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Colour Naming and Classification in a Chimpanzee (*Pan troglodytes*)

A four-year-old female chimpanzee was trained to use symbols to name 11 colours: red, orange, yellow, green, blue, purple, pink, brown, grey, and black. The chimpanzee was then required to name various colour chips from the Munsell colour charts. Colour classification by the chimpanzee was similar to that in a human observer tested under the same condition. Both the chimpanzee and the human observer divided the colour space into the clusters of a broad area within which a single colour name was applied consistently. Areas of consistent colour naming were separated by narrower areas in which the names applied to the two adjacent areas were used and the response latencies were long. These results suggest that, not only the perception of colours, but also the use of colour names have characteristics in common between the human and the chimpanzee.

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1. Introduction

How does a chimpanzee see and describe the world? Riesen (1970) summarized evidence that the chimpanzee's visual system is quite similar to that of the normal human. Behavioural work on colour perception in chimpanzees done by Grether (1940) and Essock (1977) among others suggests that the chimpanzee's colour perception is quite similar to the human. Humans have the capability to describe the perceptual world by the conceptual colour "names" based on such a visual system. The present study consists of a set of experiments investigating colour perception and classification in a chimpanzee who had already learned to name 11 colours: red, orange, yellow, green, blue, purple, pink, brown, white, grey, and black.

In human natural languages, colour-naming systems are not arbitrary but are derived from the common physiological basis (Bornstein, 1973). Berlin & Kay (1969) surveyed 98 languages and found striking similarities in the semantic development of colour classification in various human societies. They described seven stages in the evolution of colour classifications from division into two categories, black and white, to the development of fine distinctions among hues. According to Johnson (1977) the sequence matches the order in which children acquire colour names.

The purpose of the study was to determine how a chimpanzee who had learned to name 11 colours would classify various portions of Munsell colour space.

2. General Method

Subject

The subject was a four-year-old female chimpanzee, "Ai", born in Africa and received in the laboratory at about one year of age. Prior to this study, she had engaged in the language training program for about two years (Asano *et al.*, 1982). The chimpanzee had extensive experience on "symbolic matching-to-sample" tasks including matching 11 arbitrary symbols with 11 specific training colours (see Figure 1 and Table 1).

Apparatus

A computer-controlled training facility was used in this experiment. For the chimpanzee, colour names were symbols (simple geometric shapes which were white figures on a black

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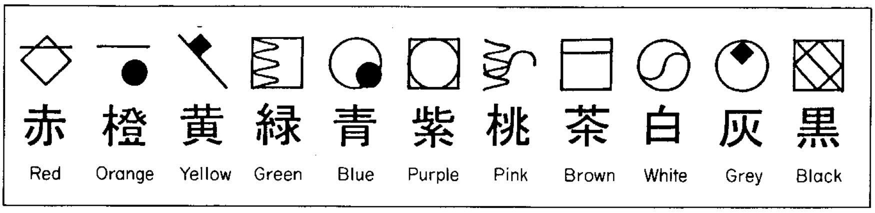

Figure 1. Figure symbols for the 11 colour names used by the chimpanzee and the corresponding "Kanji" characters used in the comparative study in the human.

background). Figure 1 also shows the corresponding "Kanji" characters used in Japanese. Each symbol was drawn on a key (2 × 2·5 cm) and could appear in various positions in a 5 × 6 key matrix on a console provided for the chimpanzee. This console was interfaced with a PDP11/V03 minicomputer that controlled the experiment and recorded key choice. The console was attached to one wall of the experimental room (190 × 220 × 180 cm).

Stimuli

The stimuli were all colour chips from the seventh loose-leaf edition (1981) of the standard colour chart conforming to Japanese Industrial Standard (JIS) Z-8721. This colour chart contains 1928 colour chips arranged in the Munsell notation system, in which a colour is specified by its hue designation (a number and one or two letters) and a value/chroma fraction to designate brightness and saturation. For example, the expression 7·5RP6/12 denotes a particular red-purple colour (Munsell hue 7.5RP) with some degree of brightness (Munsell value 6) and saturation (Munsell chroma 12). The experiment was conducted in the room which was illuminated by daylight as well as by a daylight fluorescent bulb (Mitsubishi, FL15-SW/NL) approximating the proper CIE illuminant C for the colour chart.

