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An Experimental Study on the Continuous Patterns of the Influence of Color Focality on Short-term Memory Performance of Colors

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Abstract: Past studies have reported that language-specific color focality has substantial influence on short-term memory (STM) performance of colors of the speakers of the language, which we call the “focality effect.” This study attempts to clarify the continuous patterns of this effect, that is, the manner in which correct recognition possibilities and misrecognition error distances of colors, which are two aspects of the STM performance of colors, change in a gradual fashion along the continuum of color focality. Our experiment, which tests the Japanese language, finds that a U-shaped relationship exists between the focality and the possibility of correct recognition, and that the misrecognition error distance increases as the focality decreases. We speculate that the subjects’ frequent and conscious employment of the memorization strategy of coding colors using linguistic color categories is one important cause of the detected effect patterns.

Keywords: Color focality, Short-term memory, Continuous pattern

1. INTRODUCTION

1.1 Basic Concepts and Research Objective

Language provides a means for conceptualizing our color sensations, which vary gradually along the perceptual dimensions of hue, lightness, and saturation [1]. Every language contains a set of basic color terms in its lexicon, such as black, white, red, green, blue, yellow, brown, gray, orange, pink, and purple in the English language [2]. The categories signified by the basic color terms (called “basic color categories” for short), which are natural categories, have their inner structures formed around their prototypes. This means that within a basic color category, the member colors differ in their focality, namely their closeness to the prototype, or, in other words, their goodness as a typical example of the category [3, 4].

In this study, we evaluate the universality of the phenomenon that language-specific color focality influences short-term memory (STM) for colors of the speakers of the language, which we call the focality effect, through a psychological experiment that tests the Japanese language. More important, we attempt to clarify the continuous patterns of this effect if its existence turns out to be supported in our experiment.

Section 2 describes the settings and procedure of the experiment. Section 3 introduces the definitions of the variables involved in the statistical analyses. Section 4 describes the methods and results of the statistical analyses. Section 5 discusses the general significance and a possible cause of the main findings of the experiment.

1.2 The Focality Effects in Past Studies

The focality effect is one of the central topics in the study of how the prototype-based internal structure of natural categories affects mental functions.

The focality effect was first found by Rosch [5] in the English language. In her experiment, Rosch used a simplified version of the color array that was originally developed by Lenneberg and Roberts [6] and later used by Berlin and Kay [2]. The array was composed of 160 Munsell color chips, 24 of which were selected as test chips. Eight of these chips were focal colors, that is, the colors of the highest focality for each of the eight chromatic basic color categories that were shared by numerous languages but generally corresponded to the English categories of red, green, yellow, blue, brown, purple, pink, and orange [7, 8]. The other 16 chips were of lower focality for these categories, and thus were classified as nonfocal colors. The selection and categorization of the test chips were based on the color-naming data gathered by Berlin and Kay [2]. In each trial in Rosch’s experiment, a subject was required to watch a color chip for 5 s and then search for it in the color array after a 30-s interval, where the chip was hidden from the subject. For either stimulus type, two indexes of STM performance were measured. The first index was the “memory accuracy score (MAS),” which was defined as the mean number of correct recognitions for this stimulus type across the subjects. The second index was the “error distance score (EDS),” which measured the mean error distance across the incorrect trials of this stimulus type. The English-speaking subjects showed superior performance for both...
measures of the focal colors relative to the nonfocal ones. Roberson et al. [7] employed the same experimental paradigm and stimuli in their Experiment 2a [Note 1]. Regarding their English-speaking subjects, a focality effect similar to that reported by Rosch was detected in terms of MAS. However, no focality effect was found in terms of EDS. Roberson et al. [8], which also used this experimental paradigm and these stimuli, found that the mean d’ score (a modified version of MAS) of the test chips that were focal only in Himba (a language mainly spoken in northern Namibia) were significantly higher than that of the test chips that were focal only in English. This effect was also detected in the language of Berinmo, which is mainly spoken in Papua New Guinea. The index of EDS was not used in this study.

Overall, these studies have provided some evidence for the universal existence of the focality effect across languages in terms of MAS. On the other hand, no robust focality effect has been observed in terms of EDS. Empirical evidence for more languages is necessary to test whether the focality effect exists for these two STM performance measures. In this study, we used the Japanese language, which has yet to be investigated, as the target language. Furthermore, in these studies, color focality was treated as a categorical variable with only two values: “focal” and “nonfocal.” This precluded any elaborate descriptions of the focality effect. Therefore, in this study, we quantified the concept of color focality in a continuous fashion and delved into the continuous patterns of the focality effect, that is, how STM performance for colors changes gradually along the continuum of color focality.

