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Traffic sign symbol comprehension: a cross-cultural study

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The objective of this study was to evaluate the comprehension levels of highway traffic sign symbols used in different countries, to identify underlying rules that affect comprehension levels, and recommend approaches to deal with the problem. The need for such an evaluation was based on today's travel culture where people are often licensed in one country and then drive—without any further training—in another country. We compared the comprehension levels of different traffic sign symbols in four countries with moderate to high levels of motorization: Canada, Finland, Israel, and Poland. Five different driver populations were sampled in each country: novice drivers, college students, tourists, problem drivers, and older drivers. There were large differences in comprehension among specific sign messages, different countries, and different driver populations. Signs were comprehended best when they were consistent with general ergonomic guidelines for display design as they relate to spatial compatibility, conceptual compatibility, physical representation, familiarity, and standardization. Illustrations of compliance with these principles and violations of these principles are presented, and their implication for traffic safety are discussed. Specific recommendations for sign design that is compliant with ergonomic principles, and for greater international cooperation in sign symbol design are made.

1. Introduction

Driver communication systems are an important aspect of highway safety, and traffic control devices (TCDs) are an important part of the driver communication systems. The most prevalent of all TCDs are highway signs, and for effective traffic control it is essential that all drivers comprehend their meaning. In fact, a panel of traffic sign experts (members of national traffic control device committees) and practicing traffic engineers from Australia, New Zealand, Canada, and the USA, who were asked to give their opinion about the criteria for the design of traffic sign symbols rated understandability as the most important factor. Other factors, such as conspicuity, reaction time, legibility distance, glance legibility, and learnability, were all rated as less important (Dewar 1988).

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Despite the plethora of different signs, the 'standardized' options available in each country often do not cover all the needs of the motoring public, existing options are not always comprehensible, and there does not seem to exist a standard that transcends countries (despite the existence of a 'European' system and what some call 'international signs'). An extreme example of the first problem is provided by Bowman (1993) who noted that in the USA there were over 340 devices (including markings and signals) that have been applied and are in keeping with accepted traffic engineering principles, but are not included in the USA Federal 'Manual on Uniform Traffic Control Devices' (MUTCD). Comprehension problems have been noted even for the signs included in the MUTCD. Dewar *et al.* (1994), and Swanson *et al.* (1997) evaluated the comprehension of 85 symbols included in the MUTCD. They found that while comprehension was as high as 99% for some of the symbols, 10 of the symbols were understood by fewer than 40% of the drivers. The third problem—standardization across countries—was tackled in Europe in 1968, when representatives of 18 European countries agreed on a 'standardized' set of highway signs (ECMT 1974, 1996). However, since then many signs have been modified in some of these countries and new signs have been added in these and well as other countries (Al-Yousifi 1999, 2000).

Several studies have shown that despite high levels of comprehension of the more familiar signs, there are significant differences in levels of sign comprehension among different signs and different drivers. Paniati (1989) compared several symbolic alternatives for work zones. The results showed that signs with good spatial correspondence (i.e., physical similarity) to the message they represent were all well understood, even when they differed in the details, as demonstrated by three alternative designs for a 'lane drop'—a narrowing of the road and a reduction in one lane. In contrast, when the message was difficult to convey on a sign all the proposed alternatives were poorly understood, as was the case for 'low shoulder' and some representations for 'uneven pavement'. In possibly the most extensive study of this kind, Picha *et al.* (1995, 1997) conducted multiple evaluations of the comprehensibility of different traffic signs by a total of over 3000 Texas drivers, and they too identified several signs that had low comprehension levels.

There may also be individual differences in sign comprehension. Dewar *et al.* (1994) found that older drivers had generally lower levels of comprehension than younger drivers. Jones (1992) reported that a survey of Illinois older drivers also showed that older drivers fail to understand some of the common traffic control devices. Other groups that may have specific difficulties with signs are tourists who may not be familiar with local signs, and 'problem' drivers (repeat violators) who may be disregarding signs. In contrast, novice drivers may be expected to be better than other drivers on local signs having just taken the licensing test, but not on non-local signs with which they have no experience at all.

Cultural differences probably also contribute to individual differences in sign comprehension. A poignant example is provided by Dudek *et al.* (1996). They asked international tourists in Florida to critique Florida signing practices, and to suggest ways of making these signs easier to understand. Among other findings they report that the question mark symbol (?) used to designate 'tourist information' was generally not understood. Quite a problem, considering that this sign was designed to aid this very specific population! Al-Yousifi (1999) assessed the level of comprehension of alternative sign designs and found significant differences among

designs. Furthermore, these differences were consistent across four different countries (Kuwait, Iran, Bahrain, and France) whose drivers were interviewed. In a much earlier study with Canadian students, Dewar and Ells (1977), also obtained extreme variability in sign comprehension, and one of the symbolic signs that was not correctly understood by any of the participants was a European 'tourist information' sign.

