Ann.Bull.RILP(1985)No.19, 301-314

RECOVERY PROCESSES OF COLOR NAMING DEFECTS IN PURE ALEXIA

--LONGITUDINAL EXPERIMENTAL STUDY--

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INTRODUCTION

Studies of color naming defects due to damage of the cerebral cortex have been reported extensively. Although the clinical manifestation of color naming defects may be almost identical, intricate testing procedures have proved the existence of at least three different kinds of color naming defects (Meadows, 1974). These three kinds of defects are (1) color naming defects associated with pure alexia, a modality specific disorder; (2)color naming defects accompanying aphasia (color anomia), not a modality specific disorder; and (3)color naming defects caused by cerebral achromatopsia, a perceptual problem. The present study focuses on the first type of color naming defects associated with pure alexia.

The neuropathological mechanism underlying pure alexia has been explained in terms of visual-speech disconnection by Geschwind and Fusillow (1966). They base their explanation on their postmortem confirmation of an infarction of the left calcarine cortex and the splenium of a patient, where the lesion destroyed the connective fibers of the splenium which carry the corosal fibers of the visual cortex. Thus, both right visual cortex and speech areas in the left hemisphere were intact but disconnected. They apply this explanation to color naming defects of pure alexia; i.e., a patient can perceive a color in the right visual cortex but cannot connect the visual information about the color with its corresponding verbal code. The significance of damage to the splenium is the disconnection of visual information received in the right visual cortex from speech areas in left hemisphere. Thus, pure alexia can occur as long as the connective fibers passing through the splenium are disconnected by a lesion at any point between the right visual cortex and the speech area in the left hemisphere. Accordingly, damage to the splenium per se is not a necessary condition of pure alexia (Benson and Geschwind, 1969).

Our previous study (Fukuzawa, et al. 1984) indicated that there are at least two different kinds of color naming defects in case of pure alexia. The first type of pure alexic case shows neither perceptual problems concerning color nor disturbances in the concept of color. This disorder can be clearly explained by visual-speech disconnection where a patient simply cannot name a

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given color though he can normally perceive it. The second type of pure alexic case also does not show perceptual problems but shows some pathological evidence concerning the concept of color. Color naming defects of this type possibly involve higher neurological disorders in color processing coupled with visual-speech disconnection. In the present study, we follow the recovery processes of color naming defects in the first type of pure alexia with particular reference to the structural alternation of internal representation of colors. We followed this particular type of pure alexia for two reasons. First, the availability of the case, referred to hereafter as M.S., has allowed us to examine the mechanisms underlying her disorder. Second, M.S. has shown considerable recovery in reading through therapy in the past two years making it quite reasonable to assume that she has also partially recovered her ability to process color information.

In our previous study (Fukuzawa et. al.,1984), M.S. performed three different kinds of tasks concerning color information processing. These tasks were (1) the structure of internal representations (Note 1) of color using similarity judgment of color (2) categorical judgment of colors using two-alternative-forced choices and (3) classification of colors using color sorting. The results of M.S. 's performance on the second and third tasks fell within the normal range. However, some impairment was observed in the results from the first task; i.e. The structure of the solution of M.S. 's internal representation of color differed from that of the normal control. M.S.'s reading ability has reportedly shown considerable improvement through therapy since M.S. performed these three tasks in 1983. Thus if some improvement in color processing has occured over the same period along with reading improvement, it should be reflected in the structural alternations in the internal representations of color. This does not necessarily imply any changes in the underlying neuropathological mechanism of M.S.; i.e. M.S.'s alexia can still be explained by visual-speech disconnection. The purpose of the present study is to repeat the identical task (similarity judgment of colors) which M.S. performed in 1983 after an interval of approximately two years in order to examine whether M.S.'s structure of internal representation of color has changed with the lapse of time.

SUBJECTS

The subject (M.S.) is a 55 years old, right-handed woman with pure alexia, case I in our previous study (Fukuzawa, et al. 1984). She had right homonymous hemianopia after the evacuation of a subdural hematoma. A CT scan revealed a low density area at the junction of the left parieto-occipital regions. However, no lesions in the medial portion of the occipital lobe were confirmed (Figure 1). M.S. has been receiving reading therapy since 1983 but has never received any therapy concerning her color naming defects.