2. EXPERIMENTAL SETTINGS

2.1 Participants, Materials and Environment

Twenty-two subjects (11 males and 11 females of ages $M = 31.45$ and $SD = 14.34$, all native Japanese speakers with no color-related art experience), who are either undergraduate or graduate students at Waseda University, took part in the experiment. They all passed the Ishihara Color Vision Test (38 plates, International Edition), and no one reported having color vision deficiencies. Hence, these subjects were considered to have normal color vision. Informed consents of participation were obtained from all the subjects.

A color array of Rosch’s [5] design was used. Its layout is shown in Figure 1. This array was made of cardboard (58.5 cm * 28.5 cm), and had color chips embedded in its white surface. Thirty colors (called “test colors” for short) were tested in the formal trials of Session 1. These colors were mounted on the white surface of a 5.0 cm * 5.0 cm piece of cardboard when being presented to the subjects. Chips in the Munsell Book of Color (Glossy Edition) were used. The experiment was performed indoors with fluorescent lighting (type: National FHF 32EX-N-H, daylight color, color temperature: 5000 K, resembling the CIE D50 standard illuminant). Because the experiments in relevant previous studies are conducted in natural daylight or fluorescent light that simulates daylight, the results of our experiment can be compared with the results of those previous experiments.

The experimenter and subject being tested sat opposite each other at a table. The distance between the stimuli and the subject’s eyes was controlled at 50 cm. To separate the two people, a cardboard wall was erected along the middle of the table so the subject would be unable to see the experimenter’s face while observing the stimuli, waiting during the 30-s intervals, and filling out the answer sheets.

2.2 Procedure

The entire experiment, which was carried out in Japanese, consisted of two sessions. Session 1, which used a procedure similar to that used by Rosch [5], aimed to measure the subjects’ STM performance for the test colors. This consisted of 33 trials. In each trial, a test color was presented to the subject for
5 s and then retrieved by the experimenter. After a 30-s interval, the color array was presented to the subject, and the subject was asked to report which color in the array he/she thought was the previously presented one by writing the coordinates of the color on an answer sheet. There was no conversation between the experimenter and the subject. Each test color was tested at least once with each subject, and for each subject, the order of color testing was randomly determined. Thus, for each subject, there were three repeated trials, which were intended to prevent the subject from using a strategy of excluding the already tested colors. Before the formal experiment began, a two-trial training session using a different set of test colors was conducted. For each subject, the colors tested during the training were randomly selected. After all 33 formal trials were completed, a questionnaire was given to the subject. This questionnaire asked the subject to report freely on the strategies that he/she adopted to memorize the test colors during this session.

Session 2 was targeted to elicit the coverage of six basic color categories corresponding to the six Japanese basic color terms akairo (red), pinkuiro (pink), kiirō (yellow), orenjiiro (orange), chairo (brown), and murasakiiro (purple) [9]. Then, the focality of each test color was quantified using a modified version of Berlin and Kay’s [2] method. First, the subject was required to write on six answer sheets (one for each basic color term) all colors that he/she thought could be named by the term. The answer sheets were provided to each subject in random order. Next, the subject was asked to report the colors they thought were the best examples of each of the six basic color terms. This was accomplished by writing the coordinates of the colors on an answer sheet. Multiple answers were allowed for each term, but the subject was instructed to narrow his/her selections as much as possible.

3. VARIABLE DEFINITIONS

3.1 Focality Score

We used the data obtained from Session 2 to specify the coverage of the six basic color categories over the array, and quantified the focality of the test colors. We first computed the six attributes for each test color: Red Index, Pink Index, Yellow Index, Orange Index, Brown Index, and Purple Index. These attributes measured the intersubject naming consistency of the color in terms of each basic color term. The Red Index was defined as the percentage of subjects who named the color as red, and the other five indexes were similarly defined. Then, we designated the Overall Index (OI) of a color as the largest of the six single-term-defined indexes of the color. We classified a color into the color category Akairo (Red) if its OI was its Red Index, the color category Pinkuiro (Pink) if its OI was its Pink Index, and so forth. Figure 2 shows the distribution of the nonzero OIs and the partition of the six basic color categories.

