A Study of Semantic Analysis of LED Illustrated Traffic Directional Arrow in Different Style

Chia-Chen Wu, Chih-Fu Wu, Pey-Weng Lien, Kai-Chieh Lin

***Abstract*—**In the past, the most comprehensively adopted light source was incandescent light bulbs, but with the appearance of LED light sources, traditional light sources have been gradually replaced by LEDs because of its numerous superior characteristics. However, many of the standards do not apply to LEDs as the two light sources are characterized differently. This also intensifies the significance of studies on LEDs. As a Kansei design study investigating the visual glare produced by traffic arrows implemented with LEDs, this study conducted a semantic analysis on the styles of traffic arrows used in domestic and international occasions. The results will be able to reduce drivers' misrecognition that results in the unsuccessful arrival at the destination, or in traffic accidents. This study started with a literature review and surveyed the status quo before conducting experiments that were divided in two parts. The first part involved a screening experiment of arrow samples, where cluster analysis was conducted to choose five representative samples of LED displays. The second part was a semantic experiment on the display of arrows using LEDs, where the five representative samples and the selected ten adjectives were incorporated. Analyzing the results with Quantification Theory Type I, it was found that among the composition of arrows, fletching was the most significant factor that influenced the adjectives. In contrast, a "no fletching" design was more abstract and vague. It lacked the ability to convey the intended message and might bear psychological negative connotation including "dangerous," "forbidden," and "unreliable." The arrow design consisting of "> shaped fletching" was found to be more concrete and definite, showing positive connotation including "safe," "cautious," and "reliable." When a stimulus was placed at a farther distance, the glare could be significantly reduced; moreover, the visual evaluation scores would be higher. On the contrary, if the fletching and the shaft had a similar proportion, looking at the stimuli caused higher evaluation at a closer distance. The above results will be able to be applied to the design of traffic arrows by conveying information definitely and rapidly. In addition, drivers' safety could be enhanced by understanding the cause of glare and improving visual recognizability.

***Keywords*—**LED, arrow, Kansei research, preferred imagery.

I. Introduction

THE history of light sources span across a considerable number of years, in which several light sources have been developed and used, such as the incandescent bulb, halogen bulb, fluorescent tube, and metal halide bulb. Prior to the prevalence of light-emitting diode (LED) lighting, incandescent lighting was the most commonly applied light source. LED lighting has gradually popularized since 2000, and is presently employed in traffic lights, flashlights, vehicle break lights, and indicator lights. Thus, the LED has been regarded the greatest revolution of lighting since the invention of the light bulb.

The LED is a light source fabricated using semiconductor technology, and demonstrate distinct features of high luminous efficiency, high light color purity, low power consumption (approximately 15W; roughly 1/10 of the power required by existing incandescent light sources), long life (8 to 10 years), and fast luminous response time. In addition, LEDs are environmentally friendly and compact, and their zero-pollution characteristic has earned them the title "the green light source" [1]-[3]. Under the rapid development of manufacturing technologies, LEDs have shown significant advancements, both in luminous color or brightness specifications. Moreover, as the maturity of such technologies increase, so will the cost of manufacturing LEDs be reduced [4].

Regarding visual methodologies, Nomura [5] argued that sight gains the largest proportion of external stimuli (reaching 87%) among the five senses. Through the processes of searching, exploring, and comparing, human eyes transmit the color and brightness of light to the retina. The optical nerve then inputs these signals into the brain, which processes and accepts these signals to complete a visual task [6]. Lighting conditions should be considered to enhance the recognition ability of individuals. Appropriate lighting conditions can enhance the recognition ability and security of individuals [7]; conversely, inappropriate lighting conditions hinder individuals' visual recognition performance [8]. Indicators for evaluating visual performance and reading comprise the following three attributes, namely, (1) visibility, which represents the ability to separate text and symbols from backgrounds; (2) legibility, which represents the ability to clearly differentiate text and numbers; and (3) readability, which represents the ability interpret information content by presenting text and numbers in meaningful groups [9].

Currently, clear norms to regulate offensive light emitted from LED advertising signs, car lights, and traffic signs are absent in Taiwan. In the present study, we defined this offensive light as glare. Glare can be characterized as direct glare, indirect glare, and reflective glare. Regardless of type, glare not only irritates the eyes and causes discomfort, but may also cause eye fatigue and loss of sight. However, the relationship between the surrounding environment and individuals' physiological conditions must be examined in order to determine whether lighting conditions, such as the balance between light sources and ambient brightness, direct/indirect

Chia-Chen Wu is with the Graduate Institute of Design Science, Tatung University, Taipei City, Taiwan (phone: 886921114709; e-mail: jessicawu9439@gmail.com).
Chih-Fu Wu and Pey-Weng Lien is with Department of Industrial Design, Tatung University, Taipei City, Taiwan (e-mail: wcf@ttu.edu.tw).
Kai-Chieh Lin is with the Graduate Institute of Design Science, Tatung University, Taipei City, Taiwan (e-mail: maggielin0717@gmail.com).