Table 1 **Colour names which the chimpanzee had acquired and their trained colours designated in Munsell notation system and CIE tristimulus values**

	Trained specific colour				
	Munsell		CIE system		
Colour name	Hue	V/C	Yc(%)	x	y
Red	7.5R	4/14	12·00	0·5959	0·3269
Orange	5YR	7/14	43·06	0·5252	0·4168
Yellow	5Y	8/14	59·10	0·4699	0·4920
Green	5G	3/8	6·555	0·2228	0·4380
Blue	5PB	4/10	12·00	0·1925	0·1843
Purple	5P	4/10	12·00	0·2814	0·1967
Pink	7.5RP	6/12	30·05	0·4125	0·2784
Brown	10R	3/6	6·555	0·4854	0·3467
White	N	9/0	78·66	—	—
Grey	N	5/0	19·77	—	—
Black	N	1/0	1·210	—	—

General Procedure
The experimenter exposed one colour chip at a time to the chimpanzee sitting about 50 cm away on a bench in front of the console. While exposing a colour chip, the experimenter lighted one of two sets of three rows of keys on the console containing the 11 colour-name keys and four blank keys. Two sets of keys were provided to change the position of the available keys within a session. The position of the keys was also changed from session to session in order to prevent the chimpanzee from using positional cues rather than the symbol in naming the colour. The chimpanzee was required to press a key among 11 alternatives, which produced a feedback facsimile of the figure symbol drawn on the key on a screen of an IEE inline projector located above the console. The chimpanzee then pressed a single blank key to the right of the key matrix to conclude her naming response.

Each session consisted of two kinds of trials. On some trials, the "baseline trials", the 11 colour chips that most nearly matched Ai's training colours were randomly presented. Naming responses to these chips in the baseline trials were differentially reinforced. Correct and incorrect naming responses were followed by different feedback sounds. A piece of apple or a raisin was automatically delivered after two consecutive correct responses. On the other trials, the "probe trials", the to-be-tested colour chips were presented. Naming responses in the probe trials were never differentially reinforced. When Ai made her response, no sounds followed and the next trial began. These probe trials were inserted once every four trials on the average.

The number of trials in a session varied depending on how many test chips were presented within the session. An average session consisted of about 200 trials. The various colour chips including the chips which had never been named previously were exposed successively according to a predetermined random order stored in the computer. The chimpanzee performed the task at the rate of about five to six trials per minute.

3. Experiment 1: Naming Achromatic Colour Chips

Colour classification along the brightness scale of achromatic colours was investigated in the chimpanzee.

Procedure
Nine achromatic colour chips with Munsell values from 1 to 9 were used. In her previous naming experiences of naming 11 colours, "black" was trained for a speciic achromatic colour chip N1/0 in Munsell notation, "grey" was used for chip N5/0, and "white" for chip N9/0. For the test, six chips with intermediate brightness were introduced. Each of nine chips was presented eight times on probe trials inserted among baseline trials for the 11 colours discrimination. For this experiment, the colour chips were 6·4 × 9·2 cm on all trials.

Results
Figure 2 shows the probability of three kinds of naming responses ("black", "grey", and "white") and the mean response latencies to each of the nine achromatic colour chips. Although all 11 colour keys were available, on all but one probe trial, the nine achromatic colour chips were classified into one of the three achromatic categories. In both extreme ends of the brightness scale, naming was consistent and the mean response latencies were less than one second. The standard deviation (S.D.) of the response latencies was also small, indicating that the naming responses were stable. The chips covering the middle

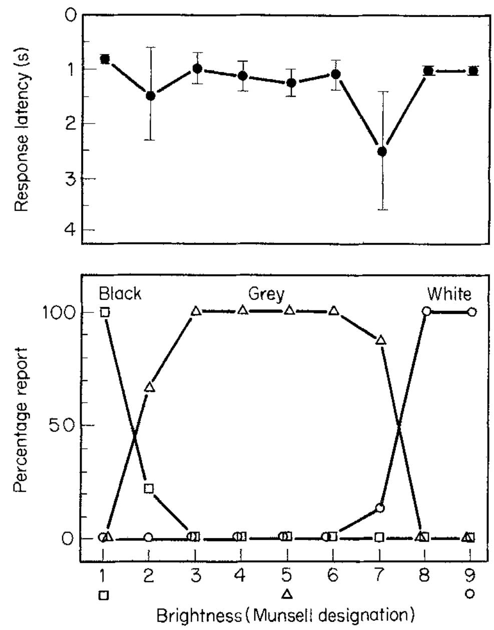

Figure 2. Colour classification along the brightness scale of achromatic colours by a chimpanzee. Proportion of the three achromatic colour names, and the mean response latencies with S.D. for the nine achromatic colour chips are shown.

range of brightness (N3/0, N4/0, N5/0, and N6/0) were also named consistently as "grey" with short response latencies and small SD. Behaviour in the presence of the two chips on the borders between black and grey and between white and grey was markedly different. The chip N2/0 was named as either "black" or "grey". The chip N7/0 was named as either "grey" or "white". The response latencies to these two chips were much longer than those in the other consistently named chips (1·5 s for N2/0 and 2·5 for N7/0 in the mean latencies). The SD of the response latencies was also large. The changes in response latencies suggest that the chimpanzee had difficulty in naming these two chips. These results clearly show that the continuum of brightness was divided into three categories.

