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The effects of driver factors and sign design features on the comprehensibility of traffic signs

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Abstract

Problem: This paper addresses the effects of driver factors and sign design features on the comprehensibility of traffic signs. *Methods*: A survey was designed to capture subjects' personal particulars, ratings on sign features, and comprehension scores, and then administered to 109 Hong Kong full driving license holders. *Results*: Years with driving license and education level were significant predictors of sign comprehensibility. Contrary to expectation, the driver factors of age group, years of active driving, hours of driving, last time driving, driving frequency, and non-local driving experience had no effect on comprehension performance. Sign familiarity was correlated with comprehension score for licensed drivers, whereas sign concreteness, simplicity, and meaningfulness were not. *Impact on Industry*: The results of this study provide useful guidelines for designing more user-friendly traffic signs in the future. It identified particular driver groups who lacked good understanding of traffic signs, and this information may assist the relevant organizations to better allocate traffic training resources, and better target future studies of traffic sign comprehension.

Keywords: Traffic signs; Drivers; Sign features; Comprehensibility

1. Introduction

The relationships between the understanding of traffic signs and driver factors such as marital status, monthly income, and seat belt usage have been studied (Al-Madani, 2000; Al-Madani and Al-Janahi, 2002a,b). Al-Madani and Al-Janahi (2002a) showed that comprehension of traffic signs generally increased with drivers' age. However, Dewar, Kline, and Swanson (1994) found that drivers in the older age groups (60 years or above) understood traffic signs more poorly than the younger ones (18–59 years). Al-Gadhi, Naqvi, and Abdul-Jabbar (1994) also found that older drivers had a lower comprehension level of traffic signs, which might be due to the reduced vision, attention, and information processing abilities of older people. It seems that previous research did not arrive at a consensus on the effect of drivers' age in sign comprehension. Regarding the education factor, Al-Madani and Al-Janahi (2002b) revealed that the comprehension level of traffic signs increased with drivers' education level in Saudi Arabia. In much of the previous research on sign comprehension, though the factor of driving experience was examined, not much detail was given as to how it was measured. Simpson (2003) defined driving experience in terms of number of years licensed. However, there may be some licensed holders who rarely drive after they obtain driving licenses. Thus, driving experience needs also to be considered in terms of actual years or hours of active driving.

A review of previous research indicated that there were no studies of traffic sign comprehension addressing the issue of last time driving and driving frequency. Study of the contribution of driving frequency to sign comprehension may lead to understanding about differences in comprehension levels reached by those driving frequently, occasionally, or those who have not driven for an extended period of time. It seems likely that there will be some decrement in performance after a user has not performed a particular task with a product for a comparatively long period of time (Jordan, 1998). Sign comprehension performance would decrease with the increase in the period of not driving, and that the comprehension level of traffic signs would be directly proportional to the frequency of driving.

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Henderson (1999) showed that retroactive interference occurs when new and somewhat similar information disrupts retrieval of information learned earlier. Hence another driver factor that needs to be studied is non-local driving experience, which would have a negative effect on the comprehensibility of local traffic signs.

The review above indicates the need of a systematic study of the effects of some driver factors on sign comprehension. The factors deemed to be of importance to be investigated were: age, education, years with driving license, years of active driving, hours of driving, last time driving, driving frequency, and non-local driving experience.

It is obvious that the success of effective communication of sign messages may not only relate to the user factors, but also the signs themselves. The terms icons, symbols, and signs often appear and are used interchangeably in the literature. According to McDougall, Curry, and de Bruijn (1999), instead of considering icon attributes that are self-evident (e.g., color and shape) or those that can be identified only in relation to other icons (e.g., discriminability), the icon features like familiarity, concreteness, complexity, meaningfulness, and semantic distance are of central concern in icon research. Familiarity is the frequency with which icons have been encountered. Icons are concrete if they depict real objects, materials, or people; those that do not depict real objects are abstract. Icons are regarded as complex if they contain a lot of detail or are intricate, and simple if they only contain few elements or little detail. Meaningfulness refers to how meaningful people perceive icons to be. Semantic distance is the closeness of the relationship between what is depicted on an icon and what it is intended to represent. The relationship between sign features and sign comprehension has been studied earlier by the authors with a group of prospective users (Ng & Chan, 2007). The findings showed that guessability score of traffic signs for prospective drivers varied with familiarity, concreteness, simplicity, meaningfulness, and semantic closeness. The associations were re-examined here with a group of licensed drivers and an additional matter investigated here was the effects of sign design features on the comprehensibility of traffic signs for licensed drivers.

