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GRUE-TYPE ERRORS ON TRAFFIC LIGHT COLOUR-NAME RESPONSES

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Abstract ‘Why do the Japanese call a green light signal blue?’ This simple question has been the subject of numerous media articles. One of the most relevant studies on this question is the finding of colour-name responses. Using the findings of cognitive linguistics based on colour vocabulary and grammatical structures as a basis, this study experimentally tests how differences in linguistic systems and vocabulary affect the cognitive processes of Japanese people in the form of Grue typology in traffic lights. The subjects were 195 university students in the 2020 group (141 valid responses) and 143 students in the 2023 group (104 valid responses), who were interviewed prior to the class through an online assignment form. They were presented with visual stimuli that reminded them of either of the two types of traffic lights with instructions only to “enter/answer the colours that go into each of the circles”, and respond with no other information given. The results showed that in both year groups, significant differences were detected between group B and the other two, while no significant differences were detected between groups R and Y. Among traffic lights, the hue of the caution signal (yellow) is slightly reddish-yellow, and discrepancies between colour perception and the actual signal name can occur for both blue and yellow lights. However, none of the yellow signals were misnamed, even with the slightly reddish-yellow tint. This can result from a grue-type error that occurs between the socially shared semantic code ‘blue light’ and green as perceptual cues.

Keywords: colour-name responses, Grue, perceptual cues, focal colours

1. Introduction

‘Why do the Japanese call a green light signal blue?’ This simple question has been the subject of numerous media articles and was featured in NHK’s popular variety programme, *Chico Will Scold You!* in 2018.

Road traffic control, introduced in the Taisho era (1912-1926), was originally based on hand signals by London police officers since 1868 (Kulkarni *et al*. 2023). Its diffusion is said to have started with central pillar traffic lights imported from the US and installed in Tokyo’s Hibiya district in 1930. Because of this, the initial name of the blue signal was Midori-shingou (Green light), which conformed to Western standards, until 1947, when the name was changed to ‘blue light’ (National Police Agency Government of Japan 2005). However, the recommended range of blue light colours in Japan, as defined by the Road Traffic Act, overlaps in part with the International Commission on Illumination’s recommendation of green, but not with the blue range at all, and does not conform to international standards. This has long been known to scholars of illuminating engineering and is

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regarded as a problem (Ayama *et al*. 1982, Nakashima 1987). Uniqueness in the colour of traffic lights is said to be due to the way they were established in the Road Traffic Act as a measure against misreading, especially by those with low colour (especially red-green) vision (Kansaku 1971). However, there are various theories regarding why the name has changed from green to blue, and most describe the meaning and usage of blue in Japanese from the perspective of the linguistic relativity hypothesis. Komatsu (2001) highlights that many compound words in Japanese with blue as a front element, such as 'seishun/adolescence', 'aomono/green food', 'aobyōtan/green calabash', and 'aomushi/green caterpillar', originally contained the meaning of green and nuances of immaturity. Stanlaw (2010), who applied this to the issue of traffic lights, introduced the fact that Japanese 'ao/blue' has the same beginning-ness and starting usage as English 'green' (e.g., ao-nisai/green recruit, ao-kusai/ green to eat, massao/looked green), and that blue may have come to replace the green traffic light as a metaphor for starting traffic. This view suggests that cultural differences in colour-name responses to traffic lights can be viewed within the framework of constructivism, which holds that people's cognitive development is influenced by the linguistic systems and vocabulary existing a priori in society or culture.

From the perspective of constructivism, research on colour-name responses conducted mainly in cognitive psychology and cognitive linguistics has provided central insights into the relationship between the processes of colour perception/cognition and language systems at the ontogenetic level in humans.

While some studies have attempted to consider genetic factors in the detailed differences in colour perception between males and females (e.g. Jameson *et al*. 2001, Rodríguez-Carmona *et al*. 2008), many studies highlight the influence of socio-cultural factors in considering gender differences in colour-name responses (Greene and Gynther 1995), and that women's superior performance in colour tasks may be determined by clothing-related interests and occupational differences. Hurlbert and Ling (2007), who educed the development of a gender role division of labour between women and men in society, such as hunters and gatherers, influence gender differences in human colour perception. In summary, it is generally accepted that humans have the ability to distinguish small differences in colour at the perceptual level much earlier than the acquisition of language (Bornstein *et al*. 1976).