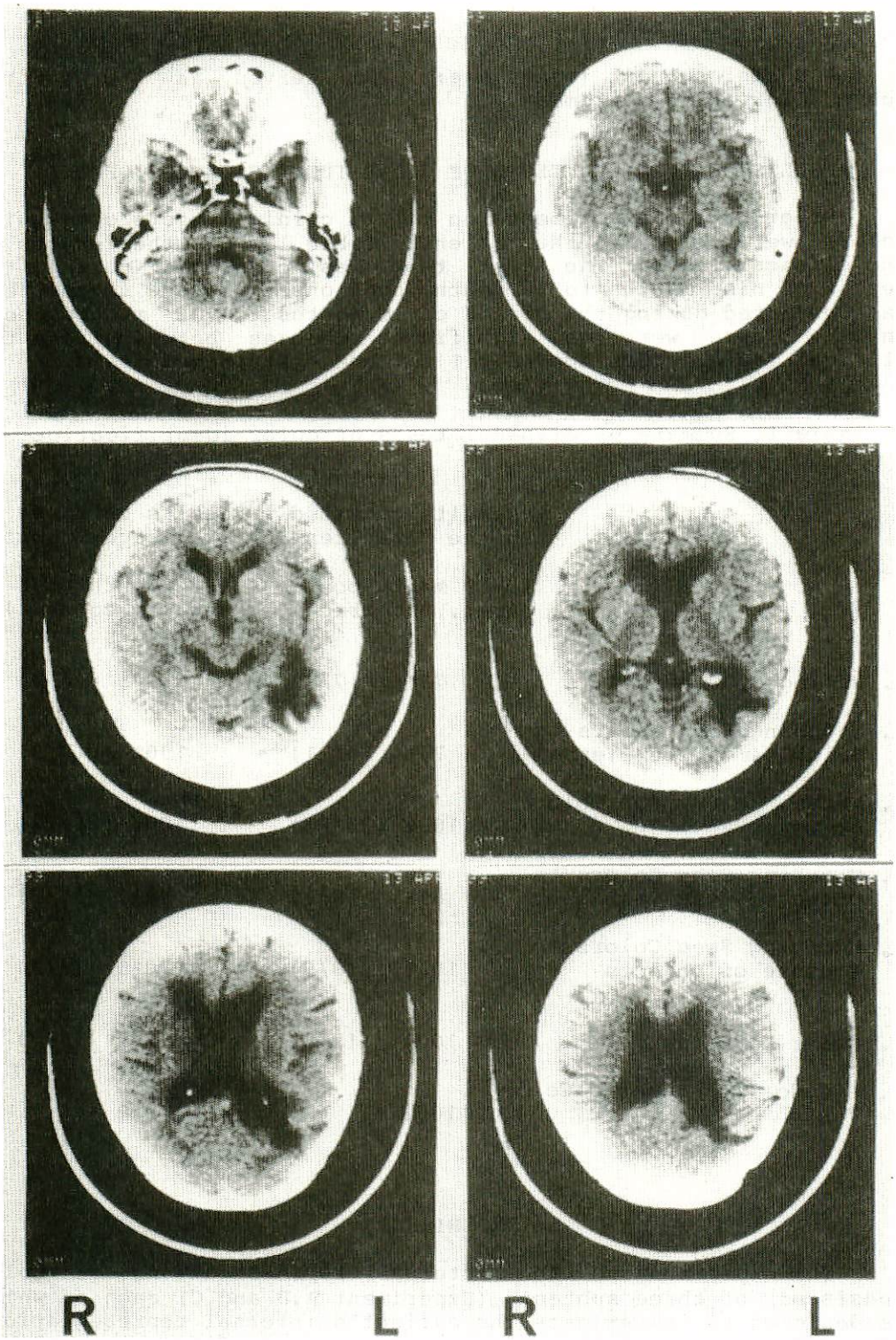

Figure 1 CT Scan of M.S.

A normal subject (male, age: 29) served as the control subject for this experiment.

RESULTS OF CLINICAL TESTS OF COLOR IDENTIFICATION OF M.S.

