Paper

Apparent Color of 10 Test-Color-Cards in Dense Fog

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Our visual characteristics are affected by various visual environments. In this experiment, we examine how object colors look in dense fog. Namely, 7 male subjects evaluated their color perception of object color in the presence of fog and in the absence of fog. Subject's task is to match the apparent color of 10 test-color-cards in dense fog with the Munsell color. In the presence of fog, apparent color showed a drastically decrease both in the chroma and in the value. We are confident that in the visual environment involving fog, these results are extremely helpful both in basic study and in practical use.

Keywords : apparent color, visibility, Munsell color system, dense fog, traffic visual environment

1. Introduction

We might say that our visual sensation plays a pronounced role in our daily lives when we want to collect some information from our environment.

It is in general said that the information collection by vision occupies about 80% or in some cases even more of that by the so-called five senses: visual, auditory, olfactory, taste and tactual(1). Assuming some situations where we become totally blind in our everyday life, we could imagine with ease and then realize how important the part our sense of vision displays is.

Should any visual information that bears so essential part be somehow interfered or intercepted, it will carry vital and severe implications. Without any visual information, we could not live any simple daily life nor fulfill even any simplistic operation, to the fullest degree at least.

As a familiar concrete instance in which we may experience these inconveniences, we may refer to some incidents in car driving under bad weather. Any driver or passenger would have encountered, once at least, thick fog, downpour, snowfall and the like that might have caused poor visibility, resulting in the inability to grasp frontal or surrounding road information, thereby provoking a feeling of uneasiness. Under such circumstances, even a veteran driver could not ensure his or her safety, since any traffic signs, signal lights and/or any other surrounding conditions would not have been checked and judged instantaneously. These situations may often give rise to some traffic accidents.

Early morning, December 1, 1998, an accident occurred in the Ban-etsu National Expressway in Fukushima Prefecture, Japan. This is impressed on our memory as a typical accident caused by poor visibility due to dense fog. In this accident, sixteen trucks and passenger cars bumped from behind one after another or crushed into other car, resulting in two dead and about 30 injured. It has been reported that the visibility was about 30 meters at the time of the accident. The serious accident did occur around 5:15 am, an early-in-the-morning time zone when the traffic volume should be relatively low anywhere. We cannot but feel a vague fear imagining what could have been if it had taken place at rush hours. This was a case where we were deeply impressed with the misery of traffic accident.

In this background, contrivances and countermeasures are craved for to improve the visibility of drivers, namely ensure sufficient visual information for drivers, to secure the traffic safety under rough weather.

So far in the optical fields, there exist several studies on fog, which lay emphasis on the scattering of light and analysis of absorption characteristics(2)-(11). However, the actual state is that we have very few research papers where color vision and visual characteristics of colored light in fog have been fundamentally and quantitatively measured using psychophysical methods(12), (13).

The authors have already collected several basic data on the visibility characteristics of the "light source color" in dense fog making use of psychophysical methods(12), (13).

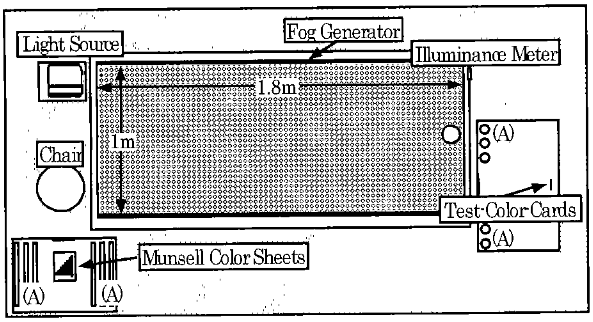
However, visual and color vision characteristics for "object color" may be said to be one of important assignments, on the other hand. When the visibility characteristics for traffic signs, signboards and the like are taken into due consideration, it is necessary to assume the "object color" as a test stimulus.

This study therefore is intended to quantitatively analyze, using the matching method, how the color of the "object color" is seen in dense fog, also taking into account some reports on the "light source color" so far submitted.