In this study, the effects of driver factors and sign design features on the comprehensibility of traffic signs were assessed in a small-scale pilot survey with a convenience sample of licensed drivers. The authors hope that the findings will provide useful information and recommendations for designing more user-friendly traffic signs, identify the particular driver groups who lacked good understanding of traffic signs so as to assist the related organizations to better allocate traffic training resources, and give suggestions for future studies in traffic sign comprehension.

2. Method

A small-scale survey based on a convenience sample was designed for capturing subjects' personal particulars, ratings on sign features, and comprehension scores, and then administered during the period from October to December 2005 for Hong Kong (HK) full driving license holders. Details of the survey are given in Section 2.2.2.

2.1. Sample

There were 1,767,821 full driving license holders at the start of the study period in September 2005 (Hong Kong Transport Department, 2005a). Sampling was needed for such a large population, and it was necessary to determine sample size for the study and to choose a representative sample of the population. From the sample size determination table (Rea & Parker, 1997), the minimum sample size required for the ±10% margin of error and 95% confidence level was 97. As a list of eligible units composing a population from which to sample was not obtained, the available resources could only allow the use of a sample of convenience. A disadvantage of convenience sampling is that it can restrict the generalization of results to the population outside the survey (Fink, 1995). Seventy City University of Hong Kong students meeting the criteria of 'holding HK full driving license' were asked to participate in the survey. To tap into a larger and wider spectrum of driving license holders and increase the response rate, 39 members of the Hong Kong Automobile Association (HKAA) and Hong Kong Motor Car Association (HKMCA) were invited to participate in the survey. The ages of the respondents were between 18 and 57 years (median = 32.5 years) and there were 100 males and 9 females. Most respondents were non-occupational drivers (94%) and had HK driving test experience (94%).

2.2. Survey instrument

2.2.1. Traffic signs

The first step in developing the survey instrument was to identify the traffic signs to be evaluated in the survey. Two criteria were set for the choice of signs for use: first, their messages are conveyed with symbols only; second, they are not used in accompaniment with other signs for transmitting a message. There are 178 signs contained in Hong Kong Schedule 1 (Traffic Signs) of the Chapter 374G (Road Traffic Regulations) of Legislation Database and 82 of them satisfy the two characteristics for selection. A long survey was undesirable, so only 21 of the 82 signs were randomly selected for testing. They were displayed in color and in squares of 1.28 cm × 1.28 cm (without boundary) on paper in the survey (Table 1).

2.2.2. Survey

A self-administered survey was designed to gather information about subjects' personal particulars, ratings on sign features, and sign comprehension scores. For effective communication, the Chinese version of the survey was used for testing. The first part of the survey asked about subjects' personal characteristics and driving habits. The first two questions served as screener questions for determining which respondents went on to subsequent questions. Personal driving experience was then assessed with questions asking about the years with license and years of active driving. Respondents were required to report exact quantities in an open-ended format. The next three questions were about last time of driving,

Table 1
Hong Kong traffic signs used in the experiment

Sign number	Traffic Sign	Meaning	Sign number	Traffic Sign	Meaning
I1		Pass either side	I2		The distance to an exit from a road: 200 m
I3		No through road	I4		Appropriate traffic lanes at junction ahead
I5		No through road on side road to left	R1		Rickshaws and pedestrian-controlled vehicles prohibited
R2		Pedestrians, pedestrian operated vehicles, bicycles, and tricycles prohibited	R3		No pedestrians
R4		Footway and cycleway	R5		Light rail transit vehicles or trams only
W1		Two way traffic	W2		Barricade
W3		Staggered junction left turn first ahead	W4		Level crossing with barrier ahead
W5		Loose chippings ahead	W6		Diversion to another carriageway to right ahead
W7		Bus lane only	W8		Advance direction sign for side roads
W9		Pedestrian on or crossing road ahead	W10		Dual-carriageway road ends
W11		Road narrows on both sides ahead			

Notes: R - regulatory signs; W - warning signs; I - informatory signs.

driving frequency, and driving hours per trip. The driving frequency and driving hours per trip in a short interval (past 6 months) and long interval (past 12 months) were assessed. By using the data of driving frequency and driving hours per trip in the past 6 months (or 12 months), the cumulative number of driving hours in the past 6 months (or 12 months) was evaluated. Another question was for evaluating subjects' non-local driving experience. The last four questions used categorical response options to ascertain subjects' demographic information on occupation, education level, gender, and age.