Prior to the experiments on color, clinical tests concerning colors were given to the patient. Table 1 shows the results of the clinical tests. The first test was conducted during the period of nine months to 10 months post onset and the second test was conducted during the period of 31 months to 32 months post onset. There were no significant changes between these two clinical tests. (See Appendix I for the test procedures)

Table 1 Summary of clinical tests of color identification

	Results obtained in the first test (9-10 month post onset. % correct)		Results obtained in the second test (31-32 month post onset. % correct)	
1. Naming of Seen Colors	78%	(7/9)	89%	(8/9)
2. Matching Seen Colors to Color Name Given Verbally	76%	(16/21)	100%	(9/9)
3. Verbal Memory for Color of Objects	100%	(25/25)	100%	(25/25)
4. Matching Seen Colors to Objects Given Verbally	89%	(8/9)	89%	(8/9)
5. Matching Seen Colors to Picture of Objects	100%	(9/9)	90%	(8/9)
6. Color-Matching	100%	(9/9)	100%	(9/9)
7. Pseudo-Isochromatic-Color Test	100%		100%	

EXPERIMENT

The experiment on the internal representations of color consisted of three subtests (Experiment A,B and C) each of which is designed to investigate the patient's internal representations of color by similarity judgments of different colors. M.S. performed the identical experiments twice at two different

times; the first experiment was conducted during the period of nine to 10 months post onset and the second experiment was conducted during the period of 31 to 32 months post onset. The normal subject performed the experiment once.

TEST MATERIALS

Test materials used were: (A) Nine colored sheets of paper [red(R), yellowish red(YR), yellow(Y), greenish yellow(GY), green(G), blue(B), purplish blue(PB), purple(P) and reddish purple(RP)] selected from the "Harmonic 166 Colored Cards" developed by the Japan Color Research Institute (See Appendix II for more detailed information concerning the physical parameters of these colors.), (B) Nine color names which correspond to the nine colored sheets of paper and (C) Nine line drawings of objects (apple, persimmon, banana, lawn, spinach, sea, eggplant, iris and sweet potatoe) whose intrinsic colors matched the nine colored sheets of paper.

PROCEDURES

Experiment A: Perceptual Color Condition (PC Condition)

The task in Experiment I-A used directly perceived color,i.e., color chips, as stimuli, thus this experiment is referred to hereafter as the perceptual color condition (PC Condition). Three colored sheets of paper randomly selected from the nine colors (a total of 84 triads) were presented to the subjects in triadic fashion as shown in the example in Figure 2. The subjects were asked to choose the one pair of colors which they judged to be the most similar of the three pairs (red vs. yellowish red, red vs. green and yellowish red vs. green in the case of the example in Figure 2). The two colors chosen by the subjects in each triadic comparison were recorded.

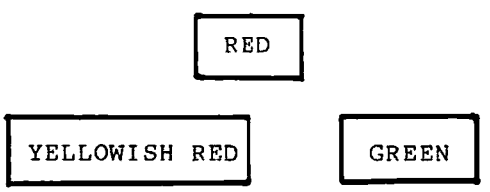

Figure 2 An Example of Triadic Comparison of the PC Condition

Experiment B:Color Memory Condition (CM Condition)

The task in Experiment I-B used the names of colors as stimuli to recall the color images, thus this experiment is referred to hereafter as the color memory condition (CM Condition). The experimenter read three names of colors, one word per second, randomly selected out of nine color names (a total of 84 trials) to the subjects. They were required to recall the images of these three colors and choose the two color images which they judged to be the most similar. The two color images chosen by the subjects were recorded.

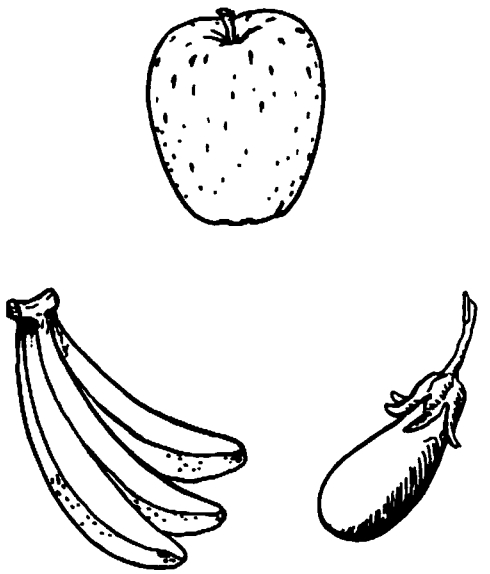

Figure 3 An Example of Triadic Comparison of the LD Condition

Experiment C·Line Drawing Condition (LD Condition)