While the perceptual ability to respond to colour stimuli is, to some extent, innate, humans live by categorising perceived colour stimuli into representative systemic colours at the cognitive level (e.g., Mervis and Rosch 1981). The shared basic colour vocabulary within a language can be captured in terms of an increasing number of shared basic colour terms, which is generally thought to increase in the order of the two colours, light and dark, with the addition of the red and blue distinction, followed by yellow and green branching from red and blue, respectively (Berlin and Kay 1969, Kay *et al*. 1991). Blue and green did not become independent from the word hœwen in the English-speaking world until the 13th century (Biggam 1997). Likewise, Japanese colour categories acquired the distinction between blue and green around the 12th century, after only four basic colours (red, black, blue, and white) were first introduced into the language (Stanlaw 2010). Hence, colour categories include 'salient areas of the colour space ("focal colours") which are universally the most linguistically "codable" and the most easily remembered' (Heider 1972: 10). There is a certain persuasiveness to the argument that the colour categories shared a priori in the host society have a fundamental influence on people's colour-name responses, as people acquire their cognitive abilities in the society in which they are born (e.g., Roberson *et al*. 2000).

Summing up the argument thus far: 'Why do the Japanese call a green light signal blue?' The research that can be cited in relation to this question is the findings on colour-name responses, based on which there are two approaches: one from a cognitive-linguistic perspective and the other from a cognitive-psychological perspective. The former is mainly based on the vocabulary and grammatical structure of corpora, historical sources, and transcribed conversational texts, and tends to answer the question in question as a general argument based on linguistic systems and vocabulary differences. While this argument is understandable in terms of how blue-light notation became widespread, it lacks interest in experimentally testing how differences in the linguistic system and vocabulary affect speakers' cognitive processes.

This is compensated for by colour-name response experiments conducted in a cognitive psychological background. However, many of these experiments are based solely on colour-name responses to simple shapes in environments where disruptors can be controlled to ensure the procedural robustness and reproducibility of results. It is uncommon for people to be asked to judge the name of a colour in an environment from which only the colour has been extracted. Situations in which people are asked to give a colour name response to light blue or blue, for example, are much more likely to occur when they are asked to name the colour of a river, lake, sky, or sea.

2. Aim

'Why do the Japanese call a green light signal blue?' This seemingly naïve question is actually a synthesis of two sub-questions: Do the Japanese misidentify the colour of traffic lights because they recognise the object as a signal, or because they have acquired a cognitive process that makes it difficult to distinguish between blue and green owing to differences in language systems? In considering the research design, it may be necessary to separate these questions and devise a way to establish this as a context-dependent study in the context of a colour–name response experiment for traffic lights. Therefore, in addition to having the participants respond to each colour of the red, yellow, and blue traffic lights, two different pictures of traffic lights with different levels of abstraction were prepared as representations to be used as cues in this case. The empirical responses to the two sub-questions were shown by examining whether the differences in abstraction level appeared as differences in the colour-name responses.

The state in which colour names are not separated between blue and green, even though the apparent colour differences can be perceptually judged and separated in terms of neural activity, is called Grue (green-blue) (Fider and Komarova 2019). Thus, this study attempts to confirm that when subjects respond to a colour name response task, a grue-type error is produced by top-down processing using their prior knowledge that the pictorial image shown is a traffic light.

As previously mentioned, a boundary overlap or semantic asymmetry has been suggested between blue and green, resulting from a priori linguistic systems and social conventions. However, the colour perceptual discrepancy in traffic light colour names should also occur in the hue of the caution (yellow) signal, which is actually 'slightly reddish yellow' (IEIJ-JIER 1989: 66). Thus, if the misinterpretation in colour-name responses appears only for blue signals, it is not a simple colour perception problem, but caused by some kind of double bind between the socially shared semantic code of 'blue signal' and the green colour as a perceptual stimulus.

3. Experimental Design and Analytical Procedures

The subjects were university students who had taken the University of Toyama's liberal education course ‘Regional Economy, Society and Culture’ in 2020 and 2023, and whose affiliations spanned the Faculty of Medicine, Faculty of Pharmacy, Faculty of Economics, Faculty of Human Development (reorganised into Faculty of Education in the 2023 group), Faculty of Science, Faculty of Engineering, Faculty of Humanities, School of Art and Design, and School of Sustainable Design. The participants included 195 students in the 2020 group (141 valid responses, 72.3% valid response rate) and 143 students in the 2023 group (104 valid responses, 72.7% valid response rate).