The second part of the survey was about traffic sign features and comprehension. Respondents were asked to give subjective ratings between 0 to 100 points for familiarity (0=very unfamiliar, 100=very familiar), concreteness (0=definitely abstract, 100=definitely concrete), simplicity (0=very complex, 100=very simple), and meaningfulness (0=completely meaningless, 100=completely meaningful) for the signs. They were also asked to complete a set of multiple-choice questions for the signs for evaluating their understanding of traffic signs. Four-option multiple-choice questions were designed as they could greatly diminish the risk of guessing by subjects (Newby, 1992). The selection choices, with one correct answer and three plausible distractors, were extracted from the common mock written tests provided by the government designated driving schools and private driving schools.

2.3. Pilot testing and assessing validity

Before distribution of the survey to the test subjects, a pilot test for the survey was conducted to estimate survey completion time and to find out whether the questions served the survey purposes, had the correct wording, and response categories and ordering. To assess how well a survey measures what it is intended to measure, the validity of a survey is usually assessed by individuals with expertise in some aspect of the subject under study (Litwin, 1995). Face and content validity of this survey were assessed by experienced staff of the HKAA and HKMCA who were invited to comment and suggest changes for the survey.

2.4. Survey administration

Each participant was briefed on the objectives of the survey and given verbal instructions at the beginning of the test.

Subjects were asked to complete the demographic information first, then the quantification of traffic sign features, and finally the traffic sign comprehension. An interviewer guided each respondent through the survey, if necessary. The interviewer also checked each returned survey to ensure that no items were unfilled. Two hundred and thirty three subjects were interviewed, 120 of them did not satisfy the criteria of 'holding HK full drivers license' and thus did not proceed with the survey. Amongst the 113 subjects with a driving license, four (3.5%) did not successfully complete the whole survey and the remaining 109 subjects' responses were used for analysis.

3. Results

3.1. Comprehension score

The comprehension scores for the four-option multiple-choice questions were adjusted to make allowance for the effects of guessing by using Akeroyd's (1982) technique: 1 mark for correct answer only, 0.5 mark for two answers indicated and one is correct, 0.25 mark for no answer given, and 0 mark for incorrect answer or combination of answers. The mean and standard deviation of comprehension score for all signs were 69.97% and 27.42%, respectively. The signs with minimum (6.65%) and maximum (99.08%) comprehension score were level crossing with barrier ahead (W4) and two-way traffic (W1), respectively (Table 2).

The International Organization for Standardization (ISO) and the American National Standard Institute (ANSI) recommend that symbols must reach a criterion of at least 67% or 85% correct, respectively, in a comprehension test to be considered acceptable (Wolff & Wogalter, 1998). There were seven traffic signs reaching both the ISO and ANSI criteria, viz. light rail transit vehicles or trams only (R5; 88.07%), no through road (I3; 89.91%), bus lane only (W7; 90.14%), no pedestrians (R3; 90.83%), footway and cycleway (R4; 93.58%), road narrows on both sides ahead (W11; 96.33%), and two way traffic (W1; 99.08%). Another eight traffic signs achieved the lower criteria of ISO only, namely the distance to an exit from a road 200 m (I2; 69.27%), barricade (W2; 71.79%), loose chippings ahead (W5; 71.79%), pass either side (I1; 78.90%), dual-carriageway road ends (W10; 78.90%), no through road on side road to left (I5; 81.65%), rickshaws and pedestrian-controlled vehicles prohibited (R1; 82.80%), and advance direction sign for side roads (W8; 83.49%).