The task in Experiment I-C used line drawings of objects as stimuli to prompt recall their intrinsic color image. Therefore this experiment is referred to hereafter as the line drawing condition (LD Condition). In order to confirm the subjects' subjective image of the intrinsic color of the objects, they were required to match the colors with the line drawings prior to Experiment I-C. Line drawings whose intrinsic colors were not identified were not used in this experiment. Three line drawings randomly selected out of nine drawings (a total of 84 trials) were presented to the subjects. They were required to recall the intrinsic colors of these objects in order to choose the two intrinsic colors which they judged to be the most similar. An example of a triadic comparison from the LD condition is shown in Figure 3. The two objects chosen at each triadic comparison were recorded. In Experiments A to C, each triadic comparison task was repeated twice in order to obtain more reliable data.

ANALYSIS OF RESULTS

The subjects' responses to the three color similarity judgment tasks were analyzed in terms of the frequencies with which the subjects chose a particular color pair as more similar than the other pairs. These frequencies were converted into

similarity matrices and analyzed using nonmetric multidimensional scaling (MDSCAL). The two or three dimensional solutions were obtained using MDSCAL for each experimental task separately.

RESULTS AND DISCUSSION

As pointed out earlier, the results of the clinical tests conducted at two different periods (during nine months to 10 months post onset and during 31 months and 32 months post onset) were basically the same (Table 1). Therefore, as far as the results of clinical tests are concerned, there was no evidence of improvement in color naming defects.

Figures 4 and 5 show the previous results of the normal subject and M.S. reported in our preceding study (Fukuzawa et. al., 1984). As Figure 4 shows, the results of the normal subject's performance on the three tasks were resolved in two dimensions. The solutions corresponded with Munsell's Color

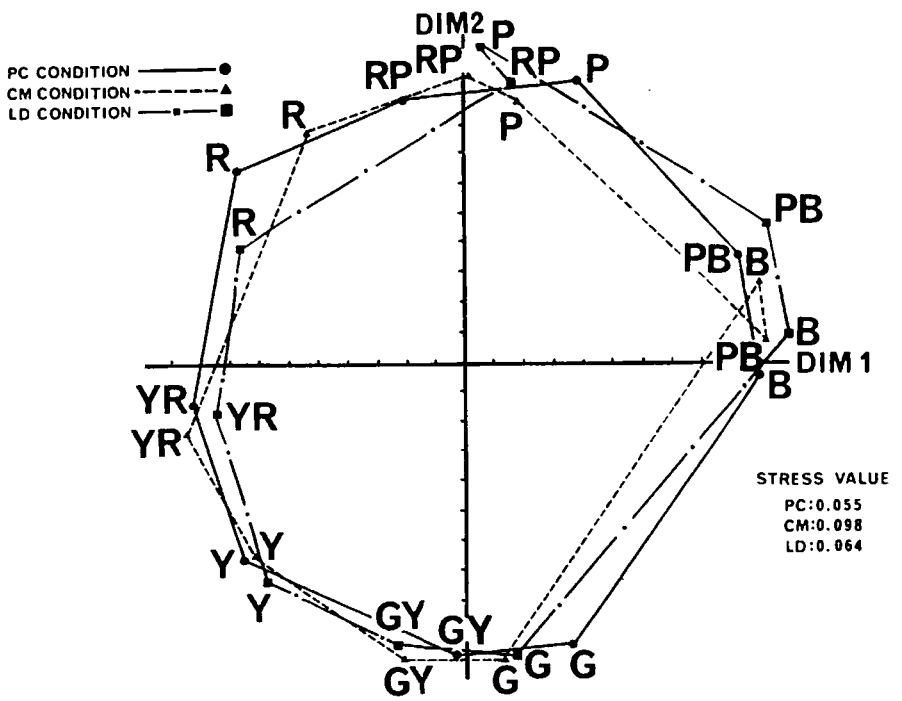

Figure 4 Two Dimensional Solutions of the Colors and Stress Values under the Three Condition (Normal Subject, K.H.)

Circle. Furthermore, the same colors in the three different conditions were plotted in basically the same areas in two dimensional space. These results indicate the existence of a functionally isomorphic correspondence between perceptual colors and their internal representations. Therefore, the criteria the normal subject used in his similarity judgment of perceived colors correspond to the criteria utilized in the similarity judgments of the internal representation of colors.