The above findings suggest that signing may be a problem. As our world shrinks towards a global village, and as more and more of us crisscross this 'village', variations in signing among countries, poor sign design, and different levels of familiarity with signs used in different countries may all contribute to reduced communications with drivers. This problem is of course exacerbated in a world where people are licensed in one country where they are required to learn one 'standard' set of signs, and then are expected to be able to drive in other countries with different sets of 'standard' signs. Some of the differences in signing practices among countries are more subtle, but critical to safety. For example, in the USA the lack of a Stop or Yield sign implies right-of-way (because crossing traffic is assumed to have one of these signs), whereas in Europe, the absence of a sign implies that cross traffic from the right has the right-of-way, and therefore drivers should yield to it (Summala 1998).

The purpose of this cross-cultural comparative study was to evaluate the scope of the problem by assessing sign comprehension of different driver groups in four different countries, using signs that were common to all four countries and one additional country (see below) as well as signs unique to each country.

2. Methods

2.1. *Participants*

The participants in the study were 1000 unpaid volunteers. The sample consisted of 250 licensed drivers from each of the following countries: Canada, Finland, Israel, and Poland. (Due to technical problems the Finnish final sample consisted of only 243 instead of 250 drivers). In each country 25 males and 25 females were sampled from each of the following five groups (G1 – G5):

G1. *Novice drivers*. License applicants who had passed the 'theoretical test' that consists of knowledge of rules of the road and sign comprehension, or drivers who had received their license within the past year.

G2. *Tourists*. Drivers who were licensed in another country. It is important to note that the tourists are not a homogeneous group. In Finland, for example, all tourists were Russians who drove across the border from Russia, where the signs are quite similar (Leppikangas and Summala 1999). In contrast, in Israel the tourists were from different countries, typically overseas, where the signage system may be very different.

G3. *Older drivers*. Licensed drivers who were at least 65 years old, and who have not taken a written or driving test in at least 10 years.

G4. *Problem drivers*. Drivers with repeated violations (characterized slightly differently in different countries, but with essentially enough points to warrant a 'remedial training course' where they were located for this study).

G5. *University students*. All were licensed drivers, registered full-time in different departments (both engineering and arts and sciences), and with at least 2 years of driving experience.

2.2. *Materials*

The materials consisted of an individually administered short questionnaire and a sign comprehension test. The questionnaire contained items on the driver's age, sex, and driving experience. The Sign comprehension test consisted of a set of 31 colour pictures of highway signs, each printed on a separate cardboard card. Diamond-shaped and square-shaped signs were 7–10 cm across, triangular signs were approximately 10 cm high, and circular signs were approximately 10 cm in diameter.

Figure 1 contains images of the 31 signs along with a listing of the specific countries that use them, and table 1 lists the meaning of the signs. Since the original study plan called for the inclusion of Australia too, the sign selection process included Australian signs too. The choice of the signs was dictated by the desire to have a subset of signs common to all countries, as well as 2–3 signs unique to each country. The search yielded 15 signs common to all four participating countries and Australia (Nos. 8, 9, 10, 11, 13, 14, 16, 17, 18, 19, 25, 27, 28, 29 and 30, in Figure 1). The remaining 16 signs were unique to specific countries: three signs unique to Canada (Nos 20, 21, and 31), three signs unique to Finland (Nos 15, 23, 24), two signs unique to Poland (Nos 3, and 4), two signs unique to Israel (Nos 5 and 22), and three signs unique to Australia (Nos 1, 2, and 6). Finally one sign was common to Finland and Poland (No. 26), one sign was common to Finland, Poland, and Israel (No. 7), and one sign was common to Canada and Australia (No. 12).

2.3. *Procedure*

All participants first answered the few biographical questions and were then presented with the sign cards, one at a time. All participants were shown all 31 signs: both those in use in their country and those that are not in use in their country. Prior to each presentation the cards were shuffled, so each participant saw the signs in a different random order. The instructions pertaining to the sign comprehension were: 'you are driving down a road when you see this sign ahead of you on the side of the highway. Tell me in as much detail as you can what you think is the meaning of this sign'. The experimenter then wrote the participant's response verbatim. If the answer was incomplete, the participant was asked to elaborate if he/she could.

3. Results

Three types of analyses were conducted. The first was a series of Analyses of Variance aimed at assessing variations in sign comprehension as a function of country, and type of driver (group, age, and gender). The second type of analysis sought to identify the level of comprehension and variations among drivers of different countries in the comprehension of the specific signs studied here. The third analysis investigated some of the differences in sign comprehension among the different signs.

The participants' responses to each sign were coded into one of the following four categories of accuracy: Correct and complete (coded as + 2), partially correct (e.g. no turn, instead of no left turn—coded as + 1), incorrect (0), or opposite of the true sign meaning (e.g., giving priority to traffic in my direction instead of giving priority to on-coming traffic—coded as − 2). In the rare cases (less than 5%) where the appropriate code was not immediately obvious, the experimenters made a group decision, and that decision then served as a guideline for the coding of similar responses in all other participating countries. In general the coding was quite straightforward.

