ORIGINAL RESEARCH PAPER

Re-usability of traffic signs for inactive drivers with consideration of personal characteristics and sign features

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ABSTRACT: There has been an increasing concern about inactive drivers who would easily lead to road accidents and fatalities once return to driving. This study investigated the re-usability of traffic signs for inactive drivers with consideration of driver factors and cognitive sign features. Fifty-seven Hong Kong Chinese, who possessed a full driving license but had not driven for an extended period, comprehended the meanings and rated the cognitive features of 21 traffic signs. The re-usability performance of participants who had not driven for at least a year was similar to those who had not been driving since obtaining driving license. The re-usability of traffic signs was better when the signs were familiar, concrete, simple and meaningful. To improve sign re-usability, designers should consider the cognitive sign features, provide direct and unambiguous visualization for underlying concepts, and make better use of eye-catching design elements and proper juxtaposition of similar pictorials in sign design.

KEYWORDS: *Re-usability; Road users; Sign design; Traffic signs; Usability*

INTRODUCTION

People who maintain driving licenses and not driving for an extended period of time are called inactive drivers. The possible reasons for license holders not driving included no interest or no desire to drive, lack of driving confidence, too nervous for driving, no car, high gasoline prices, health problem, too old, temporary license suspension, congestion or too much traffic, and reduction of environmental problems (Hakamies-Blomqvist and Washlström, 1998; Dora and Philips, 2000; Ellaway *et al.*, 2003; USA Today, 2008; Siren and Haustein, 2016). There has been an increasing concern about the hazards posed by the inactive drivers as it was indicated that these people would easily lead to road accidents and fatalities once return to driving (Hong Kong Legislative Council, 2005). Generally, the

road accidents and fatalities not only pose a great risk to these drivers themselves but also to their passengers and other road users.

For avoiding potential accidents along roads and highways, traffic signs that provide various kinds of traffic messages to regulate, warn, and guide road users are a safety precaution measure in a traffic system. The usability of traffic signs and environmental signs for controlling the behavior of road users in a traffic system might depend on a sequence of their information processing such as attention, comprehension, attitudes and beliefs, and motivation (Wogalter and Laughery, 1996; Laughery and Wogalter, 2014). Amongst different criteria, comprehension has been rated as the most important one for determining the successful design of traffic signs by traffic sign experts and practicing traffic engineers (Dewar, 1988).

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The International Organization for Standardization defined usability as 'the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use' (ISO 9241-11, 1998). In relation to usability-based approaches to design, Jordan (1998) identified five distinct components: guessability, learnability, experienced user performance, re-usability, and system potential that influence the usability of a design. Guessability is a measure of the cost (e.g. in terms of time on task or errors made) to the user of a product when performing a task for the first time. Learnability is concerned with the cost to the user in achieving some competent level of performance on a task with a product. Experienced user performance is the relatively stable performance level that an experienced product user reaches, while system potential represents the theoretical optimal performance obtainable with a product with respect to a particular task. Re-usability, the focus issue of this study, refers to the performance level achieved when a user returns to a task with a product after an extended period of non-use. Research studies on the guessability and learnability of traffic signs and other graphical symbols like industrial and security safety symbols for prospective-users had been reported (Ng and Chan, 2007; 2011; Chan *et al.*, 2009; Chan and Ng, 2010a,b, 2012), but there has been limited investigation on the other components of usability of graphical symbols. Based on the above definition and categorization, the performance of inactive drivers on traffic sign comprehension after a long period of non-driving can be determined as the re-usability of traffic signs and forms an interesting and important topic of study in human factors researches.

The success of effective communication of sign messages may be related to the characteristics of users and the design of signs (Zhang and Chan, 2013; 2014). A recent iteration of the communication-human information processing (C-HIP) model also put significant focus on the personal characteristics of information receivers (Mayhorn and Wogalter, 2010). The typical personal characteristics for inactive drivers consisted of time away from driving and previous driving experience before they paused driving. Driving experience can be measured in terms of not only the number of years licensed but also the actual number of years of driving. Sign design features are usually categorized into visual features that are able to see

visually such as color and shape and cognitive features that relate directly to perception and cognition of the message the sign is intended to convey (Ng and Chan, 2009; 2015; Chi and Dewi, 2014). The cognitive sign feature like familiarity, concreteness, simplicity, meaningfulness, and semantic closeness are of central concern in sign research. Familiarity is the frequency with which signs have been encountered. Concrete signs depict objects which have obvious connections with the real world while abstract signs do not. Signs 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, rather obviously, to how meaningful people perceive signs to be. Semantic closeness refers to the closeness of the association between what is depicted on a sign and what it is intended to represent. These five sign features are known as cognitive sign features as they relate to people's perception and cognition.

