Temporal Pattern Discrimination of Visual White Noise

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TEMPORAL PATTERN DISCRIMINATION OF VISUAL WHITE NOISE

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The psychophysical measurements of flicker pattern discrimination were carried out using the visual temporal pattern that showed the white noise oscillation in brightness.

Seventeen differently high-cut modulators were produced from original white noise having 20 kHz bandwidth. The lowest high-cut point was 2.5 Hz and the highest one was 100 Hz. The 1 msec duration pulse train of 550 Hz was frequency modulated to follow the wave form of the highcut noise modulators, thus producing the brightness change perceptually equivalent to the modulation noise wave form.

*S*s were required to report the qualitative difference in randomly oscillating brightness pattern between the two disks of 3.4° situated side by side at the center of the dark field.

According to the *S*s' verbal reports, the cues for discrimination resided in the degree or density of flicker.

The following are the results of differential threshold measurements : The modulator having the high-cut point at 100 Hz, which can be assumed to contain all the frequencies that the visual system can respond to (i.e., visual white noise), did not differ qualitatively from 40 Hz modulator, and was found to be discriminable from 22 Hz modulator 50% of the trials for NT. The lower differential threshold values were 16 Hz for KK and 10 Hz for TH.

These results could be explained by relating them to the flicker sensitivity curves of the three subjects in that in the qualitative discrimination of visual white noise task, the noise-band that had the frequency lower than the peak flicker detection sensitivity frequency or the frequency just higher than that point solely determined the performance.

Measurements of the modulators having high-cut points lower than 20 Hz performed with TH revealed that the discrimination was possible between the two flicker pattern having high-cut point difference of a few Hz.

Problem

The aim of the present study is to do the psychophysical study of the temporal pattern perception of white noise patterns which was regarded as being a temporal version of spatial random pattern.

Method

Stimulus material

Seventeen modulating waves having different high-cut characteristics were prepared from original broad-band white noise generated by a white noise generator

(NF-Co.: WG–721) by putting it through high-cut filters (NF-Co.: FV–602T). The actual high-cut points used in the present study were 2.5, 3.15, 4, 5, 6.3, 8, 10, 12.5, 16, 20, 25, 31.5, 40, 50, 63, 80, and 100 Hz (42dB/octave) as shown in Fig. 1.

They were used to modulate the 550 Hz pulse train through voltage-frequency transformation circuit, with the result that the obtained modulated pulse train had the same apparant brightness pattern as the modulating stimuli. The actual high-cutting was performed at 40 times as high frequency for 16 to 100 Hz high-cut points as the purported frequency. Then the frequency of the high-cut noise modulators was shifted down by one fortieth using two data recorders (SONY: DFR–3915). For the 12.5 Hz or lower frequency modulator, the actual high cutting and frequency shift-down were performed at the frequency of 400 times as high. These procedures prevented attenuation of lower frequency power spectrum, while keeping the S/N ratio at a desirably good level.

Fig. 2 illustrates some of the actual wave forms used as modulators which had the frequency response characteristics shown in Fig. 1.

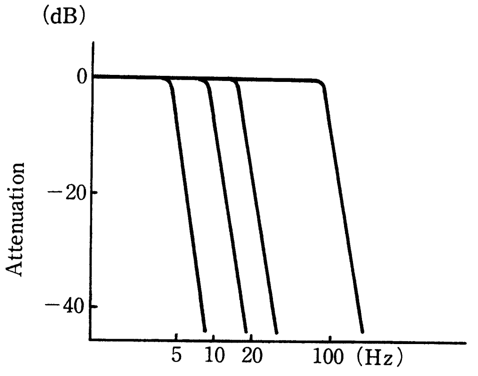

Fig. 1. Attenuation characteristics of low-pass filter.