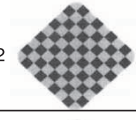
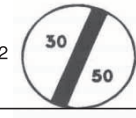
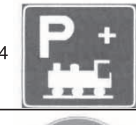
SIGN No.	PICTURE	COLOURS	COUNTRY
1		orange black	Australia
2		orange black	Australia
3		blue white	Poland
4		red, yellow black, orange	Poland
5		red, white black	Israel
6		yellow black	Australia
7		red, yellow black	Finland Israel Poland
8		dark blue white	Australia Canada Finlandia Israel Poland
9		red, yellow black	Australia Canada Finlandia Israel Poland
10		red, yellow black	Australia Canada Finlandia Israel Poland
11		red, yellow black	Australia Canada Finlandia Israel Poland
12		black orange	Australia Canada
13		red, yellow black	Australia Canada Finlandia Israel Poland
14		red, yellow black	Australia Canada Finlandia Israel Poland
15		red, black white	Finland
16		red, yellow black	Australia Canada Finlandia Israel Poland
17		red, yellow black	Australia Canada Finlandia Israel Poland
18		red, yellow black	Australia Canada Finlandia Israel Poland
19		red, yellow black	Australia Canada Finlandia Israel Poland
20		yellow black	Canada
21		orange black	Canada
22		white black	Israel
23		black yellow red	Finland
24		dark blue white	Finland
25		red, yellow black	Australia Canada Finlandia Israel Poland
26		yellow, white black	Finland Polan
27		red, yellow black	Australia Canada Finlandia Israel Poland
28		red, yellow	Australia Canada Finlandia Israel Poland
29		red, yellow black	Australia Canada Finlandia Israel Poland
30		dark blue red	Australia Canada Finlandia Israel Poland
31		yellow black	Canada

Figure 1. Signs used in the study and the countries in which each sign is in use.

Table 1. Sign numbers and meaning.

Sign number	Sign meaning
1	Railroad Crossing with Lights
2	Truck Crossing
3	Bus Lane Begins
4	No Entry for Vehicles Carrying Explosives
5	No Entry for Motorcycles/Mopeds
6	Reverse Turn (Left then Right)
7	Priority for Oncoming Traffic
8	Bicycle Path
9	Road Works
10	Bumps on Road
11	Right Curve
12	Termination of Road
13	Railroad Crossing Ahead
14	Slippery Road
15	Congestion
16	Road Narrows
17	Pedestrian Crossing Ahead
18	Children Crossing Ahead
19	Steep Hill Ahead
20	Diagonal Railroad Crossing Ahead
21	Truck Entrance
22	End Speed Limit (for trucks 30 k.p.h., for cars 50 k.p.h.)
23	End Built Up Area
24	Parking for Public Transport
25	No U Turn
26	End Priority Road
27	No Left Turn
28	No Entry
29	No Entry for Pedestrians
30	No Parking
31	Pavement Ends

3.1. *Differences in sign comprehension among drivers in different countries and among different groups of drivers*

The different measures of performance—% correct at each of the four levels of accuracy—are presented below. Significance of effects was tested with ANOVAs. However, since percentages are not normally distributed, all % scores were normalized using the recommended arcsine$\sqrt{p}$ transformation, where p is the proportion of signs identified by each driver at that level of accuracy (see for example, Ott 1993).

On average, 58.5% of all responses (to all signs) were fully correctly identified (with a score of + 2). There were highly significant differences in comprehension among the five groups of drivers in the four countries. These effects are presented in figure 2. The main effect of country was significant [$F(3, 973) = 236.09$, $p < 0.001$], with the best performance obtained by the Polish and Finnish drivers and the poorest performance obtained by the Canadian drivers. The main effect of the group was also significant [$F(4, 973) = 18.23$, $p < 0.001$]. This was due mainly to the poorer performance of the elderly Finnish and Israeli drivers but not of the elderly Polish and Canadian drivers, as demonstrated by the interaction between country and

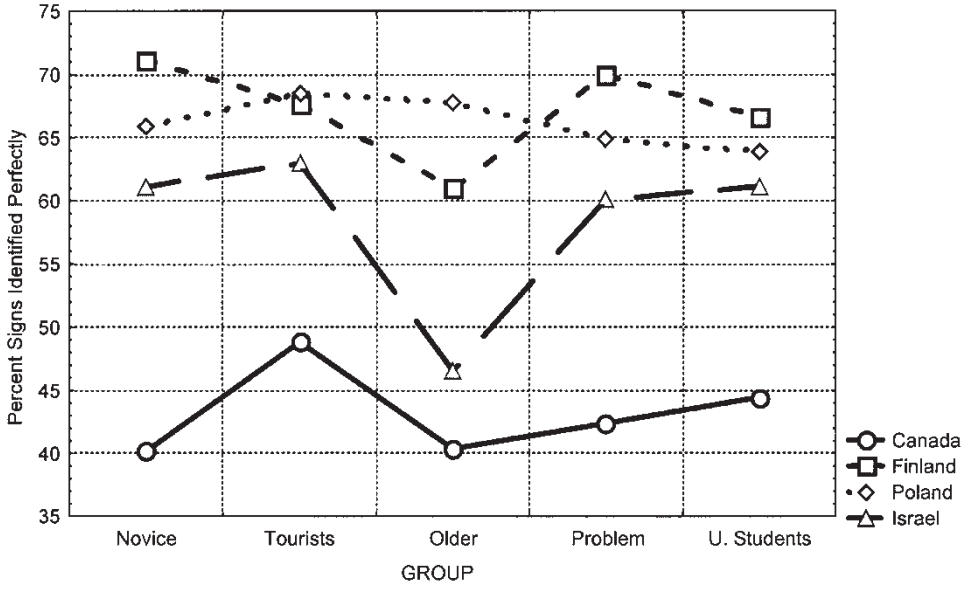


Figure 2. Per cent of signs identified perfectly, as a function of country and group.

group [$F(12, 973) = 9.51$, $p < 0.001$] . There was also a slight but significant main effect of gender showing that men identified correctly more signs than women (59.5% vs. 57.6% of signs) [$F(1, 973) = 5.93$, $p = 0.015$].