Table 1, which is a summary of the data gathered during the second part of Session 2, gives the proportion that the responses in which the colors having large OIs (designated as those \( \geq 0.80 \)) were selected as best examples account

<table>
<thead>
<tr>
<th>Basic Color Category</th>
<th>Percentage of High-OI Responses</th>
<th>Basic Color Category</th>
<th>Percentage of High-OI Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akairo</td>
<td>100%</td>
<td>Orenjiiro</td>
<td>100%</td>
</tr>
<tr>
<td>Pinkuiro</td>
<td>83%</td>
<td>Chairo</td>
<td>81%</td>
</tr>
<tr>
<td>Kiirō</td>
<td>100%</td>
<td>Murasakiiro</td>
<td>75%</td>
</tr>
</tbody>
</table>

Figure 2: Distribution of OIs of test colors (colors within area covered by thin diagonal stripes) and other relevant colors, and partition of the six basic color categories. Color depth represents OI magnitude (the color with the asterisk (*)). Orange Index = Brown Index.
for relative to total responses, in terms of each basic color category. This table shows that, in each category, nearly all the colors that the subjects selected as best examples were the high-OI colors. Thus, it is reasonable to deem the OI of a color as reflecting the appropriateness of the color as a typical example of the category to which the color belongs. In this manner, we defined the focality score (FS) of a color as its OI value [Note 2].

3.2 Discriminability Score

We defined the discriminability score (DS) of a test color on the color array as the average of the color differences between the test color and its eight adjacent colors. In this study, a color difference was defined as a Euclidean distance in the CIE L*a*b* color space. Thus, before calculating color differences, we transformed the Munsell coordinates of all relevant colors into the CIE xyY coordinates using the O.S.A.-developed conversion tables [10], then the XYZ coordinates, and finally the L*a*b* coordinates. The distribution of the DSs of the test colors is displayed in Figure 3.

3.3 Two Indexes of STM Performance

Memory Accuracy Score. We adopted MAS as one index of STM performance. It measures the probability with which a color can be accurately recognized. Since FS is continuous in our study, it is necessary to take MAS also as continuous. We defined the MAS of a test color as the percentage of the trials in which the subjects correctly recognized the color.

Error Distance Score. The EDS is adopted as another index of STM performance. EDS measures the expected error extent in the case of misrecognition. As in Rosch’s [5] and Roberson et al.’s [7] studies, the EDS for a test color is defined as the mean of the color differences between the test color and the colors mistaken for the test color in the incorrect recognition trials.

4. STATISTICAL ANALYSIS AND RESULTS

4.1 Relationship Between Color Focality and Correct Recognition Possibilities of Colors

To know the continuous pattern of the relationship between color focality and correct recognition possibilities of colors, we first conducted regression analyses on the FS data and the original MAS data of the test colors to obtain a general impression of the relationship pattern, and then we examined whether the subjects’ guessing behavior distorted this pattern, and finally we performed refined regressions on the FS data and the MAS data with the influence of the “discriminability effect”, which was another possible confounding factor, controlled.

The initial regressions, which were carried out on the FS data and the original MAS data, show no statistically significant linear relationship between FS and MAS ($R^2 = 0.066$, $P = 0.171$ [$B_{FS} = 0.152$, $P = 0.171$]), but they do show a significant quadratic relationship between the two variables ($R^2 = 0.237$, $P = 0.026$ [$B_{FS} = -1.064$, $P = 0.045$; $B_{FS*FS} = 1.073$, $P = 0.021$]; plotted in Figure 4(A)). We chose to use quadratic regression besides linear regression because we tried polynomial regressions from second to sixth order and found that the quadratic one had the smallest Bayesian information criterion (BIC) value.