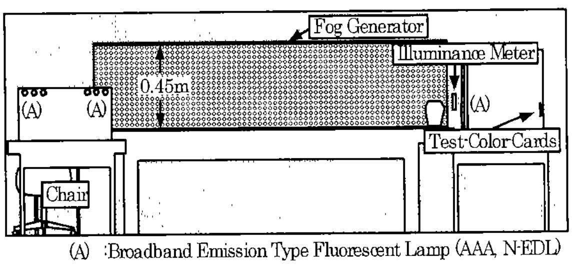
2. Experiment

2.1 Experimental Equipment Fig. 1 shows the outline of the equipment used in this experiment. In this figure, (a) represents a plan view, and (b) a side elevation view. In each of these drawings, the rectangular case at the center is a fog generator, in which two windows consisting of acrylic plates are mounted on both ends of the rectangular case made of styrene foam, 1.8 m in length, 0.45 m in height, and 1 m in width. The interior has been painted all black except the acrylic windows to prevent any useless irregular reflection of light. An atomizer for generating the fog (MiniFogger MF-1, Spraying System Japan) is set in the case. Set on one of the windows of the case are the standard color cards as test stimuli and the light receiver of illuminance meter, while the light source (Slide projector Cabin CS-30AF) and a chair for observation by subjects are set on the other window. The Test-color-cards for test stimuli to be observed by the subjects are installed on the right side of the fog generator and illuminated by a fluorescent light.

The light source as set in the upper left portion in Fig. 1(a), intended to measure the density of fog, projects light through the slide having fine round holes. Note



(a)



(b)

Fig.1 Experimental equipment,
(a) Plan view, (b) Side elevation view.

that the amount of light of the light source has been adjusted beforehand so that the pointer of the illumination meter should indicate 450 lx (corresponding to 100% of transmission factor) under the condition of no fog.

The width of the case for generating the fog has been made as broader as possible so that the light coming from the light source may diffuse in the dense fog and cannot overlap the color chips viewed by the subjects. Further, an appropriate board has been arranged between the light from the light source and that from the color chips in order to eliminate, as far as possible, any influence of diffused light from the light source on the observation.

Munsell color sheets to be used by the subjects in matching were set just near the chair for observation by the subjects shown in the lower left portion of Fig. 1(a).

In order to compare the results of this experiment with others[14], used by ten types of test stimuli, in future times, we decided to use following ten types of test stimuli to be observed by the subjects. Note that the visual angle against the test stimulus is 60' (circular). In the experiment, the visual angle possibility was determined by the color card's size which were used.

	Hue	Value / Chroma
1)	5R	5/14
2)	5YR	7/14
3)	5Y	8/14
4)	5GY	7/12
5)	5G	5/10
6)	5BG	5/ 8
7)	5B	4/ 8
8)	5PB	4/12
9)	5P	3/10
10)	5RP	5/12

The illumination for color chips used a broadband emission type fluorescent lamp (Color rendering AAA, N-EDL). The surface illuminance of test color chips and Munsell color sheet have been set 1600 lx.

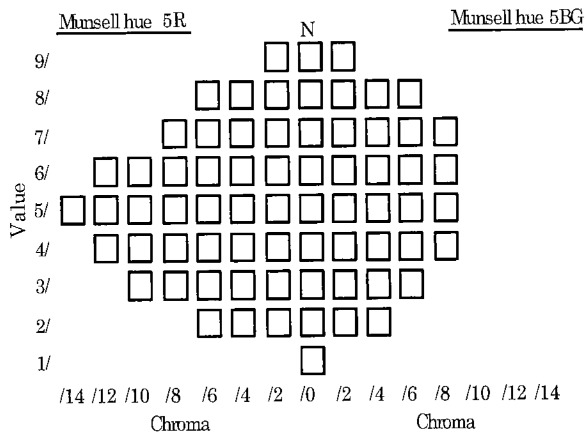


Fig.2 Munsell color sheet (Munsell hue 5R and 5BG).

Minute attention has been paid to it that even any trace of illumination light irradiating the standard color cards and Munsell color sheets should not leak to the exterior so as to maintain constant the observational conditions for the subjects.