An ANOVA conducted on all partially or fully correct identifications (i.e. scores of either + 1 or + 2) yielded similar patterns and similar statistical effects, though as expected, the mean sign identification score was higher: by approximately 10% with 68.9% of the signs identified either fully or partially.

The second analysis focused on the frequencies of the most dangerous type of misunderstanding: interpreting the sign to mean the opposite of what it really means. An ANOVA of the arcsine$\sqrt{\text{p}}$ of the signs identified by each driver in each country × group × sex combination, that were misunderstood to mean the opposite of what they really meant yielded a significant effect of country [$F(3, 973) = 48.51$, $p < 0.0001$], group [$F(4, 973) = 8.06$, $p < 0.001$, and country × group [$F(12, 973) = 5.09$, $p < 0.0001$]. The % of signs interpreted as opposite of their true meaning are illustrated in figure 3 as a function of country and group. In general, an average of 2.7% of the responses were opposite of the signs' true meaning. The mean levels for the different groups of drivers from the different countries varied from a low of nearly 0% for tourists in Finland (Russians who are used to similar signs in Russia), to a high of 4–5% for Canadian drivers. In this analysis the effect of sex was not statistically significant. These relatively low percentages, and the interaction of Country with Group mask a high degree of variance among the signs as will be shown below.

To better understand the source of the difficulty encountered by different drivers, the third analysis focused on the differences between the comprehension of local and non-local signs. In this analysis local signs for each country were the signs common to all countries as well as the signs unique to that country. Thus, the sign set was not the same in all countries. In general, as expected, performance on the local signs was

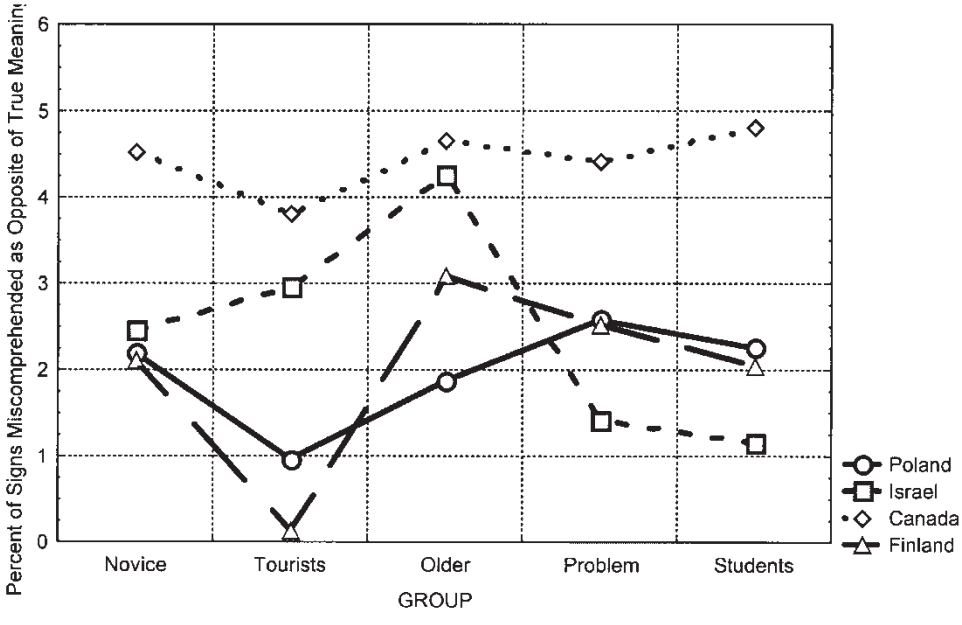


Figure 3. Per cent of signs identified as the opposite of their true meaning, as a function of country and group.

better than on the non-local signs: 77.9% of all local signs were perfectly identified, compared to 32.4% of the non-local signs ($t = 54.32$, $p < 0.001$). Separate country × group ANOVAs conducted on local and non-local signs yielded for both analyses significant main effects of country and group and significant interactions of country × group. These effects are reproduced in figure 4 for local signs and figure 5 for non-local signs. From these figures and the significant interactions it is obvious that aside from the expected and large overall difference in performance on local vs. non-local signs, a simple pattern is not the rule. For example, unexpectedly tourists generally did not do worse than local drivers in their ability to identify local signs (and as expected, they did not differ from the local drivers in their ability to correctly identify non-local signs). To understand these results, performance on the individual signs was assessed, and is discussed below.

