report on migraine [10]. The participants rated these perceptions on a 0–200 scale by using the magnitude estimation method. The standard stimulus was the square-wave pattern with 4 grids (Figure 3, first row, third picture), and its evaluated value was set at 100. A trial was carried out in the following order (Figure 4). The standard stimulus was presented on the computer 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 in which blanks for each comparison stimulus were assigned to each evaluation item. The comparison stimuli were presented in a random order.

4. Results

The mean ratings for the evaluation items (discomfort, brightness, fatigue, motion, flicker, and beauty) were calculated in each of the 4 conditions, patients/controls by square-wave/sine-wave (Figure 5). We conducted three-way analyses of variance (ANOVAs) for each evaluation item. Each analysis included one between-participants factor (group: migraine patients vs. controls) and 2 within-participants factors (grid size and wave type).

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 of the evaluation items, the main effects of grid size were significant (discomfort: $F_{3,19} = 47.4$, $p < .001$;
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: $F_{3,159} = 7.3, p < .001$).

Clearly, for participants of both 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 these evaluation items (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: $F_{1,53} = 42.0, p < .001$). With respect to fatigue, however, there was a significant interaction between grid size and pattern type ($F_{3,159} = 2.7, p < .05$), reflecting little difference between the fatigue induced by square- and sine-wave patterns with 32 grids in either participant group. However, there was a significant difference in the evaluation of patterns with stripes (the mean evaluation values with the 95% confidence limits are given in brackets; patients/square wave: 131.8 [117.9 to 130.3]; patients/sine wave: 144.1 [130.3 to 157.9]; controls/square wave: 131.1 [121.8 to 140.3]; controls/sine wave: 139.7 [130.5 to 149.0]). There were also significant interactions between grid size and pattern type in motion and flicker (motion: $F_{3,159} = 7.7, p < .001$; flicker: $F_{3,159} = 10.1, p < .001$). In both participant groups, while there was a significant difference between square and sine waves in the evaluation of the motion of patterns with stripes, there was no significant difference in the evaluation of patterns with 32 grids (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]), and also in the evaluation of 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]).

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 with 32 grids significantly induced intense strong brightness for the patients, but not for the controls (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]).

![Figure 5. Results of the experiment](image-url)

*Figure 5. Results of the experiment (The error bars denote a standard error*)
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 32 grids than did the controls.

5. Discussion

In the present study, we conducted an experiment to examine several types of perception induced by stripe and grid patterns in migraine patients and headache-free controls. Three-way ANOVAs showed differences in evaluations between participants of both groups, affected by 4 pattern grid sizes and luminance profiles (square waves or sine waves).

Participants of both 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 sine-wave patterns induced more discomfort, fatigue, motion, and flicker in both groups. The illusory motion perception can be caused by gradually changing the luminance profile in geometrical patterns [20], as exemplified in the Fraser-Wilcox illusion [21] and the Rotating Snakes illusion [22]. A neuroimaging study showed that a motion-sensitive area in the visual cortex (hMT+) is activated during the observation of geometrical patterns with gradually changing luminance profiles [23]. Since the sine-wave patterns used in this experiment also had 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. We hypothesize that the motion perception may strengthen the visual fatigue and the perception of discomfort and flicker. Indeed, the evaluations of motion in sine-wave patterns positively and significantly correlated with those of discomfort, fatigue, and flicker (Pearson product-moment correlation coefficient [N = 55], with discomfort: $r = .38, p < .01$; fatigue: $r = .33, p < .05$; flicker: $r = .66, p < .001$).

With regard to beauty, the perceptions of both participant groups were relatively strong with regard to the square-wave patterns with stripes and 32 grids. In contrast, the sine-wave patterns decreased the perception of beauty for participants of both groups. It has been reported that the beauty of the patterns is positively correlated with the clearness of the patterns [4]. Therefore, our results suggest that the fuzziness of the sine-wave pattern decreased the perception of beauty. Furthermore, the unfamiliarity of the sine-wave pattern could also have reduced the perception of beauty, unlike the stripe or checkerboard square-wave patterns that we frequently come across in our living environments.

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 which imply pattern sensitivity in migraine patients are remarkably consistent with the previous report [10]. It can be said that the sensitivity to contours of pattern in migraine patients can be explained by the hyperexcitability of the visual cortex [8, 24]. However, since patients with mild or moderate migraine participated in the present 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 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.

Interestingly, participants of both groups experienced both strong discomfort and relatively strong perceptions of beauty for the square-wave patterns with 32 grids. This finding implies that visual comfort and discomfort can occur at the same time, and that people may unconsciously feel visual discomfort when they appreciate complex art and design in our living environments. From the viewpoint of universal design, geometrical patterns should be used carefully, especially in public spaces such as hospitals and schools, because they might produce strong discomfort in migraine patients.

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 to conduct a more detailed examination. Besides, we used only achromatic geometrical patterns in the present study, and we cannot eliminate the possibility of an association between chromatic properties of geometrical patterns and visually evoked perceptions in people with and without migraine. Especially as for migraine patients, previous studies reported they may have S-cone deficits (i.e., blue-yellow color blindness) [25] and a preference for colored overlays that ease reading such as blue or green [26]. Further studies are necessary to examine the relationships between the spatial and chromatic...
properties of geometrical patterns and visual comfort and discomfort.

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References