light, and light angles, cause the occurrence of glare. Garvey et. al. [10] asserted that directly looking at light sources causes extreme discomfort. Thus, excessively bright lighting systems or vehicle headlights cause discomfort to drivers' eyes, increasing the likelihood of accidents. In addition, glare may occur when people look directly at the headlights of oncoming cars at night or when fog lights of oncoming cars are suddenly turned on, hindering drivers' and pedestrians' ability to process their surrounding environment and consequently increase the risk of traffic accidents [11]-[13]. Glare conditions are particularly prone to occur when drivers travel for long periods of time and are required to adjust to dark environments. However, even with the same lighting environments and locations, the glare experienced by different observers may vary depending on their physiological conditions. In this context, elderly people are more likely to experience glare and require longer time to recover from the discomfort caused by glare than those in other age groups.

To achieve favorable lighting efficiency at night, sport stadiums typically employ extremely bright lighting systems. However, increased contrast between background and light source, increased brightness of light source, and shortened distance between light source and the eyes of the observer contribute to elevating glare. Thus, when extremely bright lighting systems are employed in dark environment backgrounds, direct glare is easily generated. In stadiums, direct glare may cause spectators to feel uncomfortable and may impair the vision of the athletes. On the road, this type of glare may obstruct surrounding traffic. Munehiro [14] found that during the day, the legible distance of guide lights on the road is further than white traffic lines. However, increasing the brightness of these lights during fog conditions may generate glare and reduce the legible distance, instead. Subsequently, reducing the brightness contrast between the background and light source and the light source itself, adjusting the light angle, or expanding the distance between the eyes and the light source, effectively reduces glare effects. Thus, in addition to selecting lighting equipment and the positioning angle and location, the environment is also an important aspect to consider when employing light sources.

At present, LEDs are applied in a variety of product, such as electronics, traffic signals, lighting systems, backlight sources, indicator lights, display lights, instrument displays, and vehicle lights [15]. The primary advantage of using LEDs in vehicle indicator and brake lights is the extremely high luminous efficiency. The luminous time of LEDs outperforms conventional incandescent lighting by 0.5 s or more, which in an invaluable feature for enhancing road safety. In addition, LEDs present stable luminosity, enabling vehicles to clearly illuminate road conditions, even when traveling on bumpy roads or in fluctuating temperatures. LEDs also possess rapid flashing capabilities, and are now employed to replace the warning indicators of emergency vehicles. This substitution has simplified the mechanical structures required to produce the flashing effect in warning systems. Road users can more clearly and rapidly receive and act on these warning message, which consequently reduces the response time of emergency units [16]. LEDs further demonstrate a longer lifespan and lower power consumption than other light sources, which comprise two of the reasons for the replacement of conventional road lights with LEDs. This replacement not only saves energy, but also reduces traffic incidents induced by faulty road lights.

A literature review showed that a large number of studies pertaining to lighting focus on LED. For example, Vienot, Coron, and Lavedrine [2] asserted that LED lighting can be employed to restore the original color of faded museum artifacts and avoid damage to exhibits resulting from direct intrusion. Hawes, Brunye, Mahoney, Sullivan, and Aall [17] designed four workplaces using LED lighting technologies to examine the perceptual, cognitive, and emotional states of people working in these workplaces. Findings showed that an increase in color temperature elevates positive emotions and sobriety, which consequently increases visual perception and the speed to recognize tasks. However, high color temperature light sources are not suited for all environments; rather, situational factors must also be considered. For example, warm-colored light sources are typically employed in households to create a relaxing environment; whereas cool-colored light sources are employed in workplaces to enhance a sense of coolness. The reason for employing different lighting is that such lighting impacts the psychological conditions of people. People tend to feel more comfortable and warm in an environment lit with lower color temperatures. By contrast, people tend to feel cold in an environment with higher color temperatures [18]. Physiologically, people tend to feel sleepy in an environment with insufficient lighting. Thus, full-spectrum lighting is widely employed to improve seasonal affective disorder caused by insufficient sunshine. In this context, numerous studies have endeavored to investigate the influences that lighting conditions have on the physiological conditions of emotion, memory, and processing speeds.

In addition to lighting, the use of LEDs in the representation of information is becoming increasingly prevalent. Wu et al. [19] researched LED display signs and found that people perceive less glare in an environment with high ambient light (30000Lux) than at night. Subsequently, the occurrence of glare was greatly reduced when the brightness/contrast ratio was 3:1 (Maximum L=3100 and Minimum L=1033 CD/m^2). Uchida et al. [20] asserted that the legible distance of variable message signs on engineering vehicles at night is reduced with an increase in brightness. However, if the background brightness of the signs is adjusted so that the brightness/contrast ration is 4:1 and 100:1, then the legible distance can be increased. The traffic information dashboards are typically placed on highways, intersections, and exit ramps because individuals without training are typically only able to remember five to nine chunks [21]. That is, when drivers read variable message signs, they require 1 s to read 4 to 8 characters excluding prepositions and 2 s to read 2 message units [22]. Therefore, placing traffic information dashboards at the entrance and exit ramps of highways can facilitate drivers to acknowledge traffic messages beforehand, thereby reducing message loss.