Fig. 2 illustrates an example of the Munsell color sheets. Munsell color chips of 5R are arranged on the left side as well as those of 5BG, the opposite colors, on the right. A transparent OHP sheet was put over the sheet. The subjects shall select, from the Munsell color sheets, any color that can match with the apparent color of the test stimulus as observed through the fog, and affix predetermined symbol on the OHP sheet over the color sheet.

2.2 Density of Fog and Measuring Before proceeding to this experiment, we studied first of all fog dissipating characteristics in the fog generator as preliminary experiment. Fig. 3 shows the results of the measurement of the fog used in the experiment versus the time elapse and variation in density. The horizontal axis represents the elapsed time (s) and the vertical one the transmission factor (%) corresponding to the fog density.

Now, we are going to describe how we measured. To begin with, the first atomization is conducted to generate a sufficient volume of fog within the case. The atomization shall be interrupted as soon as the pointer of the illumination meter indicates 50 lx, which corresponds to 11% of transmission factor. At the same time, the illuminance measurement shall start. That is, starting from the time point when the atomization stops, the value of illuminance shall be measured at the time intervals of 5 seconds. As soon as the transmission factor becomes 100%, namely when all the fog within the case is cleared, the second atomization shall commence. In the similar fashion, the atomization shall be interrupted when the transmission factor reaches 11%, and the second measurement shall begin as in the earlier case. Fig. 3 depicts the measurements from the third atomization performed according to the similar procedure.

From the measuring results, it is understood that the time up until the fog is cleared is relatively short in the first atomization. However in the second and subsequent tests, the same time before the fog is cleared tends to be somewhat longer.

The reason is conceived to be that, in the second atomization, the humidity in the case has come to be already higher than that in the first atomization, coming nearer to the saturated state, which suggests the suppression of fog dissipating effect. From the same results, it is clear that the third characteristics within the range of 11% to 55% of transmission factor almost overlap those of the second atomization.

From the above results, it has been manifested that in the second and subsequent atomizations, the fog density continues to change showing approximate and relatively stable attenuation characteristics.

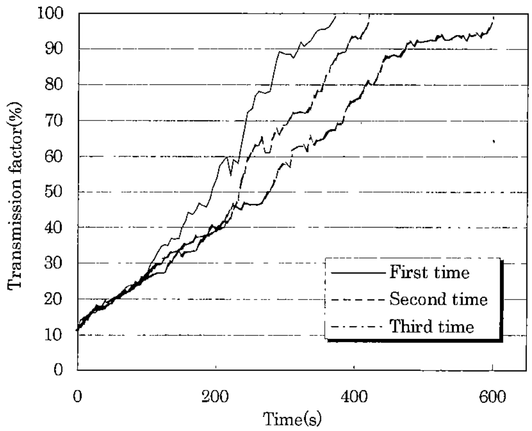


Fig.3 Time elapse and variation in density of fog.

In this experiment, therefore, a sufficient volume of fog was generated in the case without fail, once before the commencement of the experiment in order for us to be able to measure with stable fog density characteristics in the second and subsequent measurements.

In this experiment,

1) It is impossible to increase the fog density down to 5% or lower of transmission factor.
2) At 55% or higher transmission factor, it is difficult to set some specific fog density due to a large illuminance value, that is too large a secular (with time) variation of density.

Because of these two reasons, we decided to adopt the fog density in the range of 11% to 55% of illuminance.

2.3 Experimental Procedure First, sufficient fog density is generated in the case. Next, a color card is selected and set in place for viewing. As different cards are set in place, the subjects are asked to match the colors on the Munsell color sheets with the apparent colors of test stimulus at various fog densities. Careful note is made whenever a subject observes the color chips in the gray background in his or her observational field of view. Since, in other words, the interior of the fog box is almost all black, it is thought that the impact of the fog density as viewed from the subject side corresponds to the variation in luminance of the color chips.