However, there exists the possibility that the quadratic pattern came from a tendency of the subjects to select the color with the highest or lowest degree of focality when they felt unsure about which color was the right answer within a group of candidates. We call this possibility the “guessing hypothesis.” To check this hypothesis, not only the hits, which were measured by MAS, should be considered but also the false alarms. We defined the false-alarm rate (FAR) for a test color as the number of the trials in which the test color was erroneously selected divided by the number of the trials in which the test color was not the actual presented one. Similar to Rosch’s [5]

![Figure 3](image-url) Distribution of DSs of test colors. Color depth represents DS magnitude.
method, we looked into the relationship between FS and FAR for the test colors. The result of the quadratic regression analysis, which is plotted in Figure 4 (B), failed to achieve statistical significance ($R^2 = 0.068$, $P = 0.386$ [$B_{FS} = 0.030$, $P = 0.245$; $B_{FS^2FS} = -0.022$, $P = 0.318$]). This implies that the colors with the highest or lowest focality were no more likely than the medium-focality colors to be selected when the subjects were guessing. Thus, the guessing hypothesis was ruled out.

Brown and Lenneberg [11] found that color discriminability could facilitate STM performance for colors, which we call the “discriminability effect.” Later, Rosch [5] and Lucy and Shweder [12] pointed out that because the colors in the color array were unequal in discriminability, it was possible that it was color discriminability, not color focality, that caused the detected variance in STM performance for colors. We checked this possibility of data distortion using the following procedure. First, we looked into the relationship between DS and MAS. A significant positive linear regression model could be established between these two variables ($R^2 = 0.353$, $P = 0.001$ [$B_{DS} = 0.024$, $P = 0.001$]; plotted in Figure 4 (C)). The guessing hypothesis was tested using the same method as in the case of FS. No significant linear relationship was found between DS and FAR ($R^2 = 0.042$, $P = 0.275$ [$B_{DS} < 0.001$, $P = 0.276$]; plotted in Figure 4 (D)), which indicated that the linear model established between DS and MAS was not an artifact caused by the subjects’ biases in guessing. Then, the regression analyses studying the relationship between FS and DS were conducted.

![Figure 4](image_url)
producing neither a significant linear model ($R^2 = 0.014$, $P = 0.534$; $B_{FS} = 1.710$, $P = 0.534$) nor a significant quadratic model ($R^2 = 0.029$, $P = 0.675$ [$B_{FS} = -7.032$, $P = 0.527$]). Nevertheless, we noticed that a slight U-shaped relationship could be recognized in the scatter plot (Figure 4(E)). This means that the possibility that DS mediated the FS-to-MAS relationship still exists.

Hence, we conducted partial linear and quadratic regressions on FS and MAS while partialing out the influence of DS on MAS. No significant linear relationship was found ($R^2 = 0.054$, $P = 0.217$ [$B_{FS} = 0.111$, $P = 0.217$]), but a significant quadratic one was detected ($R^2 = 0.233$, $P = 0.028$ [$B_{FS} = -0.893$, $P = 0.037$; $B_{FS*FS} = 0.885$, $P = 0.018$]), which was similar to the results of the initial regressions. This means that a significant quadratic relationship exists between FS and MAS even if DS has been treated as a control variable. The results are plotted in Figure 4(F).

In summary, a significant quadratic relationship between FS and MAS showed up even when the impact of DS was controlled. In addition, no significant linear or quadratic relationship could be found between FS and FAR, which falsified the guessing hypothesis.

4.2 Relationship Between Color Focality and Misrecognition Error Distances of Colors

The continuous pattern of the relationship between color focality and misrecognition error distances of colors was investigated in the following manner. The first step was to obtain a preliminary understanding of what the relationship pattern looks like by carrying out linear and quadratic regressions on the FS data and the original EDS data. Then, these regressions were repeated but with the impact of DS controlled to remove the possible distorting influence of the discriminability effect.

The initial regressions, which were run on the FS data and the original EDS, produced no significant linear model ($R^2 = 0.110$, $P = 0.084$ [$B_{FS} = -4.694$, $P = 0.084$]), but did produce a significant quadratic one ($R^2 = 0.250$, $P = 0.027$ [$B_{FS} = -30.113$, $P = 0.019$; $B_{FS*FS} = 22.376$, $P = 0.041$]). The results are plotted in Figure 5(A). We chose to use quadratic regression besides linear regression because we tried polynomial regressions from second to sixth order and found that the quadratic one had the smallest BIC value.

Then, a positive linear relationship was found between DS and EDS through a regression analysis ($R^2 = 0.299$, $P = 0.041$).
P = 0.003 [B_{DS} = 0.692, P = 0.003]; plotted in Figure 5(B)). To remove the possible distorting influence of the discriminability effect (as in the case of MAS), we partialed out the influence of DS on EDS and ran linear and quadratic regressions on the FS data and the refined EDS data. A significant quadratic model showed up (R^2 = 0.221, P = 0.044 [B_{FS} = -22.166, P = 0.041; B_{FS*FS} = 15.895, P = 0.085]), but not a significant linear one (R^2 = 0.121, P = 0.070 [B_{FS} = -4.110, P = 0.070]), which resembles the results of the initial regressions. The results are plotted in Figure 5(C).