Currently, numerous studies pertaining to signs have been published. By using signs and icons to transfer messages, these studies examined the psychological feelings of the recipients to formulate more favorable designs. Ng and Chan [23] examined the cognitive characteristics of recipients when viewing road sign icons. The researchers conducted numerous tests to determine image familiarity, information correctness, representational meaning, and simplicity, proposed more humane road sign design directions based on the cognitive characteristics of the recipients. To examine the readability and icon interpretation of simple warning signs, Lin, Chen, and Lo [24] selected the management indicators employed by the Mass Rapid Transit system, such as warning and prohibited, to detect image readability and survey information loading. Lee, Chuang, and Young [25] conducted a readability comparison analysis between pictogram and ideographic warning signs. Findings showed that ideographic representation is superior over pictogram representation.

In summary of the abovementioned findings, numerous previous studies have examined the application of LED lighting systems in traffic signs. The findings of these studies have suggested that following the prevalence of incorporating LEDs into traffic-related applications, the conventional light sources used in road signs are gradually being replaced by LEDs. Findings further show that using the features of LEDs, information can be more clearly and rapidly transferred to viewers. However, these studies lack involvement. Therefore, in the present study, we collected and compiled the arrow styles used in foreign and domestic traffic signs. We then conducted a sensibility analysis on various arrow styles and representation methods based on an LED display method. In addition, we determined the degree of glare produced by different arrow styles when viewed from varying distances. By analyzing the results, we endeavored to determine the psychological feelings produced by the viewer's when viewing different arrow styles and identify the most important arrow compositions that influence viewer visibility and psychology. Moreover, we examined the representative sample of the participants with and without a driver's license to determine whether similar feelings were produced. The results obtained in the present study can be provided as a valuable reference for future arrow design and representation.

II. Screening of Arrow Samples

This study conducted surveys on the semantic perception of various arrow styles. The experiments were divided into two parts: The first part was the sample screening experiment, which collected arrow samples used as traffic signs in Taiwan, the U.S., the U.S., Japan, and German for experiments and testing. Five representative samples were found to serve as the research samples.

A. Participants

The participants were recruited from Tatung University, the number of whom were 30 (15 men and 15 women), aged between 18 and 30. Each of the participants signed an informed consent form. All the participants had vision corrected above 0.8 and the proportion of participants who had and did not have a driver's license issued by the R.O.C. government was 1:1.

B. Materials and Experimental Design

Arrow styles used as traffic signs in Taiwan, the U.S., the U.K., Japan, and Germany were collected to find the representativeness. The representation and frequency of the samples referenced the Traffic Control Guidelines for Expressway Construction, issued by the Directorate General of Highway. The involved arrow patterns amounted to a total of 16, as shown in Table I. Each pattern was represented in three methods: static, flashing, and sequential. The flashing and sequential methods were represented with a 40 times per minute frequency. Therefore, the sample screening experiment found 48 samples and the participants were required to take 48 tests.

TABLE I
SAMPLE SCREENING EXPERIMENT

I	II	III	IV
			
V	VI	VII	VIII
			
IX	X	XI	XII
			
XIII	XIV	XV	XVI
			

C. Experimental Equipment and Environment

This experiment focused on the screening of arrow samples, and the samples were displayed on a 24-inch computer screen, ENVISION P2 471hL. The screen resolution was set to 1280×1024; the experiment venue was a quiet room with an illuminance of 350 lux; the participants were distanced from the screen at 50 cm; the height of the desk was 70 cm; and the height of the chair was 40 cm.

D. Experimental Procedures

During the experiment, the computer screen displayed the experimental samples. The participants were asked to complete six evaluation scales according to how they felt after seeing each sample. The total number of questionnaires required to fill in were 48 for each participant. The questionnaire comprised Likert 5-point scales, which ranged from "strongly agree" to "strongly disagree." The first three questions were visual evaluation, the fourth and fifth were psychological evaluation, and the sixth was the overall evaluation of the samples.

E. Data Collection

The experimental questionnaire incorporated Likert 5-point scales: "strongly agree" was five points, and "strongly disagree" was one point. The results of the 30 questionnaires were compiled before the mean scores of all samples were sent to clustering with SPSS version 12. The representative samples were retrieved after the samples were grouped and the semantic experiment for the LED arrows were administered.

F. Sample Screening Experiment Results

Arrow styles as traffic signs used in Taiwan, the U.S., the U.K., Japan, and Germany were comprehensively collected. A categorization showed 16 arrow samples (Table I). Each of the samples was represented in static, flashing, and sequential. Therefore, a total of 48 samples were required for testing. The participants were asked to fill in an evaluation questionnaire of six questions after looking at each sample, and the experiment results would be cluster analyzed to screen five representative samples, which could serve as the experimental samples for the LED arrow semantic tests. The representative samples were listed in Table II.