This study was conceived and designed to examine the re-usability of traffic signs for inactive drivers in Hong Kong in 2015 with the consideration of driver characteristics and cognitive sign features. During the study, participants who possessed a valid Hong Kong driving license but had not driven for at least one year were asked to participate in the quantification and analysis of cognitive sign features and the comprehension of traffic signs. The results of this study would help understand the traffic sign comprehension level of the inactive drivers, so as to better design the road safety campaign and driving improvement courses. In addition, the results would provide useful information for designing more user-friendly traffic signs in future.

MATERIALS AND METHODS

Participants

Fifty-seven Chinese people (51 males and 6 females) meeting the criteria of 'having experience of Hong Kong driving test', 'holding Hong Kong full driving license' and 'not driving for at least a year' were identified as inactive drivers and invited to participate in the study. The ages of the participants were between 18 and 57 years.

Traffic signs

Two criteria were set for the choice of traffic signs for test: first, their messages are conveyed without text but with symbols only; second, they are not used in accompaniment with other signs for transmitting a

message. There are 178 signs contained in the Laws of Hong Kong (Bilingual Laws Information System, 2001), and 82 of them satisfy the two characteristics for selection. As it was not feasible to test all 82 signs, only 21 of them were randomly selected for testing (Table 1). They were displayed in color and individually in squares of 1.28 cm x 1.28 cm (without boundary) on paper.

Procedure

Participants were briefed with the objectives and instructions at the beginning of the study. They were asked to report their age group, number of years with full driving license, number of years of active driving since obtaining full license, and time away from driving. The years with license, years of active driving, and time away from driving were reported in an open-ended format in units of years and months, whereas gender and age group were asked with the use of categorical responses options.

Then the participants were asked to complete the quantification of traffic sign features task. They 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 traffic signs. The cognitive feature of semantic closeness was not considered here, because the intended meaning of what was depicted on the traffic sign had to be asked in the later part of the study examining comprehensibility of traffic signs.

Finally, the participants were asked to finish a set of multiple-choice questions for evaluating their understanding of traffic signs. Four-option multiple-choice questions were designed as they could greatly diminish the risk of guessing by participants (Newby, 1992). Amongst the four choices participants were asked to select the best answer. 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. The time needed for each participant to complete the study was about 30 minutes.

RESULTS AND DISCUSSION
Results

In this study, comprehension performance denotes the performance level of a participant on the comprehension task, while comprehension score of a sign refers to the accuracy level of understanding its meaning by participants. The raw comprehension scores for the four-option multiple-choice questions were adjusted to make allowance for the bias of guessing with the Akeroyd (1982)'s technique: 1 mark for correct answer, 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.

Driving characteristics and comprehension performance

The years with license of the participants ranged from 1 year to 25 years. There were 46% participants who had not driven after getting a license. Participants who had been driving since obtaining driving licenses (54%) reported that their years of active driving was less than a month to 12 years and 6 months, and their time away from driving was between 1 year and 20 years.

The comprehension performance of all participants ranged from 42.86% to 95.24% (mean = 72.43%, standard deviation = 10.22%). The comprehension performance was further studied in accordance to the driving characteristics of years with license, years of active driving, and time away from driving. These three driving characteristics and comprehension performance were not normally distributed (Shapiro-Wilk test, p's > 0.05). Spearman correlation analysis was conducted and the results showed that years with license, years of active driving, and time away from driving did not relate significantly to traffic sign comprehension (p's > 0.05). The comprehension performance of drivers who had not been driving since obtaining driving license ranged between 52.38% and 95.24% (mean = 73.81%, standard deviation = 10.71%). The comprehension performance of drivers who had been driving but did not drive for at least a year varied from 42.86% to 85.71% (mean = 71.27%, standard deviation = 9.82%). Independent samples t test showed that there was no significant difference in comprehension performance between these two groups of drivers (p > 0.05).