Judging from the similarity matrices of M.S., the colors considered to be unstable in processing were omitted from the analysis. These colors were greenish yellow (GY) and purplish blue (PB). These colors are often times unstable in processing not only for individuals with some kinds of neuropathology but in normal individuals. Figure 5 shows the MDSCAL solution and the stress value obtained for M.S. during the period of nine to ten months post onset. The solutions of the PC condition (top) are identical to Munsell's Color Circle although the color circle was expressed three dimensionally. The same correspondence was also confirmed in the solutions of the CM condition(middle) and the LD condition (bottom). Note that the color orders in the first and second trials of the LD condition are the mirror image of each other, leaving the circular structure unchanged.

This correspondence suggests that the criteria M.S. used in similarity judgments in the PC condition were functionally similar to those used in the other two conditions. Therefore, the relations among the directly perceived colors (PC condition) and the relations among the internal representations of colors (the CM condition and the LD condition) can be said to have remained intact in M.S.. Moreover, it is quite possible to assume that a functional and structural correspondence exists among these three color representations. From these observations, it is clear that the case retained normal representations of directly perceived colors as well as the internal representations of colors. Therefore, a second-order isomorphic relation between these two representations exists in M.S..

The performance of similarity judgment tasks of colors in normal subjects is expressed two dimensionally since colors are usually perceived in terms of hue alone (Masui 1977). On the other hand, as Figure 5 shows, the solutions of M.S. resulted in three dimensions. Therefore M.S. must have used some other physical parameter in addition to "hue" in the similarity judgment tasks. Since the color stimuli used in the PC condition are all pure colors whose saturation (chroma) are all the highest, saturation cannot be used to distinguish different colors. The "lightness" of the color is a logical choice as a cue in this case and also in the other two similarity judgment tasks. Thus, dimension 3 in Figure 5 is interpreted as "lightness".

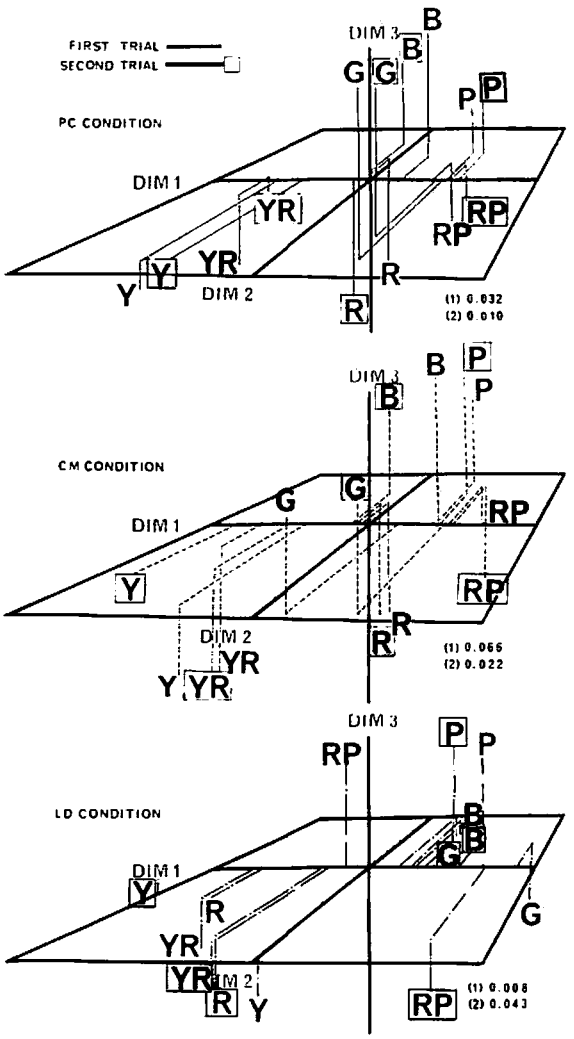

Figure 5 Three Dimensional Solutions of the Colors and Stress Values under Three Conditions obtained during the period of nine to 10 months post onset (M.S.)