3.2. *Comprehension of specific signs*

Figure 6 illustrates the comprehension levels of all signs across all respondents. As can be seen from this figure there are large differences among the signs, with some signs being fully understood by more than 90% of all respondents (S9, S14, S19, S25, S27. See figure 7 for S9—Road Works—for example), and others being either misunderstood or not fully understood by 80% or more of the respondents in a fairly uniform manner across all four countries (S2, S4, S12, and S20. See figure 8 for S12—Termination of Road—for example).

However, the error patterns were not the same for all signs. While in a few cases poorer performance was due to partially correct answers (S1, S6, S20, and S24), the most common errors were simply wrong answers. The most extreme examples were S4 (No entry for vehicles carrying explosives) and S12 (Termination of road) with

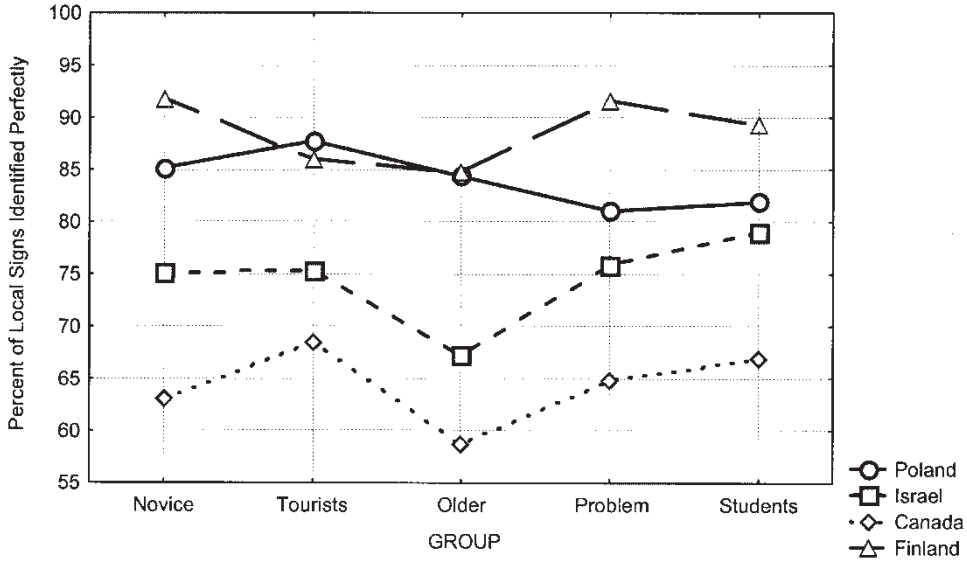


Figure 4. Per cent of local signs identified perfectly, as a function of country and group.

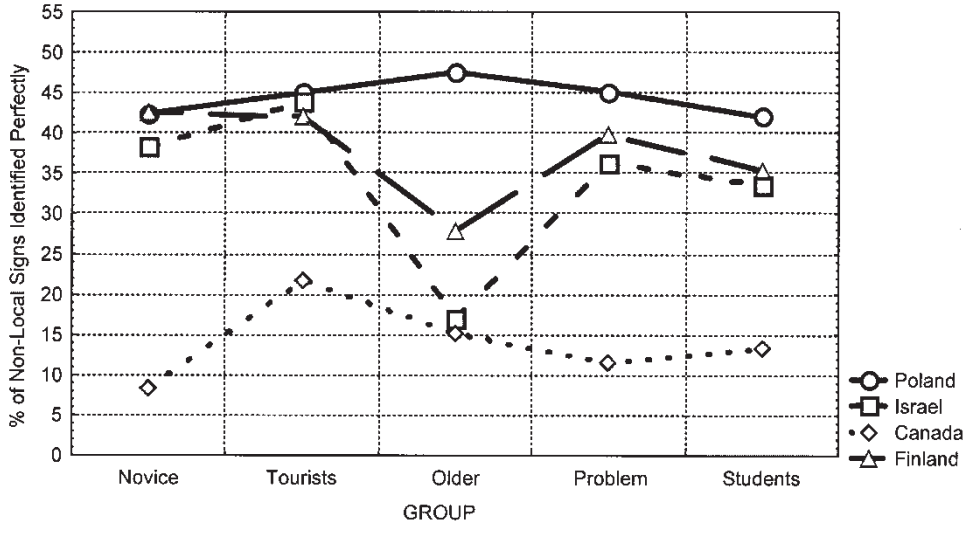


Figure 5. Per cent of non-local signs identified perfectly as a function of country and group.

78% and 86% of the respondents providing wrong answers, respectively. Three other signs yielded over 50% wrong responses (S15, S21, and S26), seven signs had over 30% wrong responses (S3, S7, S20, S22, S23, S24, and S30), and four more signs had 20–30% wrong answers (S1, S6, S13, and S31). Finally, perhaps most disturbing, three signs were misinterpreted to mean the opposite of their true meaning by 10% or more of the respondents: S2 (10%), S5 (21%), and S22 (26%) (see figure 9, for S22–End of speed limits for trucks and cars).