Samples I and II were indicated in the static form. As compared to Sample II, Sample I had a different arrow style and a slimmer shaft. Moreover, the fletching of Sample I was ▶ shaped, whereas Sample II did not have fletching. Samples III and IV were both flashing. As compared to Sample IV, Sample III had a different arrow style and a slimmer shaft. Moreover, the fletching of Sample III was > shaped, whereas that of Sample IV was ◣ shaped. Different from the other four samples, Sample V was sequential and did not have a shaft. Identical to Sample III, the fletching was > shaped.

TABLE II
REPRESENTATIVE SAMPLES OF THE LED ARROW SEMANTIC EXPERIMENT

Number	I	II	III
Arrow style			
Representation	Static	Static	Flashing
Number	IV	V	
Arrow style			
Representation	Flashing	Sequential	

III. RESEARCH METHODS FOR THE LED ARROW SEMANTIC EXPERIMENT

The LED arrow semantic experiment focused on the representative sample extracted from the screening experiment. The samples were then displayed on the LED panel. The participants who had seen the samples were asked to complete the preference questionnaire, overall evaluation, and glare measurement scale. This experiment tried to examine the preferred design factors of arrows, as well as the correlation between arrow styles and distance, and glare and holistic experience.

A. Participants

The participants were recruited from Tatung University, the number of whom were 30 (15 men and 15 women), aged between 18 and 30. Each of the participants signed an informed consent form. All the participants had vision corrected above 0.8 and the proportion of participants who had and did not have a driver's license issued by the R.O.C. government was 1:1. During the experiment, the participants in physical conditions were able to leave immediately.

B. Materials and Experimental Design

Samples for Experiment II were selected from Experiment I (screening experiment). The five representative samples were displayed on the LED panel one by one. The participants, after looking at each sample, were required to complete a scale measuring the feelings, overall evaluation, and an evaluation questionnaire of glare perceived at different distances (8.7 and 27.7 m). The establishment of the preference questionnaire involved collecting and selecting appropriate adjectives describing the arrows. A total of 86 adjectives related to traffic, arrows, and driving psychology were comprehensively collected, and 30 participants were asked to employ Kansei engineering to categorize the top ten adjectives that were closely correlated to traffic and arrows (Table III).

TABLE III
THE ADJECTIVES IN THE PREFERENCE QUESTIONNAIRE

I	Dangerous–Safe	II	Untidy–Unified
III	Abstract–Concrete	IV	Accelerating–Decelerating
V	Panic–Calm	VI	Complicated–Simple
VII	Forbidden–Moving	VIII	Vague–Definite
IX	Negligible–Focused	X	Unreliable–Reliable

C. Experimental Equipment and Environment

The experiment simulated the visible distance of a general driving situation. The visual distance was equal to the sum of disappearing distance and reading distance. The LED panel adopted was shown in Fig. 1, which was half the size of the LED changeable message sign used by a general engineering vehicle. The experimental equipment was set up by re-calculating the visible distance and the disappearing distance (Fig. 2). However, due to the restriction of the experiment venue, the testing points were at 8.7 m between the disappearing distance and the reading distance and at 27.7 m, which was half of the reading distance. During the experiment, the two points were signified with two chairs to provide an eye height of 1.07m that corresponded to that of the driver.

The LED character generator was first set up upon the platform, and, subsequently, the LED panel was connected to the laptop. The arrow sample controlled by the panel was proportionately reduced to half the size of the changeable message sign on an engineering vehicle. To prevent from the effect on the participants, areas of samples that were not to be displayed were covered by black, plastic corrugated fiberboard. Orange was specified for the arrow as indicated in the Traffic Control Guidelines for Expressway Construction (Fig. 3).

