Traffic Sign Comprehension: a Review of Influential Factors and Future Directions for Research

Tingru Zhang, Alan H.S. Chan

Abstract— **Traffic signs are effective only when users clearly understand their meaning. This paper reviews recent studies concerning traffic sign comprehension and finds that unsatisfactory comprehension is a common problem for drivers in many countries. The influence of user characteristics and sign cognitive features on understanding levels are summarized and discussed. While the positive relation between comprehension level and educational background is confirmed by various researchers, conclusions about effects of other factors are not unanimous. Finally, possible future traffic sign comprehension research topics and directions for future research are proposed to fill the present knowledge gap.**

Index Terms—**traffic sign comprehension, user characteristic, sign cognitive feature**

I. INTRODUCTION

TRAFFIC signs use symbols with different shapes, colors and sometimes with the assistance of words and labels to regulate road traffic. They are the most commonly used devices for controlling traffic [1]. Well-designed traffic signs with clear symbols can communicate instructions quickly and are useful to road users with reading difficulties [2]. According to Dewar, the most important factor for a well-designed sign is the understandability of the sign [3]. Pline pointed out that to be effective, signs should satisfy the following requirements: fulfill a need, command attention, convey a clear and simple meaning, command respect of the road users and give adequate time for proper response [4]. Among these requirements, the third one (convey a clear and simple meaning) emphasizes the need for signs to be intelligible. So, for successful application of traffic signs they must be accurately comprehended by users.

Research concerning traffic sign comprehension dates back to 1966. Early studies focused on evaluating user understanding levels of local traffic signs and most of the results indicated that the general comprehension performance was far from satisfactory [5]. Some research further investigated individual differences in performance on comprehension test and proposed that user characteristics like age, gender, driving experience, education background etc. might significantly influence comprehension level. More recently, the effects of sign cognitive features including familiarity, concreteness, simplicity, meaningfulness and semantic distance have been explored. This paper reviews research on the ability of drivers to understand traffic signs and summarizes techniques used in evaluation. Work from previous studies on the effects of both user and sign characteristics are also analyzed and summarized. Some possible factors and the future directions of research on this topic are also proposed.

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II. COMPREHENSION LEVEL AND MEASUREMENT

Accurate understanding is a dominant factor for the effectiveness of a traffic sign system. With poor comprehension, memory for sign meanings and the likelihood of prompting effective driver reactions will decrease [6]. Some unfamiliar and ambiguous signs may even give drivers an impression that they are allowed to take certain actions although in fact it may be dangerous to do so [7]. Lack of comprehension or misunderstanding may reduce the intended benefits of traffic signs or, even worse, may actually cause a traffic sign to become the main reason for an accident.

According to ISO 3846 (2002), signs are considered acceptable when a level of at least 67% accuracy is obtained in a comprehension test [8]. The American National Standard Institute (ANSI) is stricter and has a criterion of 85% accuracy. Based on these criteria, studies have shown that lack of traffic sign comprehension is a serious problem in many countries. For example, Ogden et al. interviewed 205 motorists in the US and found that the respondents had some difficulty in interpreting both word and symbol messages on signs [9]. Another study showed that out of all the 85 standard traffic symbols used in the U.S., only 16 were understood by more than 95% of motorists and the rest could not be comprehended well by most drivers [10]. Even worse, 10 signs were understood by less than 40% of motorists. Similar comprehension problems were found in Turkey, which is an important transport hub between Europe and Asia [11]. A survey found that of the 30 signs investigated, only 12 were considered "well known" eliciting over 70% correct responses; 13 of the signs were either "partially known" or produced "no comments". Surprisingly, there were five signs, for example, "Minimum speed limit", where more than 10% of drivers interpreted the meaning as opposite to the intended meaning. Such opposite interpretation may create situations

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more dangerous than not knowing the meaning of a sign, because such drivers may perform undesirable and prohibited actions. Since a lot of research has shown that drivers exhibit unsatisfactory comprehension of many signs, it seems imperative that traffic administration institutes and/or governments must take action such as reviewing sign design, training courses, and publicity and promotional events, in order to strengthen driver comprehension of signs.