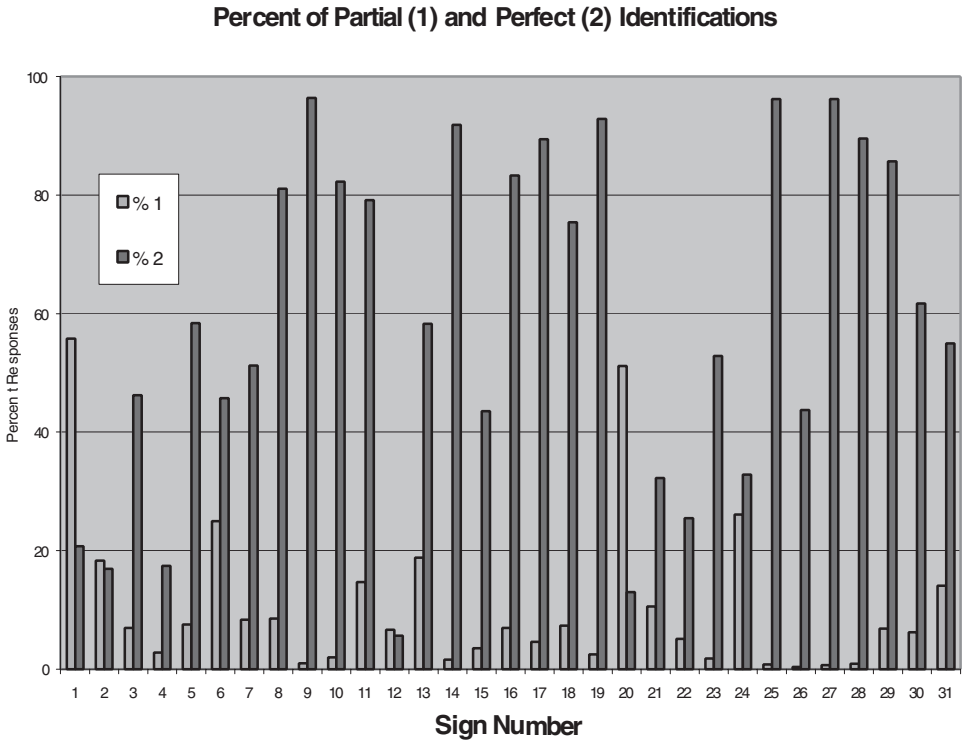


Figure 6. Comprehension levels of all study signs.

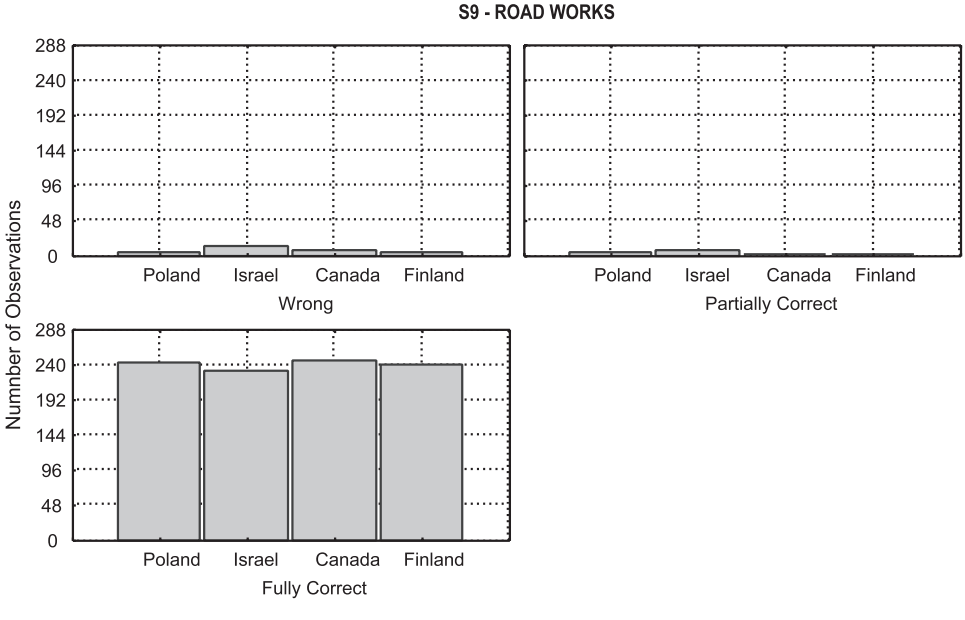


Figure 7. Levels of comprehension of S9—Road Works—for each group in each country.