A box plot of comprehension score for all signs showed that sign W4 (level crossing with barrier ahead) and sign R2 (pedestrians, pedestrian operated vehicles, bicycles, and tricycles prohibited) were marked as outliers below the box, indicating that the comprehension scores for these two signs (W4 – 6.65%, R2 – 12.16%) were much lower than that of other signs. For sign W4, 6.42% of the subjects successfully identified it and other subjects interpreted it as 'a gate or barrier ahead' or 'railway crossing ahead with gate or barrier.' For sign R2, 11.93% of the subjects correctly comprehended its meaning and other subjects identified it to be 'no bicycles,' 'no pedestrians and cyclists,' or 'no pedestrians.' The comprehension performance for each subject was in the range from 42.86% to 90.48% (mean = 69.97%, standard deviation = 10.63%).

Table 2
The signs with minimum and maximum comprehension score

	Sign		Correct meaning	Comprehension score (%)
The lowest three	W4		Level crossing with barrier ahead	6.65
	R2		Pedestrians, pedestrian operated vehicles, bicycles, and tricycles prohibited	12.16
	W9		Pedestrian on or crossing road ahead	26.61
The highest three	W1		Two way traffic	99.08
	W11		Road narrows on both sides ahead	96.33
	R4		Footway and cycleway	93.58

Notes: R-regulatory signs; W-warning signs.

3.2. Driver factors

Table 3 shows the driver factors, the number of subjects' responses to each of the factors, and the comprehension performance of the subjects in each of the response categories. The major findings were: (a) most respondents (57%) were in the age group of 18–27 years, 32% were in the age group of 28–37 years, and 11% were in the age group of 38–57 years; (b) amongst the 91 respondents that had been driving in HK since obtaining HK full driving licenses, 43% said that their last time driving in HK was today, 46% one day ago to less than one year ago, and 11% at least one year ago; (c) only 30% of the participants drove outside HK (e.g., Mainland China, the United Kingdom, Australia, Canada, Thailand, Taiwan, Macau, America, and Japan) and the remaining 70% did not.

3.3. Relationships between driver factors and comprehension performance

Four of the driver factors were continuous variables, namely, years with license, years of active driving, last time driving, and hours of driving. The remaining four factors were categorical variables. Analysis of variance (ANOVA) and Kruskal-Wallis test were conducted to examine whether there were any statistically significant differences in comprehension performance among different levels of each categorical driver factor. The assumptions underlying ANOVA and Kruskal-Wallis test

Table 3
A summary of responses for the eight driver factors and mean comprehension performance for different groups of subjects

Driver factor	Response	Number	Comprehension performance (%)	
			Mean	Standard deviation
Age group	18–27 years	62	71.83	9.43
	28–37 years	35	68.45	12.05
	38–57 years	12	67.30	10.17
Education level	Below university	27	65.43	10.49
	University or above	82	71.46	10.31
Years with license	Less than 1 year	14	74.83	7.34
	1 to less than 2 years	12	71.83	11.74
	2 to less than 4 years	20	71.49	11.67
	At least 4 years	63	68.05	10.44
Years of active driving	Less than 1 year	31	73.58	8.32
	1 to less than 2 years	14	69.39	9.10
	2 to less than 4 years	19	70.24	13.46
	At least 4 years	45	67.54	10.78
Hours of driving (in past 6 months)	0 hours	31	71.35	9.17
	1 to 100 hours	29	71.55	10.59
	101 to 200 hours	23	68.43	11.95
	201 to 400 hours	11	66.02	11.66
	401 hours or above	12	69.15	11.24
	Cannot recall	3	69.84	11.98
Hours of driving (in past 12 months)	0 hours	28	72.36	8.70
	1 to 100 hours	13	67.77	13.63
	101 to 200 hours	19	70.36	9.56
	201 to 400 hours	24	69.54	11.70
	401 hours or above	22	68.34	11.04
	Cannot recall	3	69.84	11.98
Last time driving	Never drove	18	72.49	8.42
	At least 1 year ago	10	72.14	9.66
	1 day ago to less than 1 year ago	42	71.32	10.17
	Today	39	66.79	11.80
Driving frequency (in past 6 months)	Never drove in past 6 months	31	71.35	9.17
	1 to 4 times a month	17	72.83	11.99
	More than 4 times a month	61	68.46	10.84
Driving frequency (in past 12 months)	Never drove in past 12 months	28	72.36	8.70
	1 to 4 times a month	21	70.29	12.32
	More than 4 times a month	60	68.73	10.79
Non-local driving experience	Drove outside HK	33	67.96	10.28
	Did not drive outside HK	76	70.83	10.73