Both open-ended questions and multiple-choice questions (MCQs) can be used to measure driver comprehension of traffic signs. Open-ended would allow drivers to verbally describe the meaning of the sign and then several judges with adequate sign knowledge should independently judge the correctness of the answers. In some studies, responses were classified into one of the four categories: correct and complete, partially correct, incorrect or opposite meaning [11-13]. The conventional format of MCQs includes three components: the stem, the correct answer, and several incorrect but plausible answers or distractors [14]. The format characteristics of a multiple-choice question such as quality of the wrong answers, number of options or order of the correct answer usually influence the difficulty and discrimination of MCQs. Compared with open-ended questions; the multiple-choice question method can reduce time, cost and analysis effort, and help the respondents who have difficulty to better communicate their ideas. Table I is a summary of different testing methods, together with other experimental information, used in various previous research.

III. User Characteristics

The fact that comprehension level varies among individuals encouraged researchers to explore the relations between understanding and characteristics that are associated with the users themselves. Factors like age, gender, driving experience, culture and education background have most often been analyzed, while marital status, monthly income, and last time driving have also been tested [11, 15, 16]. However, results concerning the influence of user characteristics have not been unanimous due to the use of different study sample populations, diverse experimental and analytical methods or other various uncontrolled conditions. Nevertheless, the following sections will review studies on age, gender, driving experience, education and cultural background.

A. Age

It has been generally found that age does not affect comprehension of traffic signs and even where there is some impact, there is no consensus concerning the trend of the impact. Hawkins Jr et al. found that misunderstanding of over two thirds of the signs that they tested were not related to age [17]. No significant differences among three age groups (18-27 years; 28-37 years; 38-57 years) in comprehension performance were observed in a survey done by Ng and Chan

TABLE I
SUMMARY OF TESTING METHODS USED IN TRAFFIC SIGN COMPREHENSION RESEARCH

Year	Author	Sample Size	Country	Tested Signs	Equipment	Testing Method
2012	Kirmizioglu	1478 drivers	Turkey	39 signs with new and old version of the same signs on different questionnaires	Colored pictures on questionnaires A and B	Open-ended questions that can be answered either verbally or in writing. Answers were evaluated by one person.
2012	Ou & Liu	30 Taiwanese and 30 Vietnamese drivers	Taiwan	203 traffic signs: 50 warning 75 prohibition 63 indicatory 15 auxiliary	not mentioned	Verbally describe sign meanings and answers were evaluated by three scorers
2010	Ng & Chan	109 Hong Kong drivers	Hong Kong	21 signs using only symbols	Color and square paper display	Four-option multiple-choice questions
2008	Lesch	43 drivers	U.S.	92 safety symbols not limited to transportation	Software-controlled display on computer	True-false questions
2003	Shinar et al.	250 for each country	Canada, Finland, Israel and Poland	31 highway signs with some unique to one country while others used in more than one country	Card display	Verbally described sign meanings and answers were evaluated by experimenters
2002	Al-Madani et al.	4774 drivers	5 Arab counties	28 posted signs: 18 regulatory 10 warning	Colored pictures on questionnaires	Multiple-choice questions on testing comprehension and short-answer on personal characteristics
1994	Dewar	480 drivers	U.S.	85 traffic signs in US	Projected color slides	Open-ended questions
1993	Hawkins Jr et al.	1745 drivers	U.S.	38 signs: 13 regulatory 18 warning 7 pavement markings	Videotape	Multiple-choice questions
1990	Ogden et al.	205 drivers from farm-to-work area	U.S.	Work zone signs	Videotape	Choice-based questions & interviews
1988	Richards & Heathington	176 drivers 35 police officers	U.S.	Railroad grade crossing traffic control devices (signs and markings)	Pictorial	16 multiple-choice questions
1979	Hulbert &Fowler	3164 motorists	U.S.	16 traffic control signs, signals and markings	Motion picture test film	Multiple choice questionnaires

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[12]. However, the "old" group defined in this study was much younger than the "old" participants in other similar research, so in order to have a deeper and better understanding of the age effect, the performance of more drivers of advanced age should be analyzed.

