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INVESTIGATION OF AUTOMOTIVE LIGHT BLINKING PATTERN CONVEYING A DRIVER'S INTENTION TO YIELD

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ABSTRACT

This paper proposes a method of conveying a driver's intention to yield by blinking automotive lighting. Generally, headlight flashing indicates a driver's intention to yield to another driver or pedestrians in Japan. However, this signaling method can have several meanings, including warning other drivers of road dangers such as crashed cars, or informing other drivers of the presence of a pedestrian. There is a possibility of a misunderstanding, increasing the risk of accidents. Therefore, we have investigated an effective method for facilitating communication in traffic. This study focuses on nonverbal communication in which blinking lights convey the driver's intentions to others. In this study, visibility is not considered. Nine blinking patterns that changed the light colors, waveform, and blinking cycle were presented to fifteen healthy participants, and visual impressions were evaluated to identify the most suitable blinking patterns. These nine patterns indicate a driver's intention to yield to pedestrians and other drivers. The results indicated that a blue-green blinking pattern in which luminance changes with a triangular wave pattern with a one-second cycle was best conveyed the intention to yield.

Keywords: *driver's yield intention, automotive lighting, blinking pattern*

1 INTRODUCTION

This study was motivated by the evolution in recent years of automotive lighting as a signal to communicate with other traffic participants. In the near future, the traffic environment is expected to become more complex with the advent of self-driving vehicles. External Human Machine Interface (eHMI) has been proposed to replace the conventional communication (interaction) between the driver and surrounding traffic participants. Currently, there is no fixed design for eHMI, and target criteria are being discussed in automotive rulemaking forums such as UNECE WP29. Independence from language skills is one of the target criteria, and safety-conscious display contents are being considered. As some examples, there are road projection lamps and welcome lamps. The road projection lamp is a future lighting technology that projects information onto the ground to convey vehicle movement and information to other traffic participants. Its performance is being studied for implementation (Shibata, 2021). These are expected to be effective for facilitating communication in the traffic environment.

In this paper, we focused on “headlight flashing.” Headlight flashing in Japan is generally used as a sign to communicate a driver’s intention to yield to other drivers or pedestrians. However, it can have several meanings, including warning other drivers of road dangers such as crashed cars, or informing other drivers of the presence of a pedestrian. Therefore, drivers must guess the meaning of received headlight flashing depending on the situation. This creates the possibility of a misunderstanding, increasing the risk of accidents.

Nowadays, there are several types of automotive lighting (eg, sweeping, sequential, flashing). One research show pedestrians tend to cross sooner with a flashing signal compared to a sweeping signal. (Stefanie, 2019). Hence, we decided to identify a suitable blinking pattern to convey the intention to yield. Previous studies investigated the relationship between blinking frequency and light color, showing that a shorter blinking cycle correlates with a stronger feeling of tension for red, blue, green, and yellow colors. Conversely, the longer the blinking cycle, the stronger the feeling of relaxation (Yamashita, 2015). In this way, some studies have investigated relations between the blinking and light color and the receiver’s impression. However, few studies have investigated the blinking pattern to convey a specific intention. Therefore, this study focuses on nonverbal communication in which blinking lights convey a driver’s intentions to others.

This study aims to identify suitable blinking patterns of automotive lighting that convey a driver’s intention to yield. A blinking pattern consists of three elements: the light color, waveform, and blinking cycle. In this study, we set two steps of the experiment. The first step aims to identify one pattern that conveys yielding as a foundation pattern. Therefore, we experimented to select one of the blinking patterns they felt best conveyed the intention to yield. The second step aims to identify the relationship between the impression when blinking is received and each blinking pattern element. This paper describes the first step of this experiment.