(Norušis, 2004) were assessed prior to analysis. It was shown that the variances in all of the levels were equal (Levene's test, $p>0.05$) for all the four categorical factors. Other than the factors of age group, education level, and driving frequency, the values in different levels of the remaining categorical factor of non-local driving experience was adequately normal (Shapiro-Wilk's test, p's>0.05). Thus, the effects of age group, education level, and driving frequency on subjects' comprehension performance were analyzed with a Kruskal-Wallis test, whereas the effect of non-local driving experience on comprehension performance was examined with ANOVA.

3.3.1. Driving experience

Driving experience of subjects was assessed with three different indicators: years with license, years of active driving, and hours of driving. As years with license, years of active driving, hours of driving in past 6 months, hours of driving in past 12 months, and comprehension performance were not normally distributed (Kolmogorov-Smirnov test, p's<0.05), Spearman correlation analysis was conducted for the five sets of data of the remaining 105 subjects (Table 4). Four subjects could not recall the exact years with driving license or hours of driving.

Comprehension performance was correlated negatively with years with license ($r_s=-0.269$, $n=105$, $p<0.01$), and it was greater during the first year of holding a driving license and there was a slight downward trend with increasing years with license. Positive relationships amongst years with licenses, years of active driving, and hours of driving were found (p's<0.01). However, comprehension performance was not related to years of active driving and hours of driving (p's>0.05).

3.3.2. Last time driving

Ninety-one respondents had been driving in HK since obtaining HK full driving license. Their last time driving (in terms of days) and comprehension performance were not normally distributed (Kolmogorov-Smirnov test, $p<0.05$), therefore Spearman correlation analysis was performed for the two sets of data. It was found that driver factor of last time driving was not significantly correlated with comprehension performance ($p>0.05$). The results remained unchanged if 39 subjects who drove 'today' were ignored.

3.3.3. Age group, education level, driving frequency, and non-local driving experience

There were no significant main effects of age group (Kruskal-Wallis test; $p>0.05$), driving frequency (Kruskal-Wallis test; p's>0.05), and non-local driving experience (ANOVA; $p>0.05$) on comprehension performance of licensed drivers, but there was a significant main effect of education level on comprehension performance of licensed drivers (Kruskal-Wallis test; $p<0.05$). Subjects with university education or above could perform significantly better in comprehension of traffic signs (71.46%) than those without a university education (65.43%).

Table 4
Spearman correlation coefficients amongst years with license, years of active driving, hours of driving, and comprehension performance

	Years with license	Years of active driving	Hours of driving	
			in past 6 months	in past 12 months
Years with license	1			
Years of active driving	0.752*	1		
Hours of driving in past 6 months	0.294*	0.593*	1	
Hours of driving in past 12 months	0.309*	0.634*	0.918*	1
Comprehension performance (%)	−0.269*	−0.167	−0.109	−0.084

*Correlation is significant at the 0.01 level (2-tailed).

3.3.4. Driving experience by driving frequency relationship

Regarding driving frequency, subjects who drove more than four times a month were regarded as driving frequently whereas those who drove one to four times a month or never drove were considered as driving infrequently.

Some researchers distinguished between inexperienced and experienced drivers on the basis of years with license. Macdonald and Hoffmann (1991) regarded subjects possessing a license for less than five years as inexperienced drivers and those with more than 10 years as experienced drivers. In October 2000, the HK government introduced a probationary driving license scheme for inexperienced drivers of motorcycles (Hong Kong Transport Department, 2005b), and this scheme will extend to private cars and light good vehicles drivers shortly. Under the scheme, inexperienced drivers are those who have passed the driving test for one year or less whereas experienced drivers have more than one year experience. In this experiment, subjects who obtained HK full driving licenses for the first year were hence categorized as inexperienced drivers, while those with more than one year were regarded as experienced drivers.

Analyses of variance were conducted to assess the comprehension performance of the four subgroups of drivers (frequently driving and experienced, frequently driving and inexperienced, infrequently driving and experienced, and infrequently driving and inexperienced) for the two different cases: (a) driving frequency in past 6 months and years with license driving and, (b) frequency in past 12 months and years with license. The results showed that there were no significant differences among the four mean values ($p>0.05$) in each of the two cases. Reanalyses for all the cases with different definitions for infrequent driving showed that there was no significant difference in comprehension performance amongst the four driver groups if those who never drove were excluded ($p>0.05$).