Comprehension score for individual sign

Table 1 shows the mean comprehension scores for individual signs. The sign with minimum comprehension score (1.75%) was S14 'level crossing with barrier ahead'. The signs with maximum comprehension score (100%) were S11 'two way traffic' and S21 'road narrows on both sides ahead'. The International Organization for Standardization (ISO 3864-3, 2012) and the American

National Standards Institute (ANSI Z535.3, 2002) recommend that symbols must reach a criterion of at least 67% or 85% correct, respectively, in a comprehension test to be considered acceptable. There were nine traffic signs meeting both the ISO and ANSI criteria, viz. pass either side (S1; 89.47%), no through road (S3; 87.72%), rickshaws and pedestrian-controlled vehicles prohibited (S6; 91.23%), no pedestrians (S8; 98.25%), footway and cycleway (S9; 94.74%), two way traffic (S11; 100%), bus lane only (S17; 87.72%), bus lane on major road ahead (S18; 89.47%), and road narrows on both sides ahead (S21; 100%). Another seven traffic signs achieved the lower ISO criteria only, namely the distance to an exit from a road: 200m (S2; 73.68%), no through road on side road to left (S5; 80.70%), light rail transit vehicles or trams only (S10; 84.21%), barricade (S12; 82.46%), loose chippings ahead (S15; 73.68%), diversion to another carriageway to right ahead (S16; 70.18%), dual-carriageway road ends (S20; 78.95%). The remaining five signs (S4, S7, S13, S14, and S19) were not satisfactorily designed under the ISO and ANSI criteria.

For the sign S4 'appropriate traffic lanes at junction ahead', more than half of the participants (63%) identified the correct sign meaning, 33% of the participants recognized it as 'no through road at left' and the remaining 4% specified that the meaning should be 'appropriate traffic lanes at junction ahead and no through road at left'. For the sign S7 'pedestrians, pedestrian operated vehicles, bicycles, and tricycles prohibited', 86% of the participants could not get the fully correct comprehension and interpreted it as 'no bicycles' and 'no pedestrians and cyclists'. For the sign S13 'staggered junction left turn first ahead', more than half of the participants (63%) could not give the right answer and read it as 'side road ahead'. Regarding the sign S14 'level crossing with barrier ahead', only one participant could get the entirely correct comprehension and the remaining participants perceived it as 'railway crossing ahead with gate or barrier' and 'a gate or barrier ahead'. For the sign S19 'pedestrian on or crossing road ahead', 79% could not interpret the sign accurately and recognized it as 'caution! children crossing road' and 'pedestrian crossing ahead'.

Cognitive sign features and comprehension score

The mean subjective ratings on familiarity, concreteness, simplicity, and meaningfulness for all traffic signs were 60.55, 62.85, 65.20, and 65.45 respectively, illustrating that the selected traffic signs were perceived to be moderately familiar, concrete, simple, and meaningful in general. Detailed information of subjective ratings on the four cognitive sign features for each traffic sign is shown in Table 1. The box plots showed that much lower simplicity and meaningfulness ratings were given for signs S12 (barricade) and S14 (level crossing with barrier ahead), and S12 (barricade) was also the one with extremely low concreteness rating. Spearman correlation analysis revealed that the four cognitive sign features were significantly related to comprehension score for eight of the 21 signs (S1, S2, S3, S5, S6, S9, S17, and S20, $p < 0.05$).

Discussion

The purpose of this research was to study the re-usability of traffic signs with characteristics of inactive drivers and cognitive sign features. Generally a full understanding of traffic signs for licensed drivers is expected, as a misinterpretation of traffic signs could lead to road accidents and fatalities. However, no inactive drivers here could complete the traffic sign comprehension at the maximum 100% performance level. The driver factors of years with license, years of active driving, and time away from driving were not individually related to comprehension performance. But the combination of driver factors showed that the comprehension performance of licensed holders who rarely drove was similar to that of drivers who did not have any on-road driving experience since obtaining license. To improve the re-usability of traffic signs, inactive drivers should be encouraged to review the meaning of traffic signs in road users' code themselves before they resume driving. Government and related organizations should organize and lead public education campaigns to inform drivers of the meanings of poorly understood symbols.

For each traffic sign, its comprehension score was further studied in term of the cognitive sign features of familiarity, concreteness, simplicity, and meaningfulness. The four cognitive sign features were revealed to be positively and significantly related to sign comprehension for eight traffic signs viz. S1 'pass either side', S2 'the distance to an exit from a road: 200m', S3 'no through road', S5 'no through road on side road to left', S6 'rickshaws and pedestrian-controlled vehicles prohibited', S9 'footway and cycleway', S17 'bus lane only', and S20 'dual-carriageway road ends'. As expected,

Table 1: The mean comprehension score and sign feature ratings for each traffic sign