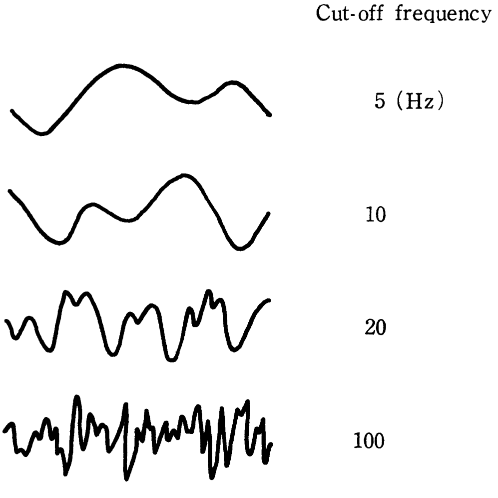

Fig. 2. Stimulus waveforms.

Optical System

Fig. 3 shows the schematic diagram of the apparatus and the stimulus patch. The light emitting diodes (LEDs) were used as light source, which were driven by a train of 1 msec pulses at the central freqency of 550 Hz. They were frequency modulated within the limits of 150 Hz to 950 Hz in accordance with the wave form of the band-pass noise modulators produced in the way as described above. Thus, the modulated pulse train gave the impression of incessantly flickering after the wave form of a modulator as the Talbot-Plateau law tells us (Maruyama & Matsumura, 1974). The maximum amplitude of modulation (m) that was possible with the present method was 0.73.

Subjects observed through the Maxwellian view the two horizontally arranged disk patches having the visual angle of 3.4° each, at the center of the dark field, and judged whether the right standard disk looked same as the left comparison disk whose modulator noise changed randomly from trial to trial its high-cut frequency. The disks had a mean luminance of 600.6 nit and the range of 163.8 to 1036.2 nit.

All the observations were done with the right eye.

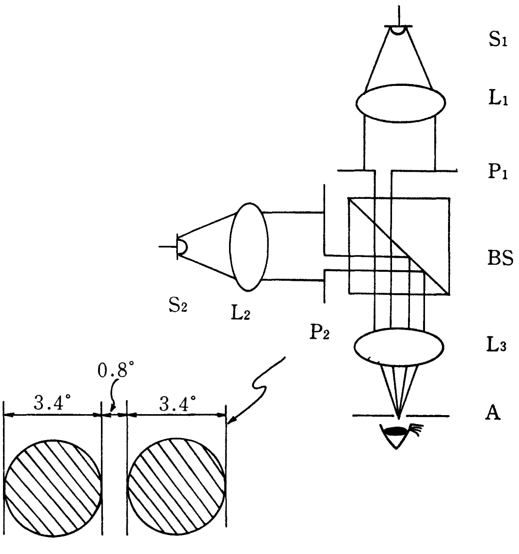

Fig. 3. Diagram of optical system and stimulus patch.
S_1, S_2: light source (LED); L_1, L_2, L_3: lens; P_1, P_2: stimulus disk; BS: beam splitter; A: artificial pupil (2 mm diameter).

Procedure

With the band-pass noise of different high-cut characteristics, the otherwise continuously lit disks changed their brightness in accordance with the wave form of the noise modulator. Different high-cut characteristics produced qualitatively different appearance in the flicker pattern or temporal texture. The purpose of the psychophysical measurements here was to determine for several of the 17 band-pass noises the discrimination thresholds at which one modulator gave different impression from the standard modulator. The differential thresholds were represented as the cut-off frequency point of the comparison modulator where the performance deteriorated to be 50% correct discriminations.

The constant method was used and the obtained thresholds were the lower differential thresholds.

As an illustration, the following is the description of the actual procedure for the subject TH. Using, for example, the 100 Hz modulator (the modulator that had the cut-off point at 100 Hz) as a standard, judgements were made with 7 different modulators (20, 16, 12.5, 10, 8, 6.3, and 5 Hz). The range of the comparison modulators was determined during the preliminary trials such that it would cover the range from perfect discriminability to complete impossibility of discrimination. Consequently, the choice of the comparison modulators depended on both subjects and standard modulators. For this subject the 5 Hz and 6 Hz modulators were discriminated perfectly, whereas 16 Hz and 20 Hz noise stimuli were impossible to distinguish from the standard. In other cases also, the two comparison stimuli on either end of the range were chosen so that the discriminations would be either perfectly possible or impossible. The results of these outmost modulators were omitted from the figures to make them easy to read.