3.4. Traffic sign features

Mean ratings on familiarity, concreteness, simplicity, and meaningfulness for all signs were 61.95, 61.88, 64.05, and 66.97, respectively, illustrating that the traffic signs were perceived to be moderately familiar, concrete, simple, and meaningful. Table 5 shows the signs with the lowest and highest ratings on familiarity, concreteness, simplicity, and meaningfulness. Although all the subjects were licensed drivers, sign W4 (level crossing with barrier ahead) was rated as very unfamiliar (28.25). The most familiar one was sign R3 (no pedestrians). Even though sign R2 (pedestrians, pedestrian operated vehicles, bicycles, and tricycles prohibited) contained more elements than sign W2 (barricade), the sign R2 was perceived to be very simple while the sign W2 was identified as the most complex, implying that the perceived simplicity of a sign is not only related to the number of elements in the sign but may be affected by other factors such as sign concreteness or meaningfulness.

3.5. Traffic sign features and comprehension score

Simplicity rating was normally distributed, while familiarity rating, concreteness rating, meaningfulness rating, and comprehension score were not (Shapiro-Wilk test, p's<0.05). Spearman correlation analysis was used to test for interrelationships amongst sign features and comprehension score. Simplicity was strongly correlated with familiarity ($r_s=0.900$, $n=21$, $p<0.002$), concreteness ($r_s=0.835$, $n=21$, $p<0.002$), and meaningfulness ($r_s=0.956$, $n=21$, $p<0.002$), indicating that perceived simplicity of a sign might be related to other cognitive sign characteristics. Meaningfulness was closely associated with familiarity ($r_s=0.884$, $n=21$, $p<0.002$) and concreteness ($r_s=0.834$, $n=21$, $p<0.002$). Familiarity also related significantly to concreteness ($r_s=0.756$, $n=21$, $p<0.002$). However, comprehension score did not correlate with any of the four sign features (p's>0.05). Sign R2 (pedestrians, pedestrian operated vehicles, bicycles, and tricycles prohibited) had the highest rating in concreteness and simplicity, but had only 12% comprehension score. The above analyses were repeated excluding subjects without local driving test experience. There were no markedly different results, except that sign familiarity was related to comprehension score ($r_s=0.448$, $n=21$, $p<0.05$).

Table 5
Signs with lowest and highest ratings on familiarity, concreteness, simplicity, and meaningfulness

Sign features	Signs with lowest rating	Signs with highest rating
Familiarity	 W4 – Level crossing with barrier ahead (28.25)	 R3 – No pedestrians (81.31)
Concreteness	W2 – Barricade (31.19)	 R2 – Pedestrians, pedestrian operated vehicles, bicycles, and tricycles prohibited (77.56)
Simplicity	W2 – Barricade (42.56)	 R2 – Pedestrians, pedestrian operated vehicles, bicycles, and tricycles prohibited (76.05)
Meaningfulness	W2 – Barricade (36.88)	 R3 – No pedestrians (81.08)

The mean ratings are shown in brackets.
Notes: W – warning signs; R – regulatory signs.

4. Discussion

The purpose of this experiment was to examine the effects of driver factors and sign design features on the comprehensibility of traffic signs. It was found that comprehension scores differed significantly from sign to sign and the following discusses sign comprehensibility in terms of driver factors and sign design features.

4.1. Driver factors

Eight driver factors were studied in this experiment. Regarding age, there was no difference in comprehension performance amongst the three age groups of subjects. In this

experiment, subject ages ranged from 18 to 57 years, and these were all younger than the old subjects used in the Dewar et al. (1994) study. The subjects here are not likely to have suffered from the reduced attention and information processing abilities of older people (Al-Gadhi et al., 1994), and hence the poor performance of older subjects was not in evidence here.

The results showed that subjects with university or above education performed better in traffic sign comprehension than those with below university education, confirming the results of previous studies (Al-Madani & Al-Janahi, 2002b). It indicated that when drivers with lower education can grasp the meaning of a traffic sign, it is very likely that drivers with higher education can also understand the signs well. Further research on sign comprehension should be conducted with drivers who do not receive university or above education.