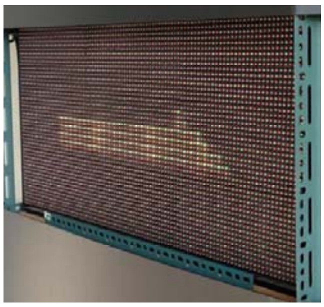

Fig. 1 LED character generator for the experiment

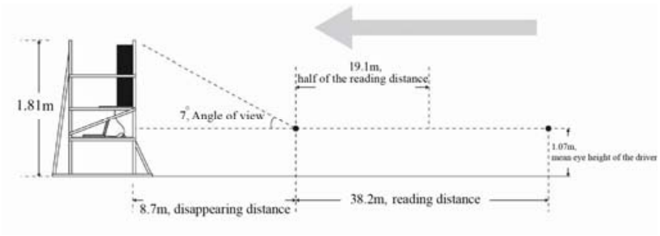

Fig. 2 Equipment setup range and visible distance

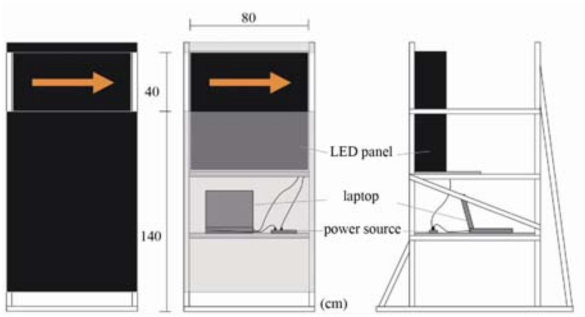

Fig. 3 Experimental equipment setup

D. Experimental Procedures

Before the experiment took place, the researchers would have to explain in details the purpose and procedures of the experiment and after the participants agreed to and fully comprehend the content and procedures of the experiment, the entire process could begin. The participants were asked to be seated at 27.7m to look at the arrow sample displayed by the LED panel. The experiment did not set time limits so that they could contemplate on their choices of preference. After seeing the arrow, they were asked to base on their psychological feelings to fill in the preference questionnaire, overall evaluation, and glare measurement scale. The participants would be asked to move forward to 8.7m after completing the scales and look at the arrow samples displayed by the LED panel in a sitting posture. In addition, they were asked to fill in the overall evaluation and glare measurement scale. These procedures should be repeated until all the samples were examined.

E. Data Collection

The preference questionnaire and the overall evaluation as well as the glare evaluation questionnaire were included in Experiment 2. The preference questionnaire was a Likert 5-point scale. On the left and right were respectively two opposite adjectives. The scores, from the left to the right, ranged from five to one. The higher the mean score indicated an inclination to the adjective on the left, and vice versa. Furthermore, a mean close to three did not show significance for the adjective. Finally, Quantification Theory Type I was adopted to investigate the preference for arrow design factors and adjectives.

The overall evaluation and the glare evaluation scale both adopted Likert 5-point scales. The mean was calculated by examining the overall evaluation, which ranged from five points (good) to one point (bad) from the left to the right. Quantification Theory Type I was again employed to investigate the correlation between arrow design factors and overall evaluation. The glare evaluation questionnaire also use five levels divided. In the end, Quantification Theory Type I was applied to examine the correlation between arrow design factors and glare.

F. Results of the LED Arrow Semantic Experiment

The correlation between arrow styles, design factors, and preferred semantics were expounded through examining the representative samples displayed on the LED panel. The experiment questionnaire comprised two parts: the preferential adjective questionnaire and the overall evaluation and glare evaluation questionnaire.

The preference for arrow styles semantics were experimented and analyzed with Quantification Theory Type I, the results of which implied the correlation between compositions of various arrows and the preferred adjectives. Table II shows immensely different compositions for each sample. The samples were displayed in static, flashing, and sequential, and the shaft consisted of thick shaft, slim shaft, and no shaft. The fletching included four styles, ▶, >, ◣, and none. Sample I was represented as static, with a slim shaft and ▶ fletching. Sample II was also represented as static, with a thick shaft and no fletching. Sample III was represented as flashing, with a slim shaft and > shaped fletching. Sample IV was also represented as flashing, with a thick shaft and ◣ shaped fletching. Sample V was represented as sequential, with no shaft and > shaped fletching. The experiment analyzed the adjectives to express feelings after the participants looked at the five arrow samples.

The partial correlation coefficient revealed that fletching was the most significant item (0.99) in the adjective of "dangerous–safe." Among the four fletching types, no fletching obtained the highest points (type points = 1.22), and > shaped fletching obtained the minimal points (type points = -0.64). According to the results, "no fletching" was the most significant item among the adjectives that implied danger, and "> shaped fletching" was the most significant item among the adjectives implying safety.

An analysis on the preference for dangerous and safe adjectives selected by the participants with and without a driver's license showed similar partial correlation coefficient. Moreover, the significant factors were fletching (0.999; 0.999). "No fletching" was the most significant item among the dangerous adjectives (type points = 1.41; 1.02), and "> shaped fletching" was the most significant item among the safe adjectives (type points = -0.68; -0.6).

The partial correlation coefficient revealed that fletching was the most significant item (0.97) among the compositions of arrow, among the adjectives indicating "untidy and unified." The most significant item of the untidy was "thick shaft" (type points = 0.44), and the most significant item of the unified was "no shaft" (type points = -0.49).

The partial coefficient correlation analysis on the adjectives of "untidy and unified" demonstrated the differences between the participants with or without a driver's license. The most significant factor influencing the participants with a driver's license was the shaft (0.97), and the most significant item of the untidy was "thick shaft" (type points = 0.49). The "no shaft" was the most significant item (type points = -0.57) of the unified. For the participants without a driver's license, the most significant factor was fletching (0.97). "◣ shaped fletching" was the most significant item (type points= 0.58) of the untidy, as the most significant item of the unified was "> fletching" (type points = -0.28).

The most significant arrow composition that influenced the "abstract and concrete" was fletching (partial correlation coefficient = 0.99). Among the four types of fletching, "no fletching" was the most significant among abstract adjectives (type points = 1.46), and the most significant concrete adjectives was "> shaped fletching" (type points = -0.73).