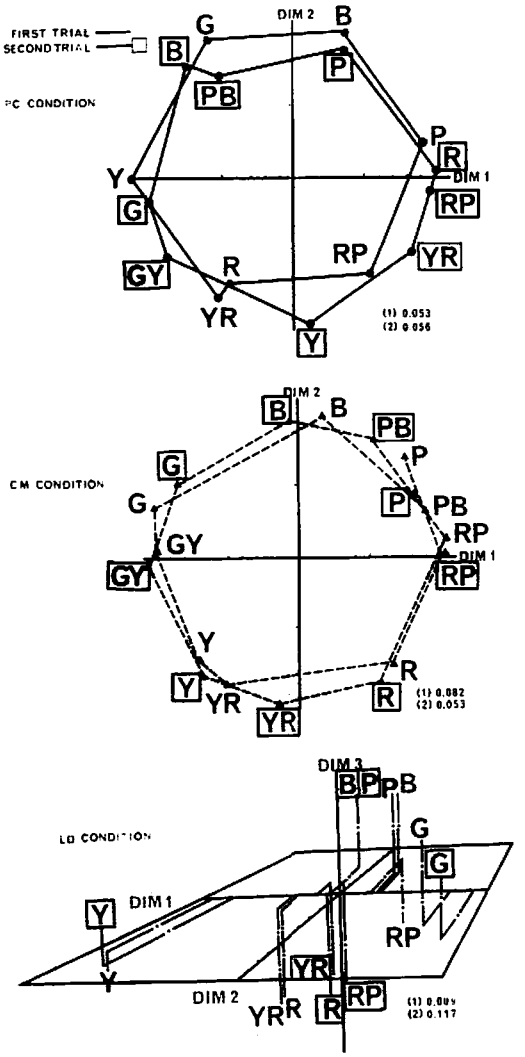

Figure 6 Two and Three Dimensional Solutions of the Colors and Stress Values under Three Conditions obtained during the period of 31 months to 32 months post onset (M.S.)

This dimensional difference between M.S. and the normal subject is not critical here. In looking at whether or not the structure of internal representation of colors is intact and to confirm the "second-order" isomorphism, the most important factor is whether or not the solutions matched Munsell's Color Circle. However, it should be mentioned that the utilization of "lightness" cue in similarity judgment task is considered as an impairment of color processing of some sort, because it is known that a case of achromatopsia also used the same cue in the same task (Masui, 1977). Although the neurophysiological reasons for the utilization of "lightness" as a cue in case of achromatopsia and pure alexia are not known, the underlying pathological mechanism in each case should be different because the color processing disorder in pure alexia is an acquired disorder while the disorder of achromatopsia is congenital.

The MDSCAL solution and the stress value obtained during the period of 31 to 32 months post onset are shown in Figure 6. Judging from the similarity matrices of M.S., the colors considered to be unstable were omitted from the analysis. These colors were greenish yellow (GY) and purplish blue (PB) in the first trial of the PC condition and both the first and second trials of the LD condition. The solutions of the second trial in the PC condition and both the first and second trials in the CM condition showed a circular structure with all nine colors. Compared with the solution obtained during the period of nine to 10 months post onset (Figure 5), the solutions of the second trial in the PC condition and both the first and second trials in the CM condition obtained during the period of 31 to 32 months post onset (Figure 6) included greater number of colors. However, this difference is not strong enough evidence to prove M.S.'s improvement in color information processing. This kind of difference could occur due to very subtle errors in the task of similarity judgment of color. Therefore, this difference should be interpreted as a reflection of random error.

As Figure 6 shows, the two dimensional solutions for the PC and the CM conditions clearly correspond to Munsell's Color Circle except for the spatial relation between purple (P) and purplish blue (PB) in the CM condition. Although the results of the LD condition were not resolved two dimensionally, the solution perfectly correspond to Munsell's Color Circle. Moreover, the circular formation of the solution became much clearer compared with the corresponding results shown in Figure 5. One of the obvious differences between the previous and the latter results is that the dimensional solutions of the latter were basically expressed two dimensionally except for the LD condition while all of the previous results were expressed three dimensionally. This dimensional alternation from three to two indicates that M.S. used "hue" alone in the PC and CM conditions in the second experiment as the solutions to the PC and CM conditions became essentially identical to the normal's. The use of "hue" alone without "lightness" as cue in this task can be interpreted as suggesting that color information processing in M.S. has recovered to some extent. The three dimensional

solution in the LD condition remained the same as in the previous test but some improvement is clearly shown in the better circular formation of the solution compared with the previous one.