Some studies have shown that young drivers have an advantage in understanding signs. For example, Dewar found that approximately 39% of US traffic signs were better understood by young drivers both before and after modifications to some of the symbols [10]. This was also true in Saudi Arabia, where Al-Sharea found that younger drivers possessed much more traffic safety knowledge than older drivers [18]. Possible reasons for the better performance of younger drivers include: they may have passed the driving test relatively recently so they should have a fresh memory of the meanings of the signs; also, young people have generally better information processing capabilities as well as better vision than old drivers [19].

Opposing results concerning an age effect have also been reported. Richards and Heathington conducted a survey of motorist comprehension of railroad grade crossing traffic control devices (signs and signals) and found that both very young drivers (under 19 years) and elderly drivers (over 54 years) had difficulty in understanding and recognizing such devices [16]. Hulbert et al. studied the understanding that over 3000 drivers had of eight traffic signs in the U.S. and concluded that there were significant differences in comprehension among different age groups: comprehension level was 70% on average for young drivers (under 24 years), 79% for middle-aged drivers (between 24 and 50 years old) and 72% for the old group (over 50 years) [20].

In summary, clear differences exist between research results regarding age-influence on driver understanding capabilities of traffic signs probably because of the differences in types of signs used, study methods, samples, definitions and limitations.

B. Driving experience

Before discussing the influence of driving experience, it is necessary to consider the ways in which it is measured because there are no commonly agreed criteria. Some studies have used a definition from Simpson, that driving experience can be taken as number of years licensed [21]. Al-Madani reported that there was a small increasing trend of sign comprehension with years of driving and those with at least two decades of experience performed significantly better than those with at most five years of experience [7]. However, as there might be a high correlation between age and experience, the effect of experience with age constraint involved was further explored in a follow-up study by Al-Madani et al. [1]. They only explored one age group and the results showed that experience had no significant influence when drivers were 45 or older. Ng and Chan proposed that actual years of active driving and hours of driving in the 12 months prior to the study should be additional measurement for driving experience, as there were situations where licensed drivers rarely drove after obtaining a driving license [12]. Using the three different indicators, they concluded that comprehension level was not related to the factors of years of active driving and hours of driving in past 12 months, but was found to be negatively correlated with years licensed.

C. Gender

Many previous studies on gender have shown that males were generally better than females with regard to traffic sign comprehension. Al-Madani et al. found that male driver comprehension of posted signs was better than that for females in Arab as well as European and American countries [15]. In research reported by Hawkins Jr et al., men were better in correctly identifying one fifth of warning signs [17]. The causes of such phenomenon may be complex. There were no explanations given by the authors. It may be due to the congenital difference in space perception or intellectual functioning or different cultures and exposure rates to signs between males and females. For example, in some Middle Eastern countries females have very much more restricted lives than males and in some places are not allowed to drive at all.

When education background is controlled for, the differences between males and females may become less remarkable. A study has demonstrated that when European and American male and female drivers with at least undergraduate degrees were compared, gender had no statistically significant impact [1]. It was found in a recent study by Ng and Chan, that for males and females of similar education levels, there was no significant difference between them for traffic sign guessability [22].

D. Education background

Several attempts have been made to explore possible associations between comprehension and educational level. A recent study by Al-Madani et al. found that drivers with bachelor's or higher degree had better understanding of post signs than those with lower educational background [15]. A similar conclusion was reached by Ng and Chan [12]. In an experiment investigating Hong Kong driver comprehension of local traffic signs, Ng and Chan found that comprehension scores were higher for those with university education or above than for those without a university education or above. This might be reasonably explained since in general people with high education level are more likely to have had experiences to encourage them to be quick learners, use their memories and have better information processing abilities.