2 EXPERIMENT

The first step of the experiment was conducted in a constant 650 lx illumination (Height from floor 1.1m) environment. Fifteen healthy participants sat in chairs spaced 2500 mm apart, and two lamps were installed at line-of-sight height (Figure 1). We provided nine blinking patterns (Table 1) that changed randomly the light color, waveform, and blinking cycle using the LED lamps (Figure 2). All blinking patterns except sample ④ have a constant chromaticity. Only sample ④ changed color (yellow → white → blue) with time. These blinking patterns were created by nine people who engage in developing an automotive lighting system, before the experiment. They were told respectively that create the blinking pattern that they thought could convey an intention to yield assuming the two scenes shown in Figure 3. Scene 1 shows communication between drivers, and Scene 2 shows communication between drivers and pedestrians. In both scenes, it is assumed that the front part of the vehicle illuminates when signaling.

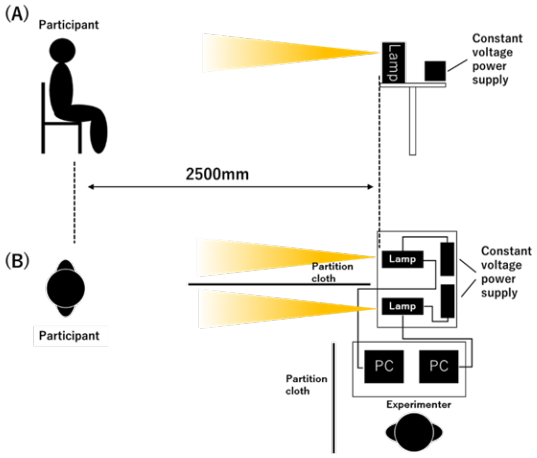

Figure1. Experimental environment: (A) Side view; (B) Front view.

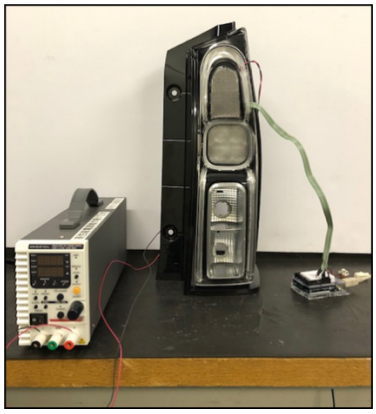

Figure2. Apparatus: LED lamp, Constant-voltage power supply

Table1: Characteristics of each blinking pattern.

Sample No.	①	②	③
Waveform	Sine wave	Triangular wavex2 + 50%off	Sine wave+ 50%off
Time	1000ms	1500ms	1000ms
Chromaticity(x,y)	(0.24,0.18)	(0.19,0.73)	(0.23,0.11)

Sample No.	④	⑤	⑥
Waveform	B, R,G	Sine wave	Triangular wavex2 + 50%off
Time	1000ms	1000ms	1000ms
Chromaticity(x,y)	Yellow→white→blue	(0.16,027)	(0.17,0.44)

Sample No.	⑦	⑧	⑨
Waveform	Trapezoidal waves x2 + 20%off	Trapezoidal waves x2 + 20%off	Trapezoidal waves x2 + 20%off
Time	2000ms	2000ms	2600ms
Chromaticity(x,y)	(0.25,0.18)	(0.15,0.15)	(0.18,0.76)

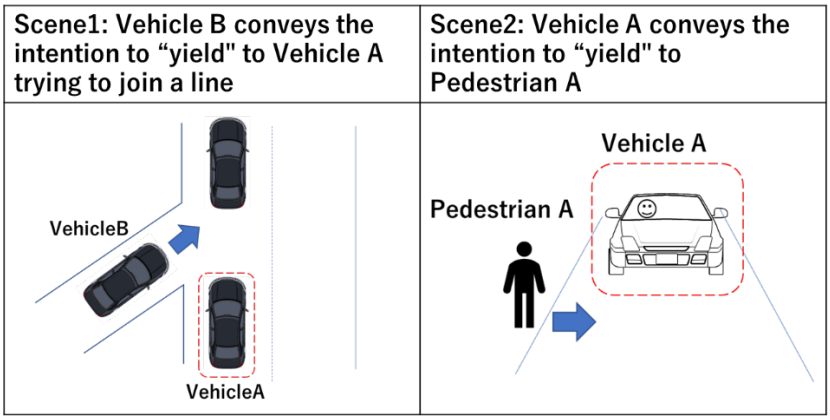

Figure 3: Assumed vehicle and pedestrian situations.