4. Experiment 2: Naming Chromatic Colour Chips of 40 Hues

This experiment was designed to investigate the chimpanzee's perception of the various hues forming the so-called colour circle. It was also a first step in the exploration of naming to various parts of the tridimensional colour space.

Procedure

Forty chromatic colour chips representing 40 hues in the Munsell colour system were used. The 40 chips used were at the maximum level of saturation for a given hue. The brightness level of the chips varied from 4/ to 8/ depending on their hues. All chips were 1·7 cm in width and 1·3 cm in height and were attached to the pages of the book. The chips were exposed to the subject by using a grey cardboard mask of Munsell notation N7/0, which revealed only one colour chip at a time. Each of the 40 colour chips appeared once in a daily session in a probe trial. The chimpanzee received 10 sessions in total in this phase of the investigation.

Results

Figure 3 shows the probability of each naming response and the mean response latency for each of the 40 colour chips. Among 400 probe trials in total, there was no trial in which the chimpanzee used the three achromatic colour names or "brown". The chimpanzee pressed the key for either red, orange, yellow, green, blue, purple, and pink although all 11 keys were operative. Again, it was found that each name was used categorically. Twenty-eight out of 40 chips (70%) were consistently named, that is, given the same colour name throughout 10 sessions. The other 12 chips (30%) were consistently assigned the names of the two adjacent categories. The response latencies to these border colours were longer than those to the consistently named colour chips.

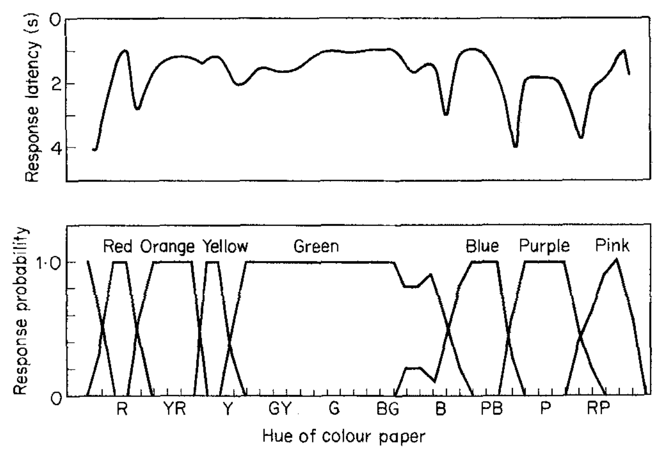

Figure 3. Colour classification of 40 hues forming the so-called colour circle. The horizontal axis represents the hue designation in Munsell notation system. Proportion of each colour name and the mean response latencies are shown.

Figure 4 shows the probability of consistent naming for 40 hues across 10 sessions. As testing progressed and the same stimuli were presented repeatedly, the probability of consistent naming decreased at first then remained constant. This result indicates that presenting each stimulus three times is necessary and sufficient for testing the consistency of naming for each colour chip.

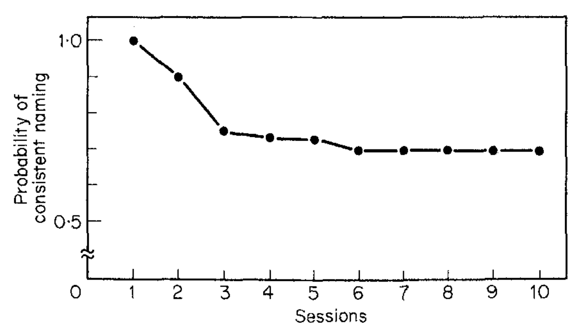

Figure 4. The probability of consistent naming for 40 colour chips with various hues across 10 test sessions.

5. Experiment 3: Naming Chips of Maximum Saturation for a Given Hue and Brightness Value

The purpose of the experiment was to gather more detailed information about colour naming and classification of both various hues and various brightnesses. A second purpose was to obtain comparative data on colour classification by the chimpanzee and the human under the same condition.