Nevertheless, there exists a test color that appears to be isolated from the cluster of other high-FS test colors at the EDS coordinates. Owing to the employment of the least squares method, this data point could have exerted a disproportionately strong influence on the relationship pattern. To determine what pattern the relationship actually takes in the general case, we reran the regressions on the corrected dataset but did not include this data point. This time we obtained a linear relationship (R^2 = 0.236, P = 0.010 [B_{FS} = -5.669, P = 0.010]; plotted in Figure 5(D)) instead of a quadratic one. (When adding FS*FS to the regression as a predictive variable, neither B_{FS} nor B_{FS*FS} achieved significance, although the model remained significant). Because this linear regression model is free from the effects of extreme data and therefore represents the general-case relationship between the FS and the corrected EDS, the discussions on FS-EDS relationship in Section 5 are based on this model.

In summary, with the EDS data corrected by eliminating the confounding influence of DS, a statistically significant negative linear tendency appears between FS and EDS under the general circumstance.

### 4.3 Memorization Strategies

In the questionnaire conducted at the end of Session 1, the subjects reported a total of six memorization strategies. For each strategy, Table 2 offers a brief description and shows how many subjects reported it.

<table>
<thead>
<tr>
<th>Name</th>
<th>Number of Reports</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linguistic categorical coding</td>
<td>16</td>
<td>Use basic color concepts as reference points, and then fine-tune along the dimensions of hue, lightness, and/or saturation</td>
</tr>
<tr>
<td>Absent object association</td>
<td>14</td>
<td>Associate the test color with the color of a familiar object in memory, e.g., the banner of Waseda University, a Bordeaux wine, or lipstick, and then fine-tune along the dimensions of hue, lightness, and/or saturation</td>
</tr>
<tr>
<td>Direct retention of visual image</td>
<td>3</td>
<td>Directly memorize the visual image of the test color</td>
</tr>
<tr>
<td>Preference evaluation</td>
<td>2</td>
<td>Use the degree of preference for the test color as a cue</td>
</tr>
<tr>
<td>Present object association</td>
<td>1</td>
<td>Use the color of an object located in the experimental environment, e.g., an answer sheet, as a reference point, and then fine-tune along the dimensions of hue, lightness, and/or saturation</td>
</tr>
<tr>
<td>Reference on past test colors</td>
<td>1</td>
<td>Use a previously presented test color as a reference point, and then fine-tune along the dimensions of hue, lightness, and/or saturation</td>
</tr>
</tbody>
</table>

With regard to the continuous patterns of the focality effect, a significant U-shaped quadratic regression function can be established between FS and MAS, which implies that the STM performance is best for colors at the two terminals of the focality continuum, and decreases as the focality moves toward the intermediate level. In addition, a significant negative linear regression function can be established between FS and EDS under the general circumstance. This suggests that the average error extent in the case of misrecognitions for a color decreases as its focality increases.

Both focality effect patterns were computed with the influence of the corresponding discriminability effect controlled, since our study verified the existence of the discriminability effect in both STM performance measures. Specifically, color discriminability was found to have positive impact on correct recognition possibilities of colors. This tallies well with Brown and Lenneberg’s [11] experimental result, which, like our study, used the physical attributes of color to define color discriminability. We also found that color discriminability had a positive influence on misrecognition error distances of colors. No past study has ever probed the existence of the discriminability effect in terms of misrecognition error distance, despite its importance in “purifying” the detected focality effect pattern.
5.2 Memorization Strategy of Linguistic Categorical Coding as One Cause of the Focality Effect Patterns

5.2.1 How Linguistic Categorical Coding is Applied

To determine what caused the continuous patterns, we examined the memorization strategies reported by the subjects (Table 2). We noticed that the strategy of encoding colors using linguistic color categories (“linguistic categorical coding”), which has the highest number of reports, might have played an important role in the formation of the detected focality effect patterns.