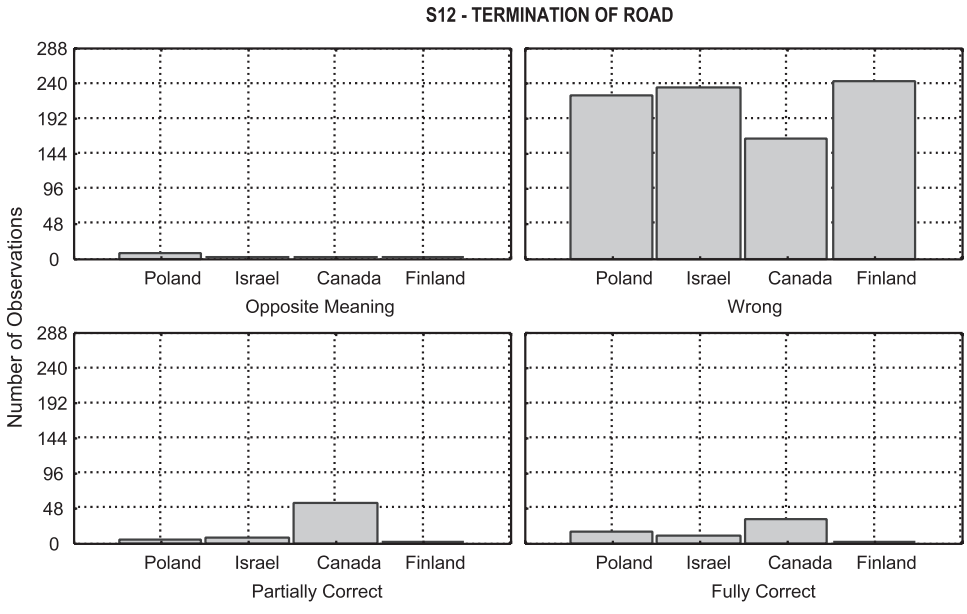


Figure 8. Levels of comprehension of S12—Termination of Road—for each group in each country.

Some of the differences among the respondents were due to large inter-country variations in the comprehension of individual signs. Some signs were well identified in some countries but not in others (for examples see S12 in figure 8, S22 in figure 9, and S26—End Priority Road—in figure 10). All of these signs, except for S30 (No Parking) were unique to individual countries, and were poorly comprehended by drivers in the other countries.

4. Discussion

The results of this study demonstrate the existence of significant differences in traffic sign comprehension among drivers of different countries and different populations within these countries. Some of the variability among cultures is due to the exposure to signs. As expected, comprehension levels of locally used signs are much higher than of signs that are not used locally, with comprehension levels of non-local signs being disturbingly low. Possibly the most worrisome is the small—but significant—% of signs that were misinterpreted to mean the opposite of their true meaning. Among the different populations, we did not find that high risk drivers perform any worse than other drivers, and we did not find that newly licenced drivers performed any better than other drivers. However, older drivers—at least in Finland and Israel—tended to perform worse than others.

The analysis of performance of individual signs yielded findings that are consistent with well understood—but often ignored—ergonomic principles of display design. Although the selection of the signs for this study was not based on such considerations, the variations in sign design and comprehension allow for a discussion of these relationships between sign design and comprehension. From an ergonomic perspective, to enhance comprehension, displays should embody as many

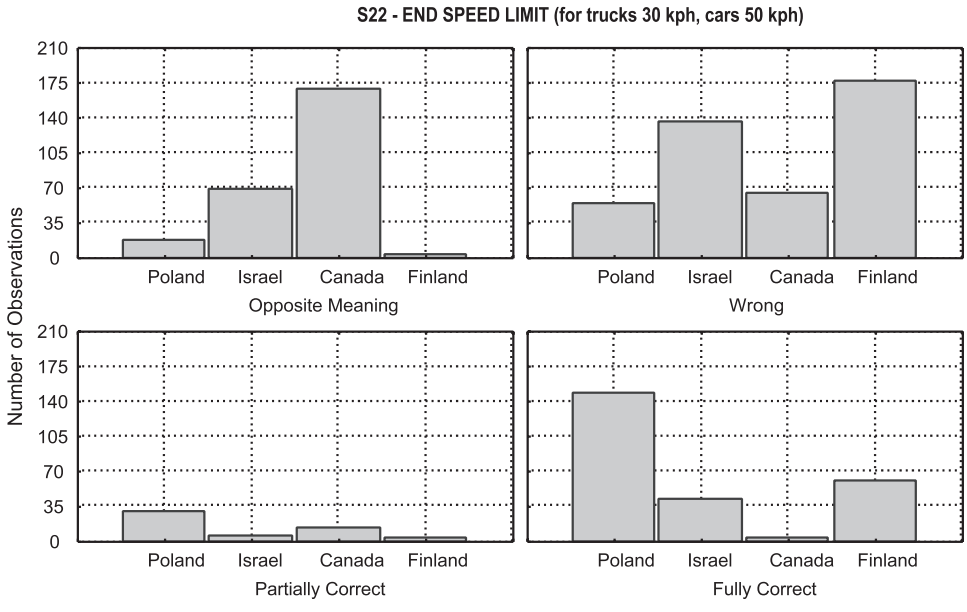


Figure 9. Levels of comprehension of S22—End of Speed Limits for Trucks and Cars—for each group in each country.