E. Culture background

Among some of the different nationality groups tested it has been found that drivers from Europe and America scored highest while those from Arabian States performed worst [15]. This may be due to the higher educational qualifications of the European drivers compared to others even when age and education are controlled. Using 31 traffic signs from four countries (Canada, Finland, Israel and Poland), Shinar conducted a cross-culture traffic sign comprehension study [23]. The sample consisted of 250 unpaid volunteers in each country and they were tested on comprehension performance on both local and non-local traffic signs. As expected, drivers' performance on local signs was remarkably better than non-local signs: 77.9% and 32.4% were perfectly identified separately. ANOVA analysis also indicated that the main effect of country was significant on comprehension

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performance. Ou and Liu studied the comprehension of Taiwanese traffic signs by two user groups: Taiwanese and the second biggest foreign group in Taiwan, the Vietnamese [13]. The results showed that Taiwanese had better understanding compared to Vietnamese participants and a possible reason, according to the authors, was the different traffic sign design principles in different cultures. However, both groups showed similar performance immediately after a training programme, which partially demonstrated the effectiveness of training.

IV. Sign Characteristics

Five characteristics were proposed by Mcdougall as contributing to icon usability: familiarity, concreteness, complexity, meaningfulness and semantic distance [24]. Familiarity measures the frequency of user encounters with the symbols. Concrete symbols depict objects, people and materials that are familiar to people in the real world while abstract symbols use simple lines, shapes, etc. to communicate information. Many studies have found that concrete symbols are better in representing information, as they appear to be more consistent with the obvious visual images compared to abstract symbols [25, 26]. Complex signs contain a lot of details while simple signs do not. As extraneous decorative parts are likely to confound understanding of signs, it is suggested that drivers will perform better with simple signs than complex signs. Meaningful signs can convey certain messages that make users aware of what to do or what not to do. The more meaningful a sign is, the more likely that it will be understood correctly by users. Semantic distance is used to measure the relatedness or closeness of a symbol and what it is intended to represent.

Prospective drivers in Hong Kong with no traveling experience in Mainland China were asked to give subjective ratings on these five characteristics for 120 Mainland China traffic signs. The results showed that the Hong Kong participants perceived the test signs as moderately unfamiliar, concrete, simple, meaningful and semantically close [27]. Pearson correlation analysis was used to explore the interrelationships between the sign features and it was found that while concreteness had high and positive correlation with meaningfulness, semantic closeness and familiarity; simplicity only correlated with familiarity. A similar experiment was conducted by the same researchers to further examine relationships between sign characteristics and understandability using Hong Kong traffic signs [12]. Surprisingly, only familiarity showed a significantly positive relation with the testing score. This conclusion conflicts with the result from a more recent study. When studying the effects of sign design features on Taiwanese and Vietnamese user comprehension of traffic signs, Ou and Liu concluded that all five characteristics were correlated with comprehension for both groups with only one exception: simplicity had no significant influence on the performance of the Taiwanese [13].

V. Future Directions for Research

Most of the research to date analyzes the effects of user characteristics separately. However, possible interactions may exist among those factors. This offers the research community a challenge to determine the interactive effects of factors such as age, driving experience or educational level and examine their combined influence on the comprehension abilities of drivers.

Currently, cross-country, or cross-border driving is becoming more and more common as the world is becoming a global village due to increasing multinational co-operation and communication (e.g. Hong Kong and Mainland China). In most cases, drivers will not be trained to deal with foreign traffic system before driving in a new environment; therefore it is likely that their driving activity may not fully comply with the instructions of traffic signs. Few attempts have been made to investigate visiting driver comprehension of foreign signs. A survey comparing driver comprehension levels for local and non-local signs would no doubt help detect possible problems in understanding foreign signs.

There is no doubt understandability varies among different signs. Some signs can be easily understood without much training while the others are hard to comprehend. Current research has not clarified the key design factors that make a sign easy to comprehend. So, the effects of sign design features on comprehension needs to be investigated further. Also, very little research attention has been given to the possible influence of words on the understandability of signs. Therefore, further studies focusing on the effect of words on sign comprehension, whether or not words should be added to traffic signs, the best number of words used or the influence of bilingual words is necessary and would be beneficial.

VI. Conclusion

This paper attempted to give a systematic summary of influential user factors and sign characteristics on traffic sign comprehension. Generally, drivers with higher educational background performed better in comprehension tests, but there is no consensus on the influence of age, gender or cultural background. Clearly, drivers understand familiar signs better than those less frequently encountered. Further investigation is required to clarify the effects of other sign features. With increasing communications among countries, studies concerned with the interactions among user characteristics and the comprehension issues of cross-border drivers are necessary.

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