Sign			Comprehension score (%)	Familiarity	Concreteness	Simplicity	Meaningfulness
S1		Pass either side	89.47	54.65	53.32	62.56	54.09
S2		The distance to an exit from a road: 200m	73.68	49.39	37.28	55.93	48.00
S3		No through road	87.72	70.02	65.68	68.47	70.47
S4		Appropriate traffic lanes at junction ahead	64.91	54.81	65.95	63.77	68.84
S5		No through road on side road to left	80.70	60.75	69.32	70.84	74.86
S6		Rickshaws and pedestrian-controlled vehicles prohibited	91.23	46.02	76.26	69.04	68.47
S7		Pedestrians, pedestrian operated vehicles, bicycles, and tricycles prohibited	14.04	81.79	80.25	77.35	81.21
S8		No pedestrians	98.25	86.49	84.18	81.18	86.79
S9		Footway and cycleway	94.74	80.89	77.54	73.30	78.58
10		Light rail transit vehicles or trams only	84.21	65.91	72.19	69.14	69.67
S11		Two way traffic	100.00	75.26	67.07	72.11	72.04
S12		Barricade	82.46	26.72	26.16	44.16	35.19
S13		Staggered junction left turn first ahead	36.84	59.74	55.05	60.23	63.05
S14		Level crossing with barrier ahead	1.75	30.38	39.46	44.20	42.04
S15		Loose chippings ahead	73.68	59.72	64.47	67.67	66.74
S16		Diversion to another carriageway to right ahead	70.18	51.23	52.75	60.14	60.28
S17		Bus lane only	87.72	65.28	67.81	63.63	63.68
S18		Bus lane on major road	89.47	52.37	62.07	58.07	61.77

the re-usability of traffic signs was better when the signs were familiar, concrete, simple, and meaningful. For sign familiarity, re-usability was high for familiar signs and low for unfamiliar signs. Previous research showed that traffic signs that look familiar also catch drivers' attention easily (Kurniawan and Zaphiris, 2001). For sign concreteness, concrete signs contributed to a higher re-usability than abstract ones. The results here supported the views of Banda and Sichilongo (2006) that effective signs and symbols must not be too abstract. This might be due to the fact that concrete signs have obvious connections with the real word and thus provide a direct visualization aid in helping users to elicit a meaning. However, the representational elements in abstract signs are harder to pick out within known semantic concepts and therefore it is likely that access to meaning is much more difficult with the abstract signs. Regarding sign simplicity, simple signs led to higher re-usability than complex signs. Liu (2005) also found that increasing sign content information volume could result in poor accuracy rate. This may be due to the fact that complex signs involved a greater number of cognitive or linguistic transformations for understanding and the extraneous decorative parts confounded understanding of the signs (Bruyas *et al.,* 1998). For sign meaningfulness, the re-usability was high for meaningful signs and low for meaningless signs. The result was consistent with Preece *et al*. (1994) which indicated that the more meaningful a stimulus, the easier for people to relate the stimulus to its associated imagery. Wang and Chi (2003) also found that the understanding of a hazardous material symbol was related to its meaningfulness. In future, traffic signs should be designed with consideration of cognitive sign features of familiarity, concreteness, simplicity, and meaningfulness.

It was evident that comprehension scores differed from sign to sign for inactive drivers. Two of the 21 test signs viz. S11 'two way traffic' and S21 'road narrows on both sides ahead' were very well understood, and reached the maximum 100% comprehension score. On the other hand, the comprehension scores for five traffic signs viz. S4 'appropriate traffic lanes at junction ahead', S7 'pedestrians, pedestrian operated vehicles, bicycles, and tricycles prohibited', S13 'staggered junction left turn first ahead', S14 'level crossing with barrier ahead', and S19 'pedestrian on or crossing road ahead' did not meet the ISO and ANSI comprehension criteria. Since a misunderstanding of traffic signs could lead to road accidents and fatalities, there is a need to promote the

intended messages of these five traffic signs in road safety campaign or to redesign the traffic signs as soon as possible. Previous research had indicated that a better design may be necessary for traffic signs with low comprehension levels (Purduski and Rys, 1999). In this study, the choice of responses made from participants helped to identify possible design guidelines and information that could be incorporated into redesign of existing signs and the development of new signs. The sign S4 'appropriate traffic lanes at junction ahead' is used to inform motorists of the direction they may proceed in the respective lanes. All pictorial elements in S4 were depicted in black with the exception of a red horizontal line in the left lane, and thus the red horizontal line became outstanding and attention-grabbing. It was found that around one-third of the participants could not provide the totally correct answer and they paid attention to the left lane that contained a red horizontal line and tried to decipher meaning from it as 'no through road at left'. Such comprehension response provided an implication for designers that eye-catching element should be used carefully and properly in sign design as participants concentrate on it during sign interpretation. For sign S7 'pedestrians, pedestrian operated vehicles, bicycles, and tricycles prohibited', most of the participants (86%) could not get the fully correct meaning and interpreted it partially as 'no bicycles' or 'no pedestrians and cyclists' based on the images of pedestrian and bicycle in the sign. This was not surprising that a majority of participants could not deduce the intended full meaning as the messages of prohibited pedestrian operated vehicles and tricycles were not depicted in the sign. During sign revision, designers should take extreme care that the intended sign message should be made more explicit in sign design.