A detailed description of the procedure of this strategy in a single trial is as follows: The subjects consciously encoded the test color using the basic color terms while observing the test color. The basic color terms were used as reference points, which means that the subject anchored the test color to the central points of the basic color categories, namely, the most typical colors of these categories. The subject then retained this linguistic code in his/her STM during the waiting period. Finally, during the phase of color searching, the subject decoded the code to recover the test color.

For convenience of discussion, color focality is generally divided into the levels of “high,” “medium,” and “low,” and their respective ways of being coded are described as follows.

**High-focality colors.** A high-focality color can be encoded using only one basic color term since it is, or is substantially close to, the central point of the basic color category.

**Medium-focality colors.** Coding a medium-focality color needs some modifiers in hue, saturation, and/or lightness besides a basic color term. For example, in the questionnaire, the subjects reported having used the codes “azayakasugiru [very saturate (a modifier in saturation)] orenji [orange (a basic color term)],” “tsui [light (a modifier in lightness)] chairo [brown (a basic color term)],” and “sukoshi kiroi [a bit yellowish (a modifier in hue)] pinku [pink (a basic color term)].”

**Low-focality colors.** Because a low-focality color is situated at the border region between two basic color categories, the two basic color terms corresponding to the two categories are used to constitute the code for this color. In other words, a subject only needs to memorize these two terms when encoding the color, and focus on the border of these two categories when looking for the color. As an example, a subject reported having used the basic color term orenji [orange] and the basic color term pinku [pink] to encode a test color.

5.2.2 How Color Focality Affects Correct Recognition Possibilities of Colors Through Linguistic Categorical Coding

With employment of this strategy, it is obvious that the correct recognition possibility for a color is mainly determined by 1) how easily the code for the color can be retained in STM during the waiting period and 2) the semantic ambiguity of the code for the color, or, in other words, how accurately the encoded color can be recovered from the code. Since codes for colors of all three types can be formed by just a few words, they can hardly cause a memory burden. This implies that the rate of successful retention should be high for each color type. On the other hand, the variable of semantic ambiguity bears a much larger intertype variance, which indicates its chief role in mediating the impact of color focality on STM performance for colors. The semantic ambiguity of color codes in the three situations of high-focality colors, medium-focality colors, and low-focality colors are described, respectively, as follows.

**High-focality colors.** The code of a high-focality color generally consists of a sole basic color term, which possesses a fairly plain meaning since any Japanese speaker knows the definition of a basic color term. Thus, during the searching phase, the signifier of the code can be pinpointed in high precision.

**Medium-focality colors.** For a medium-focality color, the modifiers in its code have much vaguer meanings. Even if the subjects have carried the code into the decoding phase without mistakes, they will find themselves lost in numerous possible answers, all of which more or less match the description. This will surely lower their chances of finding the one that they have actually coded.

**Low-focality colors.** The code of a low-focality color, which contains basic color terms but no modifiers, should be regarded as unequivocal in meaning. The central points of the basic color categories, as in the case of a high-focality color, can serve as reliable reference points for the localization of the encoded color.

In brief, the semantic ambiguity of color codes, which negatively influences the likelihood of correct recognition for colors, is low for high- and low-focality colors and high for medium-focality colors. Thus, high- and low-focality colors tend to have higher rates of correct recognition than those of medium-focality ones. This is exactly what our experimental results have shown.

In addition, because for any color, the semantic ambiguity of its code is a language-inherent and thus subject-independent attribute, this continuous pattern can be expected to have a high degree of intralanguage
consistency, or, in other words, a high likelihood to be replicated if the experiment is repeated using the same language.

The findings of the past studies that explored the relationship between language usage and the focality effect support our argument that subjects’ conscious encoding of colors using linguistic terms is one vital cause of the focality effect. Brown and Lenneberg [11] showed that the linguistic codability of colors possesses a strong positive influence on the correct recognition rates of colors in the English language. Also using English-speaking subjects, Garro [13] and Lucy and Shweder [14] demonstrated that the superiority of the focal colors relative to the nonfocal colors in correct recognition possibility vanished when verbal communication was allowed during the waiting intervals. One explanation Lucy and Shweder [14] proposed is that the conversations interrupted the subjects’ ability to retain the color codes in their STMs, which prevented the recognition of high-focality colors from benefiting from their advantageous verbal encoding. While these studies place their emphases on the relationship between the strategy of linguistic color coding and the correct recognition possibilities of colors, our hypothesis mainly probes into how color focality exerts its impact through this strategy.