Procedure

The chimpanzee was required to name 215 colour chips of maximum saturation for a given hue and brightness value. There were 40 hues and seven brightness levels (Munsell values from 3/ to 9/. These chips are contained in the "outer shell" of the Munsell colour solid. In the Munsell colour system, all achromatic colours lie along the central vertical axis of the colour solid and are arranged by increasing brightness. Colours of various hues and brightness but of maximum saturation define the outer shell of the colour solid, that is, these colours are most distant from the achromatic core. The size of the chips was the same as that in Experiment 2. Each of 215 chips appeared once in the predetermined random order in the probe trials during six consecutive sessions. The sessions continued until each of the 215 chips had been shown three times for a total of 645 naming responses. It took 18 sessions, about 40 minutes per session on the average, to complete this experiment.

The human observer, a 26-year-old male graduate student, was tested under the same conditions except that he received a single test session consisting of the probe trials only. For the human subject, Kanji characters representing the colour names were drawn on the keys instead of the figure symbols.

Results

Throughout the experiments, the chimpanzee accurately named the 11 training colour chips during the baseline trials. Accuracy always exceeded 99·5%. Figure 5 shows the chimpanzee's responses to the outer-shell colour chips. Areas where the chips were called by a single colour name all three times are unshaded and are referred to as consistent areas. Areas where a chip was called by more than a single colour name are shaded and are referred to as border areas. In almost all cases, two responses competed on border areas as possible names for a given colour chip, and these were the names for adjacent categories.

The chips of Ai's training colours are dotted in Figure 5. It must be noted that these chips do not always lie in the centre of the consistent areas for that hue name. Findings such as this as well as the latency data suggest that Ai's colour-naming responses were not the result of simple generalization. In describing a given colour chip the data suggest that she used the colour names categorically.

Both Ai and the human observer divided the colour space into eight clusters with a broad area within which a single colour name was applied consistently. The chimpanzee applied a single colour name to 74% of 215 chips; the human subject applied the same name to 79% of the chips. Areas of consistent colour naming were separated by narrower areas in which the names applied to the two adjacent areas were used. There were slight differences between the human and the chimpanzee in the location of these border areas.

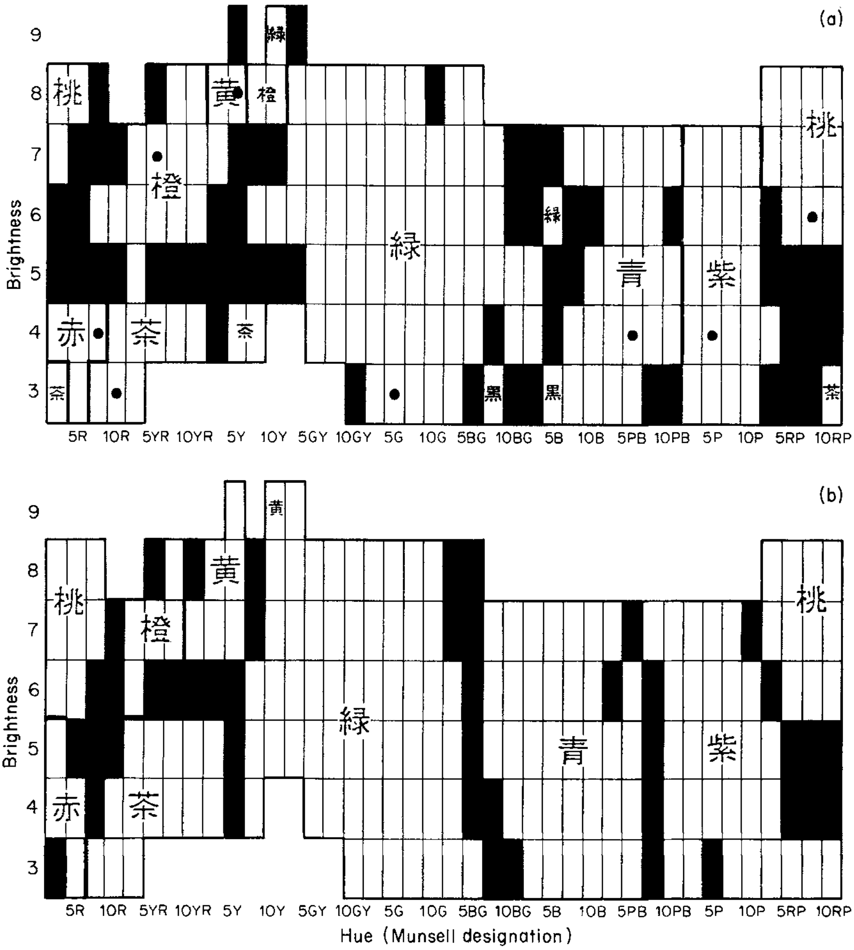

Figure 5. Colour naming of the chips of maximum saturation for a given hue and brightness value. Hue changes are shown along the horizontal axis and brightness on the vertical axis. Rectangles represent individual colour chips. Solid circles indicate the training colours. (a) Data obtained from the chimpanzee. (b) Data from a human observer under the same conditions.