If there is no color to be matched with any color on the Munsell color sheets, for example, there is only the color intermediate between certain color chips and other color chips or any colors mixed into one with an adequate proportion, the centers of these color chips are connected with a straight line, which is then equally divided into four parts and a symbol is given on the corresponding point (interpolation). The color chips for matching adopted the Munsell color sheets whose hue is the same with that of standard color cards for observation, which is the test stimulus. Namely, when observing 5R standard color cards, one shall employ 5R color chips also for the Munsell color sheets for matching. This is because measurement was conducted to know any existence of change in perception into the direction of hue, value and chroma at the stage of preliminary experiment, resulted in no perception, by the subjects, of any change in hue direction.

Thus, each subject tried three times of observations for ten types of test stimulus colors. Namely, a total three sessions of observation was performed, one session meaning a series of observation consisting of five stages of fog density for each test stimulus color. The number of subjects is seven, who are all persons with normal color vision.

All experiments were conducted in the dark room.

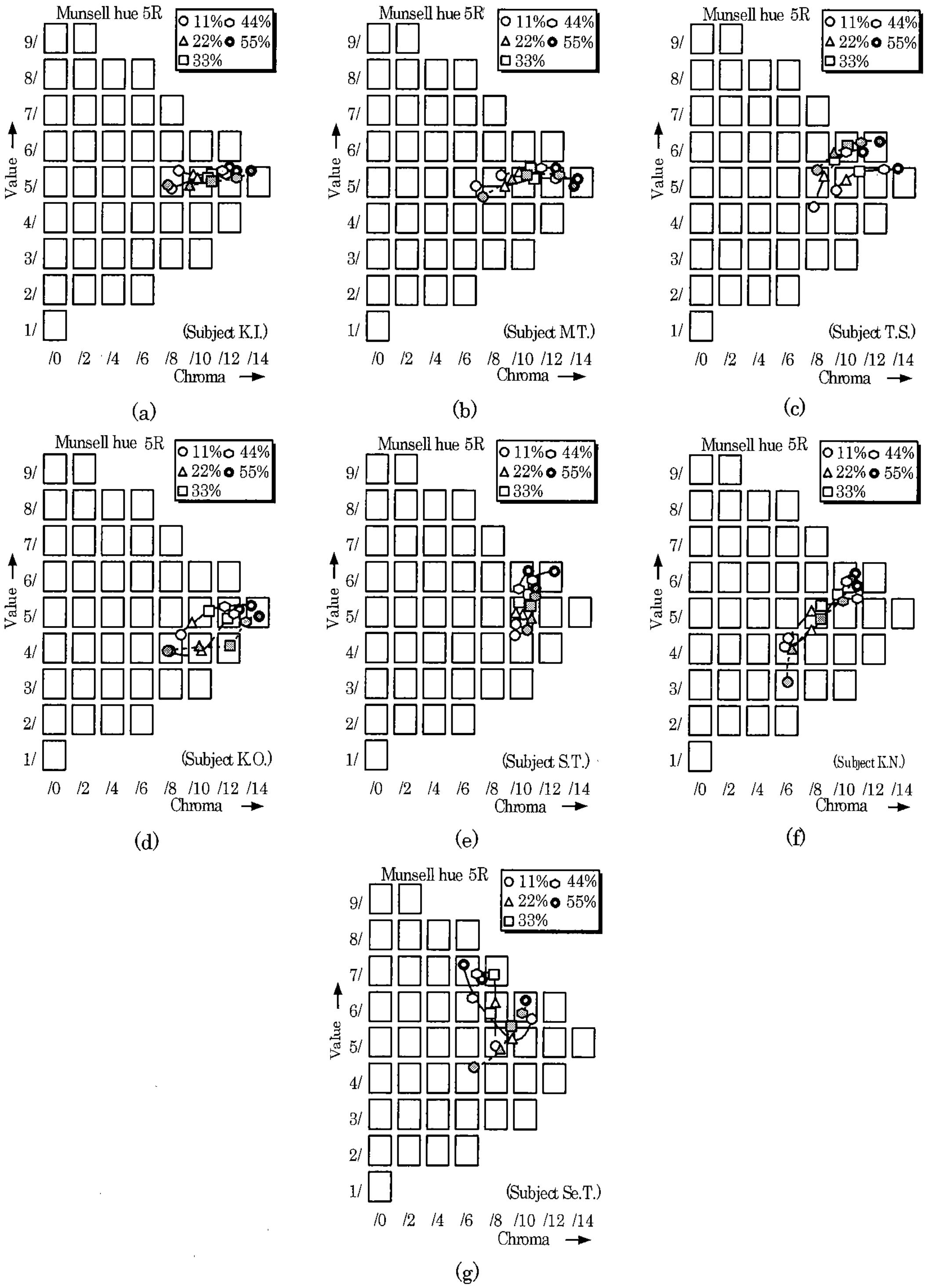


Fig.4 Evaluation of perceived color on the Munsell color sheet (Munsell hue 5R).