Sign S13 'staggered junction left turn first ahead' consists of a thick vertical line with arrow head upwards and two horizontal thin lines on left and right respectively. More than half of the participants (63%) could not achieve the right answer and perceived it as 'side road ahead'. Such response indicated that these participants realized the vertical thick line as a main road and the horizontal thin lines as side roads, but could not manage to find a message integrating all codes to get the meaning of staggered junction where several roads meet a main road at slight distance apart. In a traffic sign and navigation system, the direction of the road is imitated by the direction of the arrow on the sign. To indicate several roads meeting the main road explicitly and

unambiguously, the sign S13 might be modified with consideration of adding arrowhead at one side of each thin horizontal line. Since vehicles might enter the main road, cross the staggered junction from one side road to the other, and leave the main road to the left and to the right, the pointing direction of arrowhead should be placed in accordance with the real road situation. Regarding the sign S14 'level crossing with barrier ahead', almost all participants (98%) comprehended the sign wrongly as 'railway crossing ahead with gate or barrier' and 'a gate or barrier ahead'. This comprehension results was expected as sign S14 consisted of an image of barrier and the concept of level crossing was not given in the sign. Santa-Rosa and Fernandes (2012) also found that icons which could not actually represent their intended meanings clearly induced unexpected subjects' responses. To improve the accuracy of understanding, designers should provide direct presentation of the level crossing in the sign during review. The sign S19 'pedestrian on or crossing road ahead' showed a frontal view of standing large and small human figures. Only 21% of the participants interpreted the sign fully correct and the remaining 79% read it as 'caution! children crossing road' and 'pedestrian crossing facilities ahead'. The comprehension response 'caution! children crossing road' indicated that participants recognized the large and small human figures as an adult and a child, and tried to establish a link between the images. But the juxtaposition of the two human figures misled them to think that the emphasis was on the child. In general, the sign S19 had served its purpose in that it alerts drivers to someone crossing. Practical ergonomics recommendations for enhanced human-interface interaction are usually the expected outcomes of human factors research (Chan and Or, 2012; Ng and Chan, 2013). Overall, the results for comprehension responses on traffic signs S4, S7, S13, S14, and S19 suggested and reinforced three major principles to be applied to sign design in future: (i) what a sign is intended to represent should be depicted on the sign explicitly and unambiguously, (ii) a proper use of eye-catching element in sign design needs to be made as users usually concentrate on it for deduction of the intended sign message, and (iii) be congruous juxtaposition of similar pictorials in sign design which would mislead users to think that the emphasis was on one of the pictorials. It is presumed that when traffic signs are designed with consideration of these recommendations, the signs would be compatible with user expectations and comprehended best.

This study successfully investigated traffic sign re-usability with consideration of driver factors and cognitive sign features, however there were limitations which should be taken into account. The traffic signs used in this study were presented to participants in the absence of context where the signs might be viewed. In reality road users have to figure out the exact meaning of traffic signs in a particular context. The participants here would probably have better performance in re-usability if the traffic signs were presented in appropriate contexts that reflected the real-world situation of sign comprehension.

CONCLUSION

In summary, this research study showed that regarding the driver factors, the comprehension performance of participants who had been driving but did not drive for at least a year ago was similar to those who did not have any on-road driving experience since obtaining license. The re-usability of traffic signs was better when the signs were familiar, concrete, simple, and meaningful. The comprehension responses for the problematic traffic signs suggested and reinforced other principles to design signs. In order to improve sign re-usability, designers should consider the use of cognitive sign features, direct and thorough visualization for sign message, eye-catching design elements, and juxtaposition of similar pictorials properly and appropriately in sign design process. There is also a need for government and relevant organizations to strongly encourage inactive drivers to review the meaning of traffic signs on their own before returning to driving, to provide direct public education campaigns on poorly understood traffic signs, as well as to review the curriculum of driving improvement courses and to consider involving the learning of traffic signs as part of theory class.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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