Of the three driving experience indicators, years with license was significantly correlated with comprehension performance. Rather surprisingly, comprehension performance was better during the first year of holding a driving license and decreased with years of being a licensed driver. The findings showed that drivers who have recently passed their local driving test were more familiar with sign definitions, implying that regular testing of drivers may improve understanding of traffic signs. The results might be attributed to the fact that experienced drivers pay little attention to traffic signs during driving and seldom retrieve sign information from memory, thus fading of sign information is likely to occur over time (Henderson, 1999). According to MacDonald and Hoffmann (1991), years with license was negatively related to awareness of traffic signs during driving and the awareness level of sign information of inexperienced drivers was higher than for experienced drivers.

Although drivers could easily remember the number of years licensed, it might not have been easy for them to recall the years of active driving and number of driving hours. Positive relationships between years with license, years of active driving, and hours of driving were found, showing that all measures provided acceptable indices of driving experience. Nevertheless, comprehension performance was not related to years of active driving and hours of driving. In other words, actual driving experience was not a useful device for predicting comprehension performance on traffic signs.

Last time of driving was not significantly associated with comprehension score. Against expectation, sign comprehension performance did not decrease with time period of not driving, and driving frequency had no effect on traffic sign comprehension. There was no difference in comprehension levels reached by those driving frequently (more than 4 times a month), occasionally (1 to 4 times a month), or not having driven for an extended period of time (6 months and 12 months). In other words, sign comprehension task performance remained unchanged regardless of the time away from driving.

The combined effect of driving experience and driving frequency on traffic sign comprehension was not significant. The results here showed that frequent driving experienced drivers achieved similar performance level in sign comprehension as other subgroups of drivers. Against expectation, non-local driving experience was not a significant predictor of sign comprehension.

4.2. Traffic sign features

In general, the selected HK traffic signs were perceived to be moderately familiar, concrete, simple, and meaningful for licensed drivers in this experiment. Subjective rating on each sign feature varied greatly from sign to sign. Significant and positive relationships were found amongst familiarity, concreteness, simplicity, and meaningfulness. By controlling for the factor of local driving test experience, familiarity was significantly correlated with comprehension score but concreteness, simplicity, and meaningfulness were not related to the score. The results showed that when signs are learned and encountered frequently, driver performance on sign comprehension is better. However, concreteness, simplicity, and meaningfulness are not the key design characteristics that must be considered.

4.3. Limitations

This experiment successfully revealed relationships amongst driver factors, sign design features, and sign comprehension, but there were some limitations to take into account. First, survey reliability was not assessed in this experiment. Reliability is a statistical measure of how reproducible the survey instrument's data are, and requires administration of the survey to samples at two different and appropriate points in time (Litwin, 1995). Since it was not practical to have individuals complete the survey at two different times, the survey reliability could not be examined here. Second, the data on personal characteristics were based solely on self-reports of driving habit. It is possible that some respondents embellished their answers and there might have been a gap between self-reported and actual driving habit. Also the limited nature of the subjects available presents problems for generalizing the results, and the lack of agreed age groupings makes comparisons difficult.

5. Conclusion

The experiment was successful in studying the effects of driver factors and sign design features on the comprehensibility of traffic signs with a convenience sample of licensed drivers. There were some limitations in the study and some of the very basic questions need further research. Nevertheless, the findings provided the following useful information and recommendations for designing more user-friendly traffic signs and effective ways of using them.

1. There was no difference in comprehension performance for the subjects in the three age groups of this study.
2. Education is an important factor on sign comprehension. The result suggested that sign comprehension for drivers with education of lower than university level should be evaluated. If such drivers can grasp the meaning of a traffic sign, it would probably be understood by those with higher education.
3. Comprehension performance was inversely proportional to years with driving license. Recently qualified drivers were better than others with sign definitions.

4. Actual driving experience (years of active driving and hours of driving) was not a valuable factor to predict comprehension performance for traffic signs.
5. Last time driving, driving frequency, and non local driving experience did not affect sign comprehension.
6. Frequently encountered signs are comprehended better than less frequently encountered signs. However, concreteness, simplicity, and meaningfulness are not the major sign design features that interface designers must be considered.

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