Visual impressions were evaluated by Scheffe’s method of paired comparison as modified by Nakaya (Takagi, 2014). Participants were asked to evaluate thirty-six combinations, comparing two different lighting patterns. Four blinking pattern combinations unrelated to the results were presented to familiarize the participants with the evaluation. Participants were asked to evaluate their visual impression of each of the following nine items on a 7-point scale by comparing the two types of blinking patterns: brightness, fast blinking speed, waveform rise rapidity, colors match the intention, glare, easily understood meaning, stands out, easy to see, and suitable.

3 RESULTS

This experiment aimed to identify a pattern that accurately conveys yielding as a foundation pattern. Therefore, we used the results of "suitable" and "easily understood meaning" item results in the overall evaluation. Also, we discuss the results of "colors match the intention", "easy to see" and "waveform rise rapidity", which were found to be strongly correlated with"easily understood meaning". Other item results were used for the discussion of evaluation trends.

The results of the impression evaluation by 15 participants are shown below. Figure 4 shows the results of the average degree of preference for "suitable," and Figure 5 shows the results of the average degree of preference for "easily understood meaning". For both items, samples ⑥ and ② were highly evaluated and showed significant differences from the other samples. However, the "suitable" category confirmed the combination effect, with a two-way interaction between the sample and the participants ($p<0.01$).

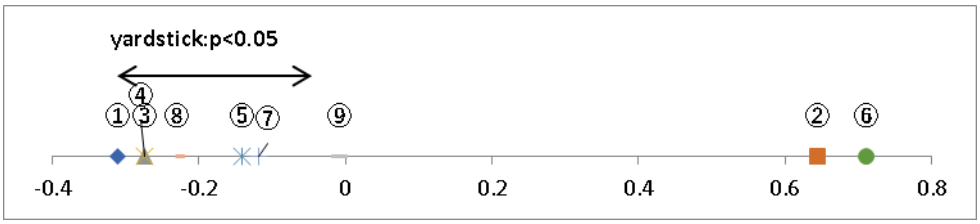

Figure 4: Average degree of preference: "suitable."

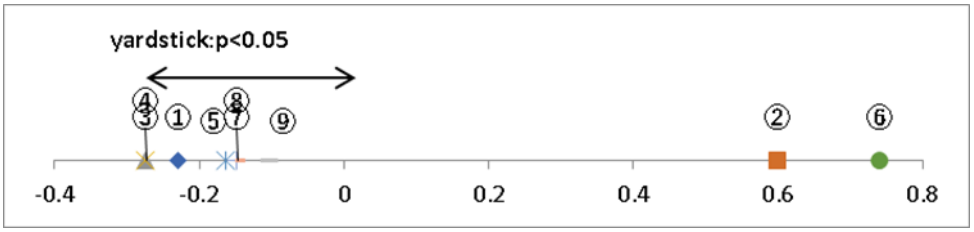

Figure 5: Average degree of preference: "easily understood meaning."

Blinking patterns with greenish colors were highly evaluated (Figure 6). However, the "colors match the intention" category confirms the combination effect, with a two-way interaction between the sample and the participants ($p<0.05$). According to the introspection survey results, this may be because the greenish color is similar to the blue of a traffic light in Japan, meaning "go." Therefore, this color was highly evaluated as a color for conveying that the signaling driver was yielding, so the signaled driver should proceed. For the waveform rise rapidity, sample ⑥ was the most highly evaluated (Figure 7). This flashing pattern is the fastest rising waveform of all the patterns and is considered highly rated because it closely resembles flashing headlights. Also, in terms of "easy to see", sample ② and ⑥ were highly evaluated (Figure 8).