The issue of the response styles that subjects possessed when they cooperated with a survey was raised as affecting the reliability of the results (Kam and Meyer 2015, Vaerenbergh and Thomas 2013), although the main focus of the research was on the reliability of questionnaires using rating scales. Of all these issues, ‘hypothetical guessing’ defined as a tendency that ‘respondents may systematically alter questionnaire responses when, during the process of answering the questionnaire, they think they know the study hypothesis’ (Choi and Pak 2005: 9) cannot be ignored. To address this issue, students were instructed via Moodle, an online assignment distribution and submission form, to simply ‘enter/answer the colours that go into each of the circles’ in online text format (or attach an image file), prior to class, with no other information given. This was done to ensure that it was not explicitly known that this was a traffic light colour name response experiment and to avoid prejudiced reactions to the experimental design affecting the accuracy of the responses. Some respondents annotated the traffic lights with the colour names with the note ‘The most important red is placed nearest to the medial so that it is not hidden by the roadside trees’ or ‘I am not sure which one (left or right) was blue’, indicating that they thought that they were being asked to sort the three colours used in traffic lights into the correct arrangement. Conversely, no one predicted that it was a colour–name response experiment that had the effect of deterring a certain degree of prejudice.

The experiment was conducted over two years to examine the effects of different levels of abstraction of visual stimuli (traffic lights) used in responses. For the 2023 respondents, visual stimuli were selected using images with a higher level of abstraction to make it more difficult to identify the subject as a traffic light (Fig. 1).

The reason for the slightly high percentage of invalid votes was that the assignment was usually submitted before the next class following the initial orientation; new students who had not yet entered the course were not yet familiar with Moodle, and students were still unfamiliar with the author’s teaching style, which required them to submit their class assignments in advance of each lesson. Moreover, when collecting the data, some students did not write down the names of the colours and used drawing software to colour their answers or attached images taken with a mobile phone on answer sheets coloured with fine point markers, because they were asked to fill in and submit their answers on a computer. This was because these samples had to be excluded as invalid votes.

The instruction, ‘enter/answer the colours that go into each of the circles’, left a certain ambiguity

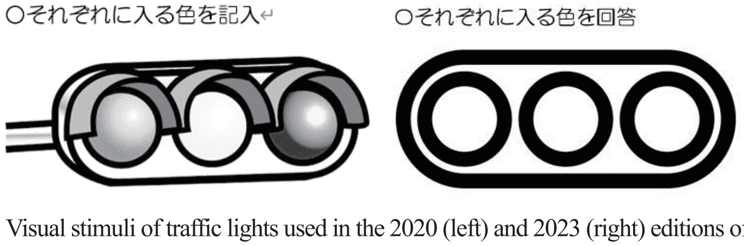

Fig. 1 Visual stimuli of traffic lights used in the 2020 (left) and 2023 (right) editions of the task

as a result of collecting the submissions in Moodle. A certain number of students interpreted the instruction as ‘paint in the colours’ rather than ‘write the names of the colours’. This issue needs to be addressed in future studies.

Responses collected in the procedure described above were counted as a dummy variable, with 1 (correct) given to those who wrote red, yellow (Y), and blue (B) when writing the colour name, and 0 (incorrect) to those who gave other responses. A chi-square test was performed by counting the frequencies (number of people) in each case to see if there was any bias in the frequency distribution. All responses in group B were ‘green’ except for two cases where the response was not blue, and these two cases were ‘blue-green’ or ‘blue/green’. Therefore, a value of 1 for blue and 0 for green was assigned, and the above two cases were excluded from the screening process. Both the cases were included in the 2023 group. No one filled in any other colour for R or Y.

4. Results, Discussion and Conclusion

Results

Tables 1 and 2 present the results calculated from students’ responses in 2020 and 2023, respectively. The results of the analysis showed that significant differences were found between colours and response tendencies in the 2020 ($\chi 2(2) = 71.585$, $p<.01$) and 2023 groups ($\chi 2(2) = 41.275$, $p<.01$). The adjusted standardised residuals for individual colours showed that in both year groups, correct answers in group B tended to be significantly lower than the expected values, while the other two colour groups were significantly higher. Therefore, this response tendency can be considered a universal response among university students.