After 5 minutes dark adaptation, the subject TH was shown 84 pairs in random order and judged their difference with each pair being repeated 12 times. Furthermore, he was instructed to discribe, if possible, the qualitative difference in the appearances between the members of each pair. There was no limits in the observation time.

Before entering in the actual trials, each subject was asked to match the ripple amplitude of the comparison modulator with that of the standard. Since it was only approximately possible to do so, he was instructed not to rely on this cue. With these procedures thresholds were measured with two more subjects: KK and NT. All of these subjects were graduate students of Tohoku University. Thresholds were measured with the 100 Hz standards as well as 100 Hz modulator. These were 40, 20, 16, 12.5, 10, 8, 6.3, and 5 Hz. The 100 Hz modulator was chosen as a standard used for all the subjects because it was considered to cover entire flicker frequency range that was detectable by the human eye.

Results and Discussion

The following is the summary of the verbal reports of the 3 *S*s and the results of their differential thresholds.

(1) According to their verbal reports on the flickering appearances of the different modulators, these modulators differed in flicker rate or density (the difference in temporal texture). The cues for qualitative differences were the degree of fine flicker, the gradual change in brightness, and the presence or absence of "spines" (small sharp changes). These differences were easily detected for widely separated pairs, though it took one or two minutes for hard-to-discriminate pairs.

(2) Fig. 4 shows the percent correct discrimination functions for the 100 Hz standard for each *S* separately. Each point represents percent correct discrimination of the 10 judgements as a function of comparison modulator. It can be seen that the slopes of three psychometric functions are approximately equal, showing that the change in the high-cut frequency from low to high resulted in the comparable change in difficulty in discrimination. This trend was similar among the three *S*s. Assuming

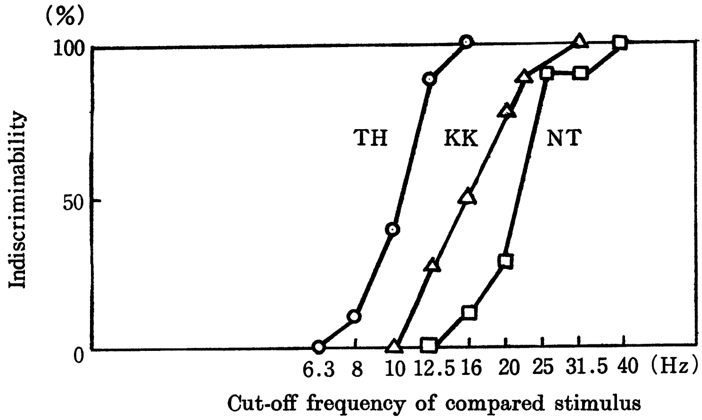

Fig. 4. Results of percent correct discrimination function for the 100Hz standard for 3 *S*s.

the 50% correct discrimination point to be a threshold value, it was about 10 Hz for TH, 16 Hz for KK, and 22 Hz for NT. It may be concluded that the lower differential threshold for 100 Hz noise modulator had the high-cut frequency at appoximately 10 to 20 Hz. *S*s could not discriminate 100 Hz modulation from 40 Hz one, but some of them could detect the difference between 100 Hz and 20 Hz. For others the high-cut frequency had to be lowered to 10 Hz to perceive the difference. Thus, for TH the lower three temporal changes in brightness shown in Fig. 2 looked identical in spite of the apparent difference in the wave forms.

In order to explain the present results in relation to the flicker sensitivity functions (Kelly, 1961), amplitude sensitive curves were measured for these subjects. Fig. 5 shows the results of these measurements for each subject as a function of sine wave frequency. Each point is a mean of 5 to 8 measurements of threshold amplitudes (m) for the stimulus of 600.6 nit mean luminance. As Fig. 6 shows peak of maximum visual response was 7 Hz for TH, 10 Hz for KK, and NT. Since these values are comparable to the differential threshold values obtained in the main experiment, *S*s' qualitative judgements were determined by the frequency range up to the peak flicker detection sensitivity frequency or just higher than that frequency. The frequency range above that point does not seem to contribute to discrimination.