This study conducted an analysis on the participants with or without a driver's license in regards with their "abstract and concrete" adjectives. The results indicated similarity (0.999; 0.999) in the partial correlation coefficient. The most significant factors were fletching: The most significant abstract item of the abstract was "no fletching" (type points = 1.73; 1.19), whereas the most significant concrete item was "> shaped fletching" (type points = -0.8; -0.66).

The partial correlation coefficient showed that the most significant arrow composition that affected "accelerating and decelerating" was fletching (0.97). Among the four types of fletching, the most significant item of accelerating was the "◣ shaped fletching" (type points = 0.5), whereas the most significant item decelerating was "no fletching" (type points = -0.9).

This study conducted an analysis on the adjectives of "accelerating and decelerating" felt by the participants with and without a driver's license. The analysis results showed that fletching was the more significant factor (partial correlation coefficient = 0.993; 0.999) that demonstrated close partial correlation coefficient. The participants with a driver's license felt the most significant acceleration when seeing "> shaped fletching" (type points = 0.42), and felt the most significant deceleration when seeing "◣ shaped fletching" (type points = -0.88). The participants without a driver's license felt the most significant acceleration wen seeing "◣ shaped fletching" (type points = 0.74), and felt the most significant deceleration when seeing "no fletching" (type points = -0.92).

The most significant arrow composition that influenced the "panic and calm" adjectives was fletching (partial correlation coefficient = 0.997). The most significant item of the panic was "◣ shaped fletching" (type points = 0.74), whereas the most significant item of the calm was "▶ shaped fletching" (type points = -1.22).

Fletching was the most significant items that influenced "panic and calm" adjectives for the participants with and without a driver's license. The analysis showed similarity (partial correlation coefficient = 0.991; 0.999). The most significant item of the panic was "◣ shaped fletching" (type points = 0.57; 0.97), whereas the most significant item of the calm was "▶ shaped fletching" (type points = -1.22; -1.21).

The most significant arrow composition that influenced the "complicated and simple" adjectives was fletching (partial correlation coefficient = 0.936). The most significant item of the complicated was "◣ shaped fletching" (type points = 0.56), whereas the most significant item of the calm was "▶ shaped fletching" (type points = -0.46).

This study conducted an analysis on the adjectives of "complicated and simple" felt by the participants with and without a driver's license with five representative samples. The analysis results showed differences between the participants. The more significant factor that influenced the participants with a driver's license was the shaft (partial correlation coefficient = 0.973). The more significant item of the complicated was the "thick shaft" (type points = 0.41), whereas the most significant item of the simple was the "slim shaft" (type points = -0.42). For the participants without a driver's license, the more significant factor was fletching (0.937). The most significant item of the complicated was "◣ shaped fletching" (type points = 0.58), whereas the most significant item of the simple was "▶ shaped fletching" (type points = -0.48).

The most significant arrow composition that influenced the "forbidden and moving" adjectives was fletching (partial correlation coefficient = 0.983). The most significant item of the forbidden was "no fletching" (type points = 1.77), whereas the most significant item of the moving was "> shaped fletching" (type points = -0.96).

A partial coefficient correlation analysis showed close values of the "forbidden and moving" adjectives for the participants with and without a driver's license. The significant factor was fletching (partial correlation coefficient = 0.969; 0.992). Moreover, the most significant item that referred to the feeling of forbidden was "no fetching" (type points = 1.68; 1.86), whereas the most significant item that referred to the feeling of moving was "> shaped fletching" (type points = -0.82; -1.1).

According to the analysis results, the most significant arrow composition that affected the "vague and concrete" was fletching (partial correlation coefficient = 0.99). The most significant item of the vague was "no fletching" (type points = 1.75), whereas the most significant item of the concrete was "> shaped fletching" (type points = -0.94).

After looking at five representative samples that involved the "vague and concrete" adjectives affecting the participants with and without a driver's license, the results showed similarity (partial correlation coefficient = 0.987; 0.992). The more significant factors were all fletching, where the most significant item of the vague was "no fletching" (type points = 1.97; 1.53), and the most significant item of the concrete was "> shaped fletching" (type points = -1.06; -0.83).

The most significant arrow composition that influenced "negligible and focused" was fletching (partial correlation coefficient = 0.96). The most significant item of the negligible was "no fletching" (type points = 1.43), and the most significant item of the focused was "> shaped fletching" (type points = -0.8).

The partial coefficient correlation analysis after looking at the five representative samples showed that the participants with and without a driver's license exhibited similar results in the perception of "negligible and focused" adjectives (partial correlation coefficient = 0.951; 0.965). The most significant factors were all fletching, where the most significant item of the negligible was "no fletching" (type points = 1.36; 1.5), and the most significant item of focused was "> shaped fletching" (type points = -0.7; -0.89).