6. General Discussion

The chimpanzee named the various portions of the Munsell colour space as consistently as the human observer did under the same conditions. The colour classification data obtained here undoubtedly are a function of the chimpanzee's physiology and her previous experience in the use of colour names. It is difficult to separate the relative importance of these factors in a single subject. Further work is necessary in order to determine how colour naming is affected as the number of colour names are increased, decreased, or restricted. The division of the colour space into areas may also be influenced by the colours used as examples for a each name.

Berlin & Kay (1969) found constraints in human colour perception which are reflected in the verbal colour classifications employed in various languages. Native speakers of twenty languages around the world (which included Arabic, Bulgarian, Cantonese, Catalan, Hebrew, Ibidio, Japanese, Thai, Tzeltal, Urdu, and others) were shown arrays of colour chips in the Munsell system. They were asked to point out the chip well representing each of the principal colour names of their language within the hue-brightness array. The results given in Figure 6 show clearly that the colour names employed by twenty languages from all over the world are grouped into mostly discrete clusters.

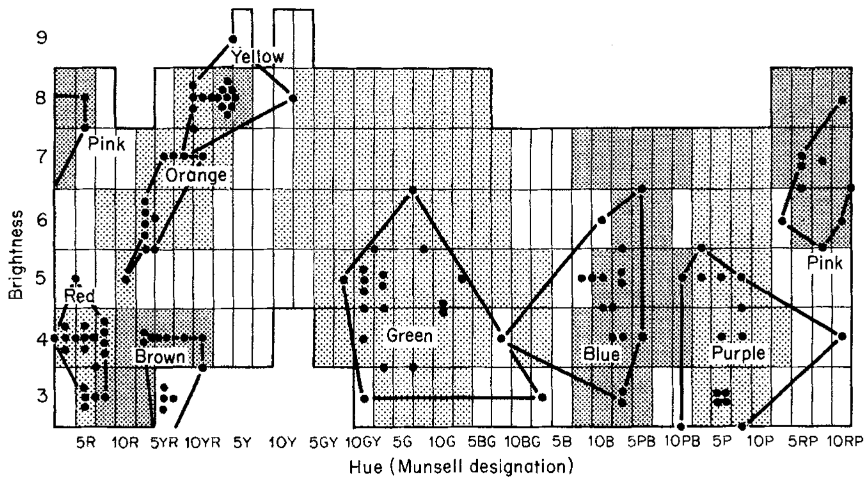

Figure 6. Cross-cultural data of colour classification in human languages are related to the consistent colour naming areas in the chimpanzee. Each point marks the average position on a Munsell hue-brightness array of a principal colour name in one language, as estimated by native speakers of the language. The colour names of 20 languages, many of which evolved independently of one another, are grouped into mostly discrete clusters. The shaded areas represent the consistent areas in colour naming in the chimpanzee. The other explanations are the same as in Figure 5. (Modified from Berlin & Kay, 1969, by the addition of the data of the chimpanzee.)

The consistent areas in colour naming by the chimpanzee were shaded also in Figure 6. It is obvious that the focal points of the principal colour names used by various languages are almost always included within the consistent naming areas in the chimpanzee. In other words, the colours for which the chimpanzee did not use a single name were not used as the focal points for principal colour names used by humans. These results suggest that there is a common basis of colour classification not only across human cultures but also across primate family lines, Hominidae and Pongidae.

These experiments suggest that chimpanzees have sufficient cognitive abilities to use arbitrary codes as colour names, and that they are capable of describing the perceptual world by using these codes. It is further suggested that the chimpanzee and the human recognize their world in similar ways by categorizing some of the features.

Use of colour names in addition to object and number names is reported elsewhere (Matsuzawa, 1985). The author gratefully acknowledges the helpful discussions and support of Drs Kiyoko Murofushi and Toshio Asano. I also thank Dr Sheila Chase for suggesting improvements to the original manuscript and Mr Junzo Inagaki for taking care of Ai. This research was supported by a grant-in-aid from the Ministry of Education, Science and Culture, Japan (240008, 56710041, 57710047, 58710059).

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