The two dimensional solution of the PC condition was somewhat expected, the stimulus colors being most stable and perceived directly in this condition. In other words, if any improvement occured at all, the evidence should first appear in the results of the PC condition. However, it is not easy to speculate why the solutions of the CM condition were best resolved in two dimensions and that of the LD condition remained in three dimensions. Some visual impairment due to right homonymous hemianopia may be related to M.S.'s poorer performance in the LD condition. However, she could perfectly identify the line drawings. Thus the poor performance in the LD condition cannot be attributed to visual defects. M.S.'s therapy may provide a clue to why she performed better in the CM condition than in the LD condition. M.S. often reported that when she could not read a given kanji she was encouraged to verbalize each radical of kanji and visually recombine them together. When each radical of kanji was given verbally, this revisualization process was reportedly facilitated; i.e.. her reading kanji often improved. This is clinically confirmed through the reading therapy she has been receiving in the past two years. Our speculation is that the auditory stimuli (color names were given auditorily in the CM condition) facilitate recall or revisualization of internal representations of color better than visual stimuli (line drawings) in M.S.. Therefore the better facilitation based on the auditory stimuli could be the reason that the dimensional solution of the CM condition was better than that of the LD condition.

In conclusion, the results of the present study showed that some improvement could occur in color naming defects in pure alexia over a period of time without receiving any direct therapy for color naming defects. The results of clinical testing of color identification did not show any significant recovery of color naming defects but the results obtained through more intricate testing procedures indicated apparent recovery. This was shown by the structural alternation of the dimensional solutions of the perceived color stimuli and of the internal representations of color.

Note 1

It is known that analog relations exist between the internal representations (simply an image of something) and their corresponding external stimuli. This idea has been referred to as the "first-order" concept of isomorphism (Shepard and Chipman, 1970). However, this neither implies nor necessitates that the physical dimensions of the external stimuli isomorphically correspond to the physical dimensions of their internal representations. The function exists as long as the physical differences among the external stimuli are reflected among the corresponding internal representations. In its place, Shepard and Chipman (1970) proposed a "second-order" concept of

isomorphism to replace the former idea: "...the isomorphism should be sought -- not in the first-order relation between (a) individual object, and (b) its corresponding internal representation --but in the second-order relation between (a) the relations among alternative external objects and (b) the relations among their corresponding internal representations" (Shepard and Chipman, 1970). In other words, although the internal representation for a triangle itself does not have to be triangle, it should at least be closer to the internal representation of a square than a red apple. This "second-order" concept of isomorphism can be applied not only to analyzable objects such as shapes of things but to non-analyzable entities such as colors.

APPENDIX I

CLINICAL TESTS OF COLOR IDENTIFICATION

The clinical tests used in the present study are as follows:

Naming of Seen Colors

The patients were required to name the color of each sheet of paper presented.

Matching Seen Colors to Color Names Given Verbally

A group of nine colored sheets of paper was presented to the patients and they were asked to select the color named by the experimenter, e.g. "Show me the blue sheet of paper".

Verbal Memory for Colors of Objects

The patients were asked to say the normal color of 25 ordinary objects specified by the examiner, e.g. apples, bananas, sea, etc.

Matching Seen Colors to Objects Given Verbally

A group of colored sheets of paper was presented to the patients and they were asked to select the one colored sheet of paper which matched the color of the object given verbally by the examiner.

Matching Seen Colors to Pictures of Objects

A group of line drawings of objects and colored sheets of paper were presented to the patients. They were required to match the line drawings and their intrinsic colors.

Color-Matching

A set of nine colored sheets of paper were placed on the desk and colored sheets of paper were given to the patients one by one. The patients matched the color of the sheet of paper they were given to one of those on the desk.

Pseudo-Isochromatic Color Test

The patients were given the Ishihara Pseudo Isochromatic test of color vision.

APPENDIX II

Physical parameters of colors used in Experiment A

	Munsell Hue	Munsell Value	Saturation
R	4R	4.50	14.0
YR	4YR	6.50	14.0
Y	5Y	8.00	13.5
GY	4GY	7.00	12.0
G	4G	5.50	10.5
B	10B	4.00	12.0
P	2P	3.50	12.5
PB	6PB	2.40	11.0
RP	6RP	4.00	13.5

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