The analysis results found that the most significant arrow composition that influenced the "unreliable and reliable" adjectives was fletching (partial correlation coefficient = 0.979). The most significant item that was perceived as an unreliable adjective was "no fletching" (type points = 1.56), whereas the most significant item that was perceived as a reliable adjective was "> shaped fletching" (type points = -0.86).

After looking at the five representative samples, with which the participants with and without a driver's license perceived the "unreliable and reliable" adjectives, the results showed similarity. The more significant factors were all fletching (partial correlation coefficient = 0.993; 0.946). The most significant item of the unreliable was "no fletching" (type points = 1.84; 1.29), whereas the most significant item of the reliable was "> shaped fletching" (type points = -1.02; -0.7).

The five arrow representative samples at 8.7m obtained an average of three points for glare, indicating poor visual perception and higher glare for looking at the arrows from a distance of 8.7m. Besides the fourth sample at 27.7m, all other scores were between 3 and 4 points. From Fig. 4 we found that all five arrow representative samples had a lower glare at 27.7m than 8.7m, indicating significantly better perception when looking at the arrows at 27.7m.

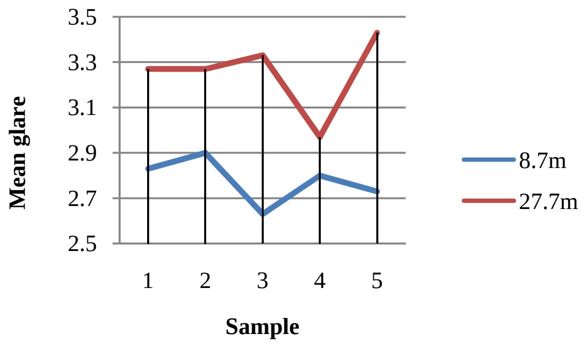

Fig. 4 Comparison of glare

Studying the partial correlation coefficient showed that all significant arrow compositions affecting the glare at 8.7m and 27.7m were all fletching (0.937; 0.979). The most significant item affecting 8.7m was "no fletching" (type points = 0.12), and the most significant item affecting 27.7m was "> shaped fletching" (type points = 0.13).

According to Fig. 5, the overall evaluation of the second sample was inferior at 8.7m and 27.7m. The first, third, and fifth representative samples obtained better scores at 27.7m than 8.7m, whereas the second and fourth representative samples obtained higher scores at 8.7m than 27.7m.

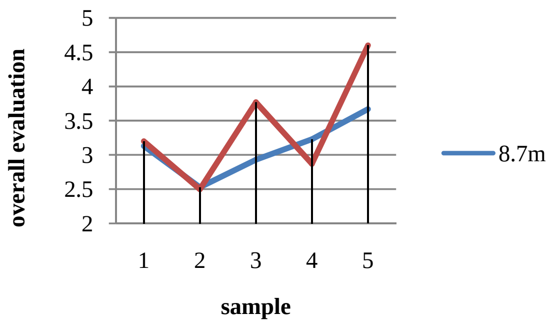

Fig. 5 Comparison of overall evaluations

Studying the partial correlation coefficient showed that the significant arrow compositions affecting the overall evaluation at 8.7m and 27.7m reflected differing patterns, and that affecting the overall evaluation at 8.7m demonstrated significance (partial correlation coefficient = 0.82). The "sequential" had the most significant influence (type points = 0.56). The most significant item affecting the overall evaluation at 27.7m was fletching (0.95), where "no fletching" had the most significant influence (type points = 1.21).

IV. Discussion

This study adopted 10 adjective combinations to investigate the influences between the arrow compositions. The subjective combinations were as followed: dangerous–safe; untidy–unified; abstract–concrete; accelerating–decelerating; panic–calm; complicated–simple; forbidden–moving; vague–definite; negligible–focused; and unreliable–reliable. Ou and Liu [26] and Ng and Chan [23] studied the design of signs and concluded with five design characteristics: familiarity, concreteness, simplicity, significance, and definite meaning. Their results correspond to the adjectives we extracted from the preferential questionnaires in the experiment. Furthermore, to increase the user-friendliness of the traffic signs and enhance their effectiveness when using them, we suggest prospective designers design and develop the signs based on their characteristics, and evaluate their appropriateness.

The results showed that fletching had the most significantly influence on Kansei adjectives among the three factors of representation, shaft and fletching, according to the results of the LED arrow semantic experiment. Moreover, the shaft had the most significant influence upon "untidy–unified" adjectives. Kirmizioglu & Tuydes-Yaman [27] studied drivers' comprehension on traffic signs and revealed that the drivers could clearly realize the directional indicators if the traffic signs were represented with "> shaped fletching." In addition to indicating directions, arrows are often considered more abstract in conveying meanings. Therefore, concrete meanings of arrows used as road construction signs could hardly be perceived, and the meanings could not be associated [28], [29]. After the arrow of the sign was represented by an LED panel, the results of this study indicated that the viewers could clearly specify their perceptions of the arrow, and most participants had the same perception for the same arrow. Moreover, this study specifically analyzed the experimental data of the participants with and without a driver's license. The result of the arrow semantic experiment did not show significant differences for most adjectives. "Untidy and unified," "accelerating and decelerating," and "complicated and simple" were the only three combination that were significantly influenced out of the ten combinations.