Next, to examine the possibility that the high level of pictorial abstraction of the traffic lights might influence the results, a chi-square test was used to examine the significant differences between the response tendencies of the sample who responded blue or green to the traffic lights in 2020, when the level of abstraction was relatively low, and in 2023, when the level of abstraction was higher. The results showed no significant differences, and the level of abstraction of the visual stimuli used in the experiment did not affect the response tendencies ($\chi 2(1) = 0.544$, $\varphi = 0.047$).

Discussion and Conclusion

The present results experimentally confirmed that the Grue type confusion occurs in the response tendency of the whole group only between the colour name ‘blue light’, which is generated by the visual stimuli evoking traffic lights, and ‘green’, which is retrieved in response to the colour perception. Moreover, the task could be performed without interference from high or low abstraction as long as the visual stimulus target provided a minimal cue to recognise it as a ‘traffic light’. This could be interpreted as indicating that Grue-type errors were observed in higher-order cognitive processes, where subjects had to read the task as matching the colour name of ‘traffic lights’ from abstracted pictorial representations.

As previously mentioned, the hue of the attention signal (yellow) in the traffic lights is ‘slightly reddish yellow’ (IEIJ-JIER 1989: 66). If we follow the assumption of the colour name response experiment that the difference between the colour used in the traffic lights and the actual colour induces a false answer, the confusion between blue and green would equally appear as an ‘orange’ or ‘golden yellow’ false answer in the yellow lights. However, there were no misinterpretations of yellow signals, even red signals, regardless of the level of abstraction of yellow as traffic light iconography. Thus, the colour name response to colour tones at traffic lights is not only a simple matching of perceived colours, but is also induced by a certain kind of double bind situation between the socially shared semantic code 'blue light' and the green colour as a perceptual stimulus. Ultimately, this result may be because blue and green are in different colour categories of focal colours, while mountain yellow and orange are in a subcategory of the focal colour, yellow.

Table 1 Chi-square test results of traffic light colour assignment task responses (2020)

		Answers	
		Correct *p*	Incorrect *p*
Blue	Measured value	108	33
	Residuals (adj.std.)	-8.461 **	8.461 **
Yellow	Measured value	141	0
	Residuals (adj.std.)	4.23 **	-4.23 **
Red	Measured value	141	0
	Residuals (adj.std.)	4.23 **	-4.23 **

**p<.01

Table 2 Chi-square test results of traffic light colour assignment task responses (2023)

		Answers	
		Correct *p*	Incorrect *p*
Blue	Measured value	83	19
	Residuals (adj.std.)	-6.425 **	6.425 **
Yellow	Measured value	104	0
	Residuals (adj.std.)	3.197 **	-3.197 **
Red	Measured value	104	0
	Residuals (adj.std.)	3.197 **	-3.197 **

**p<.01

5. Future Challenges

The cultural aspects of colour-name responses were examined through the submitted answers of Japanese students. However, since the experiment was not conducted in comparison with university students from cultures where the boundary between blue and green is not ambiguous, it will be necessary to verify whether this phenomenon is caused by the cultural background based on cross-cultural experiments in the future.

Moreover, a significant number of subjects had coloured their image (files) in response to the question 'enter/answer the colours that go into each of the circles'. This response could be interpreted as a response with an explicit meaning, given that the experiment in question was answered via an online form and not the question 'Answer the name of the colour'. As the number of submissions was not statistically tractable and was deemed outside the scope of the colour-name response experiment, these responses were discarded from the analysis in this study. Although not compiled as data, almost all of them were coloured green. Since this was an online response experiment, new reflections could have been added by discussing the statistical differences between the colour–name and colour–colour responses. Additional examinations of the validity of this instruction are required.

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References

Ayama, A., Takahashi, M., Katayose, T. and Takasu, Y. 1982. Kōtsū shingō-tō no iro-do han'i no iro no mie-kata (Apparent Hue of the Light Signal of Road Traffic Control). *Journal of the Illuminating Engineering Institute of Japan* **66** (10): 15–19.*

Berlin, B. and Kay, P. 1969. *Basic color terms: Their universality and evolution*, Berkeley: University of California Press.