3. Experimental Results and Discussion

Fig. 4 show up the experimental results of all subjects as against the test stimulus of Munsell hue 5R. Fig. 5 show the experimental results of all the subjects against the test stimulus of Munsell hue 5BG opposite to said colors. Since the subjects (e) and (g) happened to have the same initial "S.T.", the initial of the subject (g) has been changed to "Se.T" for convenience's sake.

Both figures are the results of plotting, on the Munsell color sheets, of the apparent colors (perceived colors) against the test stimulus, as observed by each subject, using the matching method. The vertical axis represents the value, and the horizontal one, the chroma. Plotted on the respective Munsell color sheets have been the measurement results as obtained from the trial in three sessions. The experimental results from the first session are represented by open symbol and thick line, those from the second session by light gray symbol and chain line, those from the third by

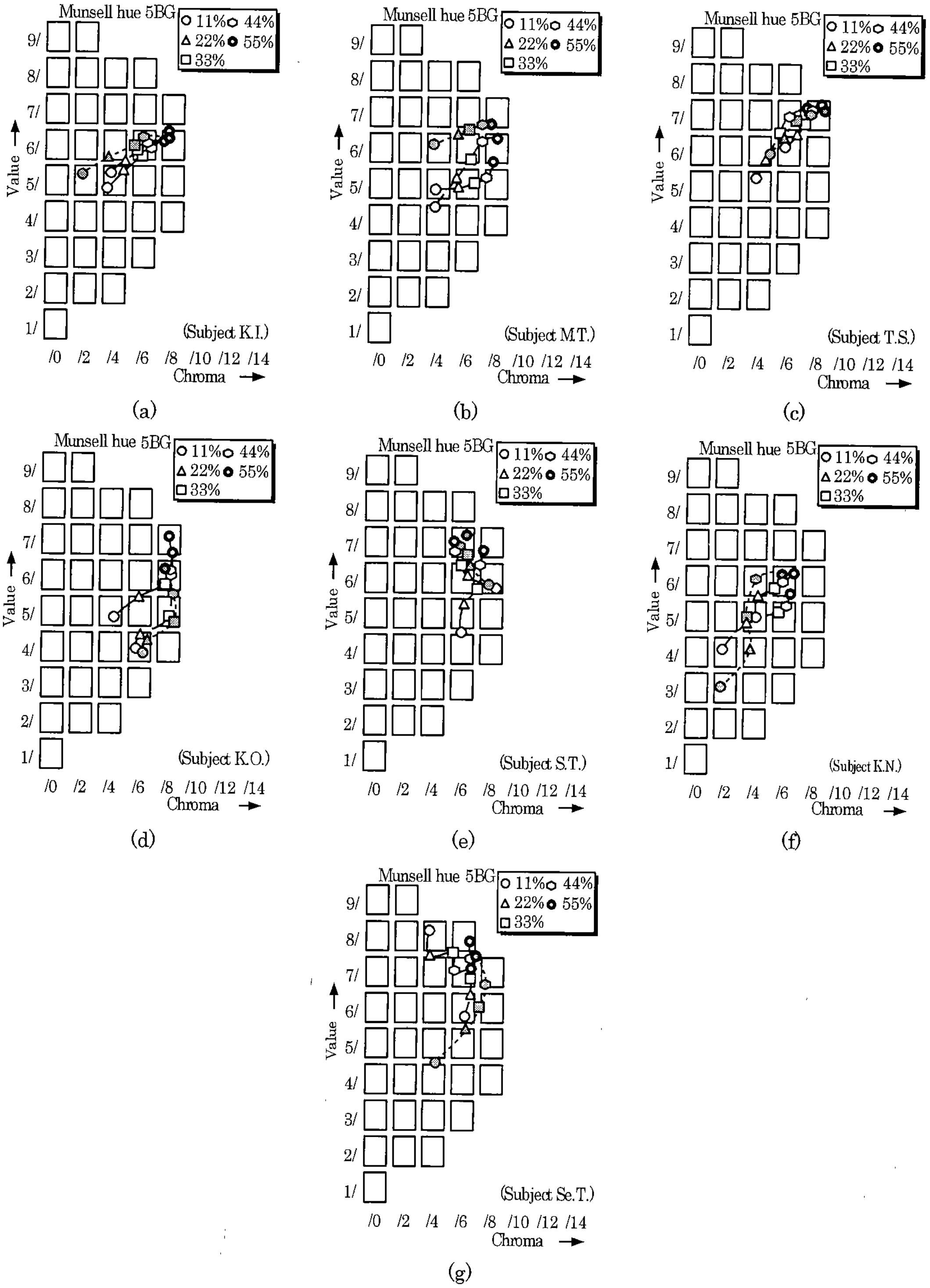


Fig.5 Same as Fig.4, but with Munsell hue 5BG.

dark gray symbol and broken line.

The transmission factor, which is a parameter, in the upper right portion of the figure represents the percentage of in-fog transmission illuminance from the light source, used to control the fog density. It implies that the smaller this value, the higher the density of the fog generated in the case is. Provided that a preadjustment has been made so that 100% should be indicated if there exists no fog, as has already been described.

In any of the figures, as the density of fog goes higher, either the value or the chroma has come decreased, or else both the value and chroma have been reduced.

Only for the subject Se.T.(g), differently from other subjects, the chroma tends partially to increase as the density of the fog goes higher, as shown in Fig. 4. In Fig. 5 the subjects S.T.(e) and Se.T.(g) exhibit partially the similar tendency.

Though, for any other subjects, there exists somewhat dispersion among the subjects or test stimulus colors, both value and chroma manifest a decreasing tendency as has already been described.

Fig. 6-1 collects together and plots the data of all the subjects against the Munsell hue 5Y, while Fig. 6-2