5.2.3 How Color Focality Affects Misrecognition Error Distances of Colors Through Linguistic Categorical Coding

The misrecognition error distance of a color, within the framework of linguistic categorical coding, mainly depends on which parts of the code the subjects have forgotten, and how many times each of these parts have been forgotten. The following paragraphs describe how these factors vary across the three situations of high-focality colors, medium-focality colors, and low-focality colors.

High-focality colors. For a high-focality color, once a subject forgets the sole basic color term during the waiting period, in the searching phase, he/she will be unable to recall the basic color category to which the test color belongs. His/her selection will thus be random, although other memory clues, such as the visual image of the test color, can be of help. It is easy to imagine that under this circumstance, a large error will occur.

Medium-focality colors. For a medium-focality color, when only the modifiers have been forgotten, given that the basic color term has become the only guide for color searching, the central point of this basic color category may pull the subjects’ selections toward it. In this case, a misrecognition is expected to occur, but within a moderate scope, that is, approximately half the “category radius.” On the other hand, the loss of the basic color term may lead to a much larger error distance, as in the case of high-focality colors.

Low-focality colors. With regard to the code of a low-focality color, when one of its two basic color terms has been forgotten, the remaining one will tend to drag the subjects’ selections toward the central point of the category it represents. On this occasion, because the low-focality color is situated at the border region of the category, a selection with an error distance of approximately one category-radius long might take place. On the other hand, the loss of both basic color terms may result in a much larger error distance, as what will happen when the sole basic color term is forgotten for a high-focality color.

Note that owing to the small total number of memory losses suggested by the small memory burden imposed by the color codes, it is possible that some of these “types of forgetting” did not occur in our experiment. Thus, one explanation for the focality effect pattern that we detected is that our subjects have never forgotten the basic color terms in the codes for the high- and medium-focality colors. In addition, the small sample size of memory losses means that the distribution of occurrence frequency across the types of forgetting can hardly be consistent across experiments even when the same language is used. In other words, if the experiment is repeated, a substantially different frequency distribution across the types of forgetting will occur, which will lead to a very different focality effect pattern. Perhaps this susceptibility to the unpredictability in subject behavior is one reason why misrecognition error distance was employed much less frequently than correct recognition possibility in past studies.

5.3 Universality of the Focality Effect Patterns

Several past studies on STM performance of colors, which used English-speaking subjects, also recorded their subjects’ memorization methods.

Lucy and Shweder [14] recorded the subjects’ incidental remarks on memorization strategies during the course of their experiments, and they carried out a questionnaire on memorization strategies when the experiments were finished. They provided a quantitative report of their recordings which shows that the strategy of linguistic categorical coding was the most frequently adopted, followed by the strategies of direct retention of visual image, present object association, and absent object association. This coincides well with the results of our questionnaire.

Brown and Lenneberg [11], Lucy and Shweder [12], and Garro [13] also reported the memorization strategies
used by their subjects, although they did not provide detailed statistics. Brown and Lenneberg [11] mentioned that their subjects transformed the colors that they had to remember into “names” and stored the names in their memory. In our view, this method generally encompasses the strategies of linguistic categorical coding and object association. Lucy and Shweder [12], by examining their subjects’ incidental comments, found that linguistic categorical coding, absent object association, and present object association were the three most frequently used memorization strategies. The direct retention of visual image was used as a supplement to linguistic categorical coding. The recordings of Garro’s [13] post-experiment questionnaire reveal that their subjects mainly employed the strategies of linguistic categorical coding, direct retention of visual image, and object association. We can see that all three studies reported the usage of linguistic categorical coding.

The fact that linguistic categorical coding is employed as a chief memorization strategy by both Japanese speakers and English speakers suggests that its applicability is possibly universal across languages. Moreover, considering the hypothesized close ties of this strategy to the formation of the continuous pattern of the focality effect, this further implies that all languages may share a common language-driven mechanism of focality-effect generation.

Regarding the focality effect pattern for the correct recognition possibility, given the likely intralanguage consistency of this pattern (explained in Section 5.2.2), we can expect to observe this pattern also in the English language, or even in other languages because of the likely universal applicability of linguistic categorical coding.