Biggam, C. P. 1997. *Blue in old English: An interdisciplinary semantic study. Costerus new series, 110*, Amsterdam: Editions Rodopi B.V.

Bornstein, M. H., Kessen, W. and Weiskopf, S. 1976. Color vision and hue categorization in young human infants. *Journal of Experimental Psychology: Human Perception and Performance* **2**(1): 115–129.

Choi, B. C. and Pak, A. W. 2005. Peer reviewed: A catalog of biases in questionnaires. *Preventing Chronic Disease* **2**(1): A13. PMID: 15670466.

Fider, N. A. and Komarova, N. L. 2019. Differences in color categorization manifested by males and females: A quantitative World Color Survey study. *Palgrave Communications* **5**(1): 142. doi: 10.1057/s41599-019-0341-7

Greene, K. S. and Gynther, M. D. 1995. Blue versus periwinkle: Color identification and gender. *Perceptual and Motor Skills* **80**(1): 27–32.

Heider, E. R. 1972. Universals in color naming and memory. *Journal of Experimental Psychology* **93**(1): 10–20.

Hurlbert, A. C. and Ling, Y. 2007. Biological components of sex differences in color preference. *Current Biology* **17**(16): R623–R625.
IEIJ-JIER: Shadanhōjin shōmei gakkai dōro shingō-tō no iro no bunpu ni kansuru kenkyū chōsa iinkai (Illuminating Engineering Society of Japan Research and Investigation Committee on the Distribution of Colours in Road Signal Lights) 1989. *Dōro shin-Gō-tō no iro no bunpu ni kansuru kenkyū chōsa iin kaihōkokusho (Report of the Research and Investigation Committee on the Distribution of Colours in Road Signal Lights)*.*
Jameson, K. A., Highnote, S. M. and Wasserman, L. M. 2001. Richer color experience in observers with multiple photopigment opsin genes. *Psychonomic Bulletin & Review* **8**: 244–261.
Kam, C. C. S. and Meyer, J. P. 2015. How careless responding and acquiescence response bias can influence construct dimensionality: The case of job satisfaction. *Organizational Research Methods* **18**(3): 512–541.
Kansaku, H. 1971. Shingō to kōtsū hyōshiki no iro ni tsuite (Colors of traffic signals, signs and markings). *Journal of the Illuminating Engineering Institute of Japan* **55**(3): 59–66.*
Kay, P., Berlin, B. and Merrifield, W. 1991. Biocultural implications of systems of color naming. *Journal of Linguistic Anthropology* **1**(1): 12–25.
Komatsu, T. 2001. *Nihongo no Rekishi: Aoshingō wa naze Aona no ka (Notable Occurrences in the History of the Japanese Language)*. Tokyo: Kasama-Shoin.*
Kulkarni, A. R., Kumar, N. and Ramachandra R. K. 2023. 100 years of the ubiquitous traffic lights: An all-round review. *IETE Technical Review*: 1–14. doi: 10.1080/02564602.2023. 2238664
Mervis, C. B. and Rosch, E. 1981. Categorization of natural objects. *Annual Review of Psychology* **32**(1): 89–115.
Nakashima, Y. 1987. Kōtsū shingō-tō no iro-do han'i to karānēmingu-hō ni yoru iro hyōka (Color limits in the chromaticity diagram for the traffic light signals and its apparent hue measured by color-naming method). *IATSS Review* **13**(1): 54–64.**
National Police Agency Government of Japan 2005. *White Paper on Police 2005*, Tokyo: Gyosei.*
Roberson, D., Davies, I. and Davidoff, J. 2000. Color categories are not universal: Replications and new evidence from a stone-age culture. *Journal of experimental psychology: General* **129**(3): 369–398.
Rodríguez-Carmona, M., Sharpe, L. T., Harlow, J. A. and Barbur, J. L. 2008. Sex-related differences in chromatic sensitivity. *Visual Neuroscience* **25**(3): 433–440.
Stanlaw, J. 2010. Language, contact, and vantages: Fifteen hundred years of Japanese color terms. *Language Sciences* **32**(2): 196–224.
Vaerenbergh, Y. V. and Thomas, D. T. 2013. Response styles in survey research: A literature review of antecedents, consequences, and remedies. *International Journal of Public Opinion Research* **25**(2): 195–217.

(*: in Japanese, **: in Japanese with English abstract)