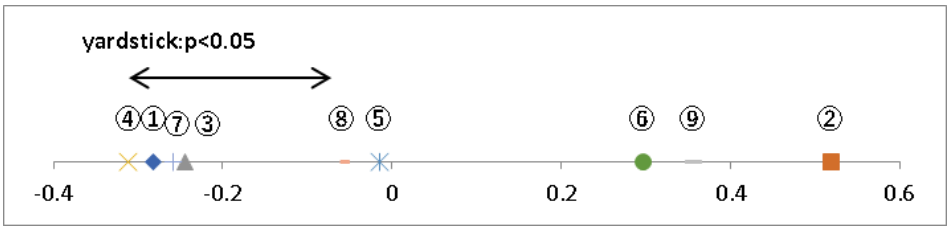

Figure 6: Average degree of preference: “colors match the intention.”

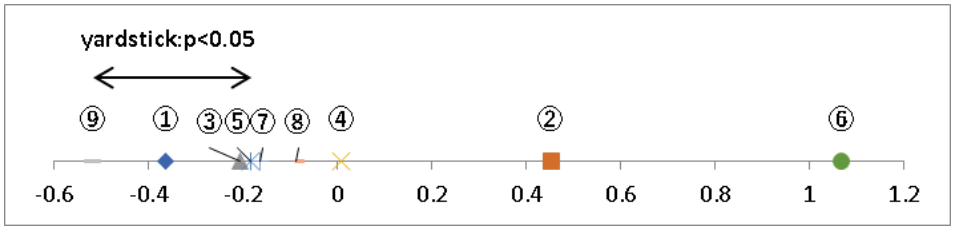

Figure 7: Average degree of preference: “waveform rise rapidity.”

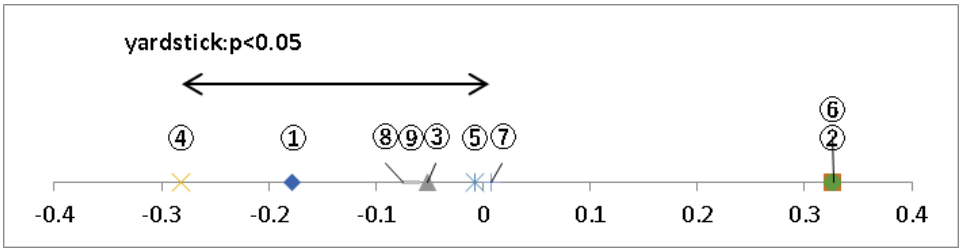

Figure 8: Average degree of preference: “easy to see.”

Based on these results, we chose a blue-green pattern with luminance changing in a triangular wave pattern with a one-second cycle (sample ⑥) as the blinking pattern that best conveyed the intention to yield. In this study, we give importance to nonverbal communication, and although there are some errors in chromaticity values between the samples used in the previous study and the blue-green emission pattern used in this study, the results are roughly in agreement with the previous study (Stefanie 2019).

4 CONCLUSIONS

We investigated blinking patterns' suitability for conveying a driver’s intention to yield by flashing their automotive lighting. We presented nine blinking patterns with different light colors, waveforms, and blinking cycles to fifteen participants and asked them to evaluate them based on visual impressions.

As a result, a blue-green pattern with luminance changing in a triangular wave pattern with a one-second cycle was chosen as the blinking pattern that best conveyed a driver’s intention to yield. This result is considered to be influenced by participants’ previous experiences, such as headlight flashing and traffic lights.

In this experiment, we investigated one of the suitable blinking patterns as a foundation pattern for the next step. Therefore, it is necessary to investigate the method of identifying the relationship between the impression when receiving the blinking signal and each blinking pattern element in the future.

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