This speculation is empirically supported by the agreement between the continuous FS-to-MAS relationship detected in our experiment and the superiority of focal colors to nonfocal colors in correct recognition possibility reported by Rosch [5], Roberson et al. [7], and Roberson et al. [8]. Specifically, their definition of focal colors generally corresponds to the colors rated high on our focality continuum, which have high MASs according to our experimental results, and their definition of nonfocal colors covers the low region of our focality continuum, which have high MASs in our study, along with the medium region, which have low MASs in our study. Thus, if we bisect our focality continuum using this dualistic definition and compare the two categories of colors in MAS based on our experimental results, a focal-color superiority will show up, just as in the previous studies.

Given that the focality effect pattern for the misrecognition error distance lacks intralanguage consistency (explained in Section 5.2.3), it will be difficult to find a focality effect pattern that is consistent across languages for this STM performance measure, even if the use of linguistic categorical coding is universal across languages.

The comparison of the results of Rosch’s [5] and Roberson et al.’s [7] studies and our study supports this speculation. Rosch’s [5] results show that colors that have higher degrees of focality tend to have lower EDSs. This agrees with the negative linear FS-to-EDS relationship detected in our experiment. In contrast, Roberson et al. [7] found no significant difference between the focal colors and the nonfocal colors in EDS.

6. SUMMARY

This study is the first to probe into the continuous patterns of the focality effect, which is a critical psychological effect of the prototype-based internal structure of basic color categories. Our experiment confirmed the existence of the focality effect in the Japanese language and, more important, clarified its continuous patterns in terms of correct recognition possibility and misrecognition error distance, which were two aspects of STM performance. Specifically, correct recognition possibility is highest at the two ends of the continuum of color focality, and decreases as color focality moves toward the medium region from either end. In terms of misrecognition error distance, it decreases as color focality increases in the general case.

The results of the questionnaire that recorded the subjects’ memorization strategies imply that the subjects’ frequent and conscious use of the strategy of linguistic categorical coding, namely, encoding colors using linguistic color categories, is an important cause of the focality effect patterns, especially in the case of correct recognition possibility.

In addition, because linguistic categorical coding is used as a chief memorization method by both Japanese and English speakers, and because the focality effect pattern for correct recognition possibility likely has high intralanguage consistency, we expect that this focality effect pattern would also be found in the English language, or even in other languages.

7. IMPLICATIONS FOR FUTURE WORK

Empirical evidence for more languages is needed to clarify whether the focality effect patterns that we detected are universal across languages. It is also interesting to see whether the patterns can be found in terms of categories in
domains other than color. These domains can be simple perceptual categories, such as shapes and phonemes; complicated multimodal concepts, such as animals and tools; or even emotionally or socially meaningful signals, such as human facial expressions.

Moreover, besides STM of colors, color focality has also been reported to be able to influence color preference. Martindale and Moore’s [15] study showed that their subjects (most of them were probably English speakers because they were students of the University of Maine) tended to prefer colors of high focality levels to colors of low focality levels. If this effect turns out to be universal, we will see that preference for colors varies across languages, as colors have different focalities in different languages. This possibility bears great significance in the fields of aesthetics, art study, and cross-cultural communications. We plan to evaluate this hypothesis by testing the existence and the continuous patterns of this effect in the Japanese language using an experimental paradigm like that used in this study.

NOTES
1. Roberson et al.’s [7] Experiments 2b and 2c used a revised color array and failed to find the focality effect in the English language. However, Berry et al. [16] and Poortinga and Van de Vijver [17] pointed out that this modification of the array layout, which was based on subjects’ response behaviors rather than physical color parameters, might have already brought in a bias in subjects’ response performance, which could facilitate what subjects were good at and hinder what subjects were poor at. Thus, they regarded the results of the two experiments as “not very relevant” to the question whether the focality effect exists or not.

2. The OIs of the chips on the left border of the category Murasakiiro do not necessarily signify the categorical membership and the focality of the chips, because the subjects might prefer to call them aoiro [blue]. So are the chips on the right and the lower borders of the category Kiño, which adjoins the category Midoriño [Green].

3. As mentioned in Section 4.2, a data point representing a high-focality test color (5YR 4/8) appears separated from the regression model. This test color was mistaken as the color one-unit above it (5YR 5/12) in all its misrecognition cases. This misrecognition pattern is difficult to explain by the strategy of linguistic categorical color coding. We conjecture that it might result from other memorization strategies, which needs further exploration.

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