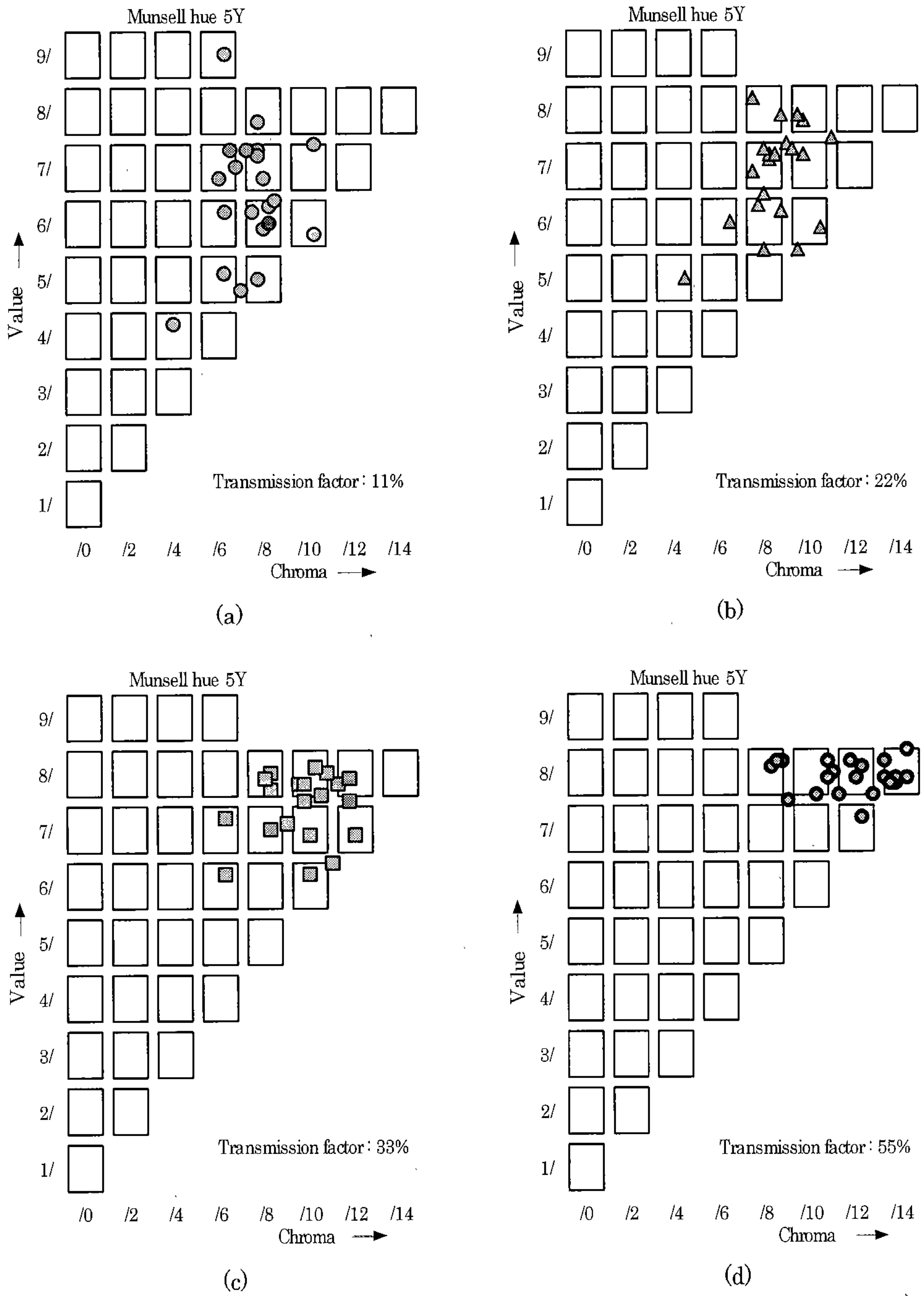


Fig.6-1 Overall subject data for Munsell hue 5Y : (Transmission factor:11%～55%).