In the glare experiment we found that the participants might have lighter visual pressure when looking at the arrow from a greater distance (27.7m), and they were less likely to experience glare. Among the arrow factors "fletching" had the most significant influence on glare. It could be induced that due to the higher number of lights for representing the fletching, the illuminance was increased, thereby increasing the chance of glare, as compared to the shaft. Mainster and Turner [30] conducted research on the cause of glare and found that glare that results in uncomfortableness is induced by excessive illuminance of the light source. That explained why we found that the eyes were more perceptive to the illuminance of LED so that the glare at 8.7m was higher than that at 27.7m when looking the arrow. Whether people feel uncomfortable at glare depends on one's adaptation to illuminance or other artificial light sources (lights). Glare might result in squint, distraction, blink, tear, and aversion to light. Furthermore, traffic accidents could happen [31]-[35]. According to our results, the glare was lower and obtained better overall evaluation at a longer distance (27.7m). Therefore, when LED is to be applied to traffic signs, illuminance is first to be considered in case of glare that discomfort drivers' vision. Moreover, a similar proportion between the fletching and shaft may blur the vision at a larger distance, thereby resulting in superior overall evaluation at a closer distance.

V. Conclusion and Suggestions

By analyzing the representation of the five arrows in various traffic applications, this study aimed to discuss the imagery of the sign arrows. We hope to improve the arrow directional signs so that road users could quickly and accurately realize the imagery represented by the sign arrows. The most significant differences between past and existing sign arrows are representations. Previous representations included signpost or traditional bulbs for showing the message of the sign arrows. However, as LEDs are gradually adopted, traditional bulbs have been substituted by LEDs. In the experiment, we focused on the application of LEDs in sign arrows and observed how the participants perceived the signs.

Among the compositions of arrows, "fletching" significantly influenced adjective preference, and the design of fletching was of highest importance as it created various psychological feelings in the drivers. "No fletching" might be negligible due to its overly abstract and vague ideas, and therefore implied significant meanings of "danger" in the adjectives. Because a design without fletching can be visually indiscernible, the drivers might find imagery of deceleration or forbiddances. "> shaped fletching" conveyed a clear and definite imagery of arrow design that stands for safety, and "▶ shaped fletching" was a more common and universal arrow design that made people feel simple and calm. No significant feelings were attached to other adjectives. The design of "thick shaft" had a larger proportion and might impact the vision and create an imagery of untidiness. These results could be referenced in prospective design.

The glare evaluation research indicated that at a greater distance (27.7m), the participants would sustain smaller visual pressure and lower glare, and vice versa. At a longer distance, the eyes could easily adapt to the illuminance of the LED; at a shorter distance, the eyes were discomforted by the glare caused by excessive illuminance. The main element that affected glare was fletching. The lights indicating the fletching was obviously more concentrated and higher than the shaft. Therefore, it was more likely to see glare when looking at a close distance.

According to the overall evaluation research, at a longer distance (27.7m), visual perceptions were clearer and definite, and it was less likely to see glare. Thus, the overall evaluation was superior. However, a similar proportion between the fletching and shaft might result in inaccurate transmission of data at a longer distance, and the overall evaluation was better at a shorter distance.

The LED panel adopted in this study was half the size of that used by an engineering vehicle, and the experiment venue was proportionately reduced. Therefore, we suggest that future research could conduct a 1:1 experiment, and if possible, we hope that all samples should be implemented with LED panels. The results will draw a more definite line for the correlations between the adjectives and design factors. Moreover, future research should involve a wider population that consists of participants of all ages to examine whether age is a factor that influences preferences.

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Chia-Chen Wu was born in Taiwan. June 2013, she holds a Master degree in the department of product design, Ming Chuan University from Taiwan. Now she is a Ph.D. student in the Graduate Institute of Design Science at Tatung University. Her research interest includes cognitive psychology, service design, elderly learning ability and memory, and LED light source characteristics. She has published related research in Journal of Design and Human Factors Engineering conference in Taiwan.

Chih-Fu Wu is a Professor in the Department of Industrial Design and the Dean of Design College at Tatung University. He holds a Ph.D. degree in the Department of Mechanical Engineering from Tatung University. His research interests include Human Factors, Integrated CAD/CAM Systems, and Universal Design.

Pey-Weng Lien is a Product Design in wistron. She holds a Master degree in the Department of Industrial Design at Tatung University, Taipei, Taiwan. Her research interest includes product design and user experience.

Kai-Chieh Lin comes from Hsinchu, Taiwan and her birth July, 17. She is a Ph.D. student in the Graduate Institute of Design Science at Tatung University. She holds a Master degree in the Department of Industrial Design from Tatung University, Taipei, Taiwan. Her research interest includes universal design, product design, graphic design, human interface and interactive design. She is a Product Project Designer in a medical & healthcare company.