These considerations seem to hold true for the supra-threshold frequency-response curves, since the research note by Magnussen and Björklund (1979) has shown that the peak frequency of maximum sensitivity remained the same for the higher-than-threshold modulation value of 0.65.

(3) Threshold measurements with other modulators than 100 Hz one were performed only with TH, and shown in Fig. 6. In this observation there were 8 high-cut points were employed: i.e., 40, 20, 16, 12.5, 10, 8, 6.3, and 5 Hz as a standard modulator. In Fig. 6, the previously shown results for 100 Hz modulator is included

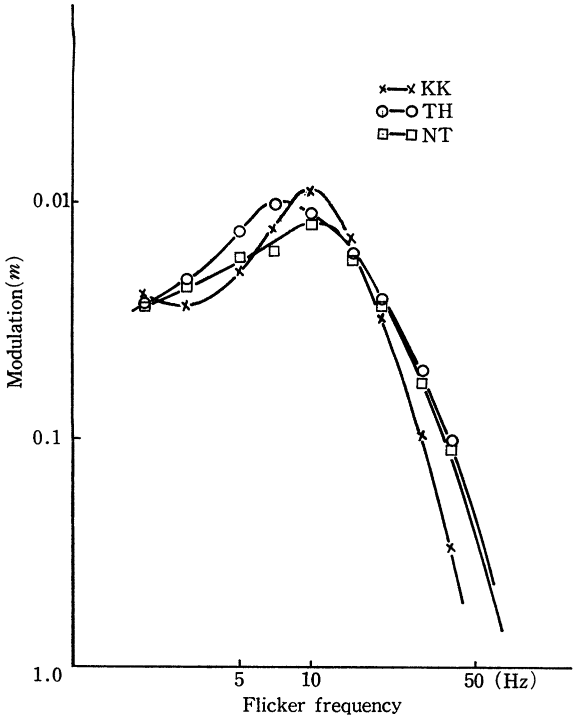

Fig. 5. Amplitude sensitivity curves measured for 3 *S*s.

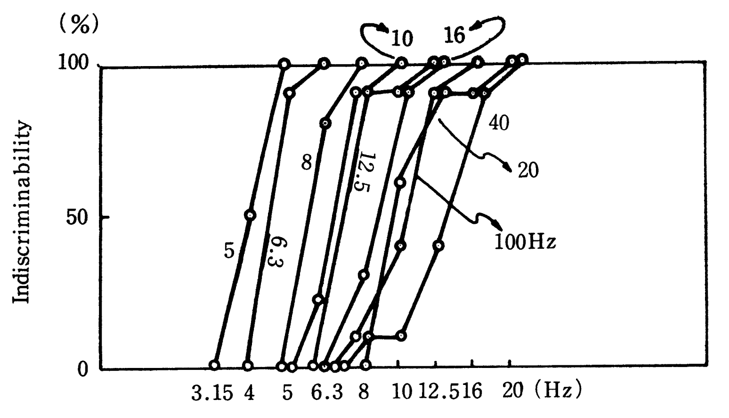

Fig. 6. Results of percent correct descrimination for the 9 kinds of standard stimuli for subject TH.

as well. The abscissa values that cross the 50% discriminability line give the lower differential thresholds for each standard modulator.

The thresholds estimated in this way are 13 Hz for 40 Hz standard, which is a bit higher than the value obtained with 100 Hz standard (10Hz). However, for 20 Hz standard, the obtained threshold is equivalent to that of 100 Hz. Therefore, it may be concluded that the high cutting of 20 Hz or above did not produce much difference in the qualitative appearance of the temporal change in brightness. In case of the high cut points lower than 20 Hz, difference in high cut point of a few Hz was found to be enough to discriminate the pair. In the present study, however, practical limitations of the filters used prevented us from determining fine-tuned threshold values for the low frequency points. It may be noted that the slope of the psychometric function tends to be steeper as the high-cut frequency is lowered, suggesting the better discrimination at the lower frequency range.

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