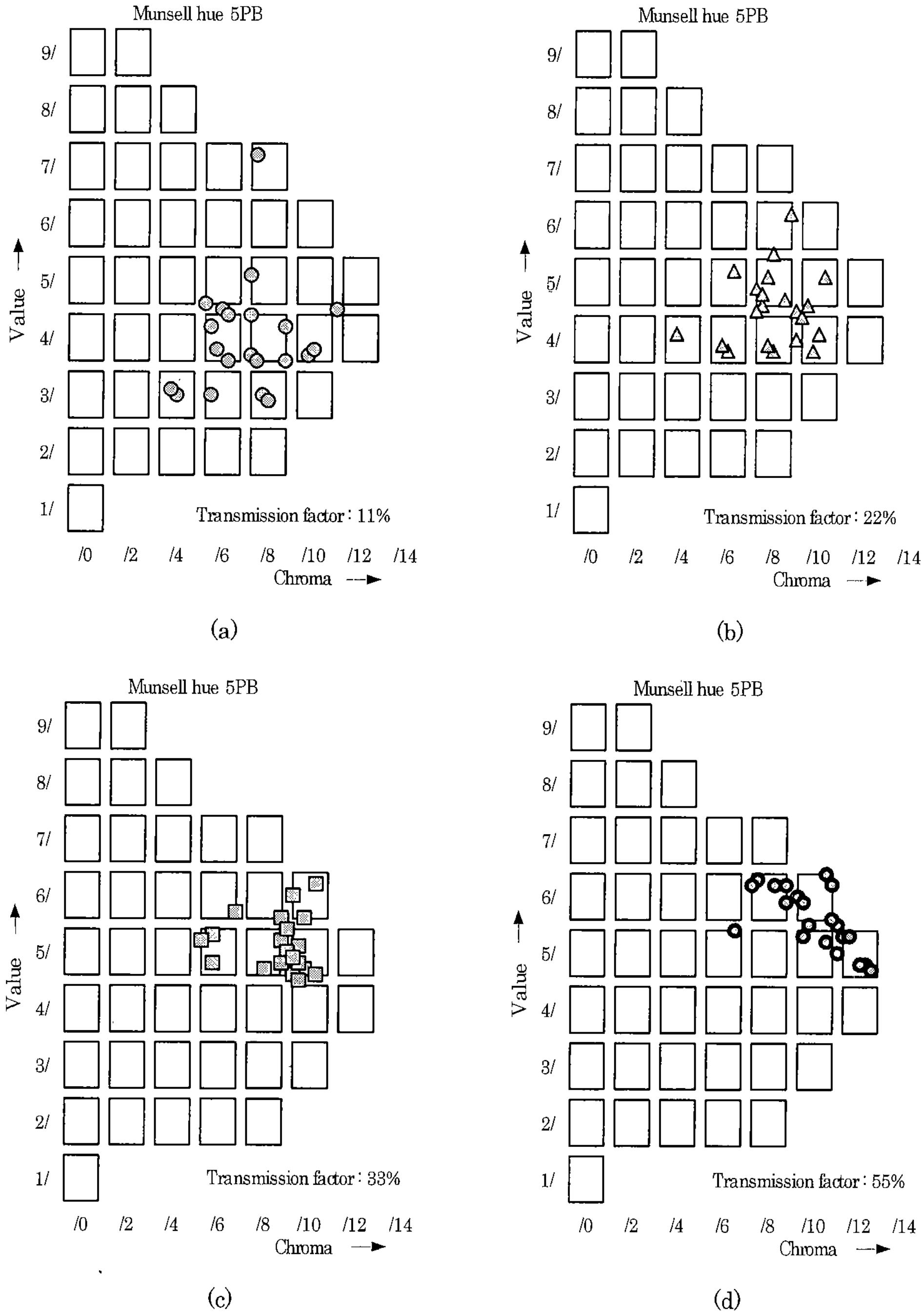


Fig.6-2 Overall subject data for Munsell hue 5PB : (Transmission factor:11%～55%).

shows the same but against the Munsell hue 5PB opposite to said color. Shown are the results of illuminance value 11% (represented by ○), 22% (△), 33% (□) and 55% (◎).

At the Munsell hue 5 Y (Fig. 6-1), the data as a whole aggregates densely around 5Y 8/12 under the fog density at 55% of transmission factor. At the Munsell hue 5PB (Fig. 6-2), on the other hand, the data as a whole closes up together around 5PB 5/10 to 6/10 under the fog density at 55% of transmission factor. In any of the figures, however, as the transmission factor reduces, namely, as the fog density increases, the dispersion in data increases gradually. In other words, the dispersion is extending both in value and in chroma. The center of gravity of the dispersion as a whole is shifting toward reducing direction both in value and chroma. This suggests that the higher the density of fog, the more the perceived color becomes unstable, that is, the identifiability to the test stimulus color decreases as much. These trends were similar for other test stimulus colors.

4. Conclusion

The results of our experiments revealed the fact that as the density of fog becomes higher, the apparent color, namely the perceived color against the object color in the dense fog exhibits a reducing tendency both in value and chroma. It was noted that compared with the color observed under no fog, the perceived color in the dense fog as a whole comes nearer to the color chips with V = 1 and C = 0, that is toward the black color.

Though several reports have so far been submitted about the change in perceived color with different levels of illuminance and luminance[15, 16], there was no change in hue seen with any change in fog density in the results of this study.

One of our future assignments may include any impact of fog used and any other different experimental conditions.

We are now confident that our findings about these object colors as acquired from this experiment, together with the valuable results[12, 13] obtained from the experiments concerning the visibility to the "light source color" in the dense fog, would certainly give some hints to clarify the vision and visual characteristics in the dense fog.

We deem it a favor if these basic data acquired from this study will contribute, even a little, to the fundamental and application fields relating to the visibility of the "object color" in dense fog.

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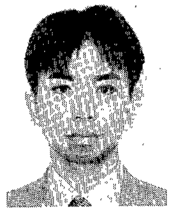

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