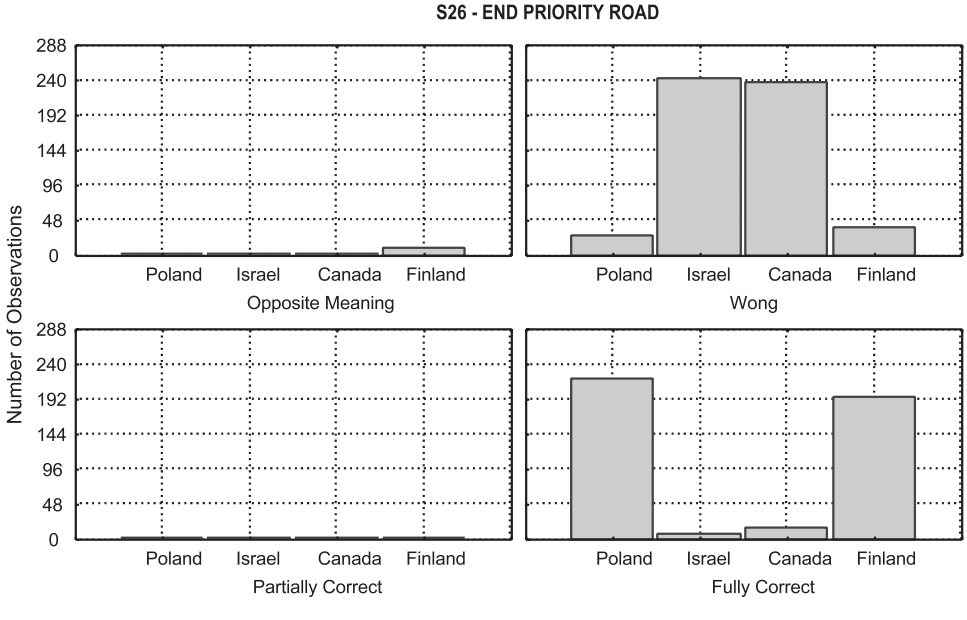


Figure 10. Levels of comprehension of S26—End of Priority Road—for each group.

of the following criteria as possible: spatial compatibility, conceptual compatibility, physical representation, familiarity, and standardization. The criterion of spatial

compatibility is illustrated by the Right Curve (S11), No Left Turn (S27), and No U Turn (S25) signs where the direction of the road is imitated by the direction of the arrow on the sign. Conceptual compatibility is illustrated by the End of Built Up Area (S23) and Parking for Public Transport (S24) signs. Physical representation is illustrated by the Road Work (S9), Pedestrian Crossing Ahead (S17), and Steep Hill Ahead (S19) signs. Familiarity is illustrated by the No Entry (S29) and No Parking (S30) signs, since their design has no intrinsic meaning and therefore they must be learned. Finally, the importance of standardization—the strict adherence under all circumstances and in all places to the symbol used for a given object it represents—is best illustrated by examples in which it is violated. This is often the case in country-specific signs where the same concept is represented by different signs in different countries. The Truck Crossing sign of Australia (S2) and End of Specified Speed Limits sign of Israel (S22) are examples.

A further design principle is that embedded additional functions should never be used in a sign. A violation of this principle is the 50 km/h speed limit implied by the European Built Up Area sign (and, implicitly, end of speed limit in End of Built Up Area—S23). Drivers neither know this additional function adequately nor conform to it to the degree they do in the case of the respective speed limit sign (Lajunen *et al*. 1996).

Good sign design should also incorporate population stereotypes, such as the use of the colour red to indicate danger (as in Stop signs); the use of different sign shapes to distinguish among regulatory, warning, and guidance signs; and the use of a diagonal line to indicate prohibition of the crossed symbol (such as 'no left turn'). Stereotypes are cultural norms that derive from the ubiquitous use of some symbols, even in contexts other than highway signs and driving. For example, we often use diagonal line over a symbol to indicate prohibition. Consequently, prohibition without such a line can create confusion. An example is the attribution of the opposite meaning to the No Entry to Motorcycles/Mopeds sign (S5), by 21% of the respondents (who believed that the sign indicates that motorcycle/moped entrance is allowed). This is despite the red border of the sign. Similarly, the use of the diagonal line to indicate repeal of the previous speed limits (S22), still caused 26% of the respondents to interpret the sign as indicating the required speed limits; probably because the line did not cross over the speed numerals.

One other factor that may account for some of the variation among the signs is relevancy. The desired recognition level should be high for highly relevant signs, and can be lower for less relevant signs. Sign 'registration' studies (e.g. Johansson and Rumar 1966, Shinar and Drory 1983) have demonstrated that drivers attend more to signs that are in some sense more relevant to their needs and goals, than to signs that are less relevant. In our study, S4 (No entry to vehicles carrying explosives) is not relevant to most drivers of passenger vehicles, and therefore its comprehension level need not be as high as that of signs that are.

The importance of one criterion—familiarity—was directly evaluated in Israel, where an independent sample of 10 drivers, with 5 + years of driving experience, rank-ordered the estimated frequency with which they encountered each of the 31 signs. Their average rank order of the signs yielded a correlation of 0.73 with the % of fully correct responses for each of the signs from the Israeli sample of 250 drivers. Thus, infrequent signs are more likely to be miscomprehended, and less likely to be correctly learned. In such cases redundant text may be most appropriate.

Signs with high comprehension values typically contain several of the above criteria. Standardization alone, for example, is not sufficient unless it is also accompanied by either a good spatial or conceptual representation, or with proper education (as in driver education and driver testing) when the representation is arbitrary. Consequently, since it can be assumed that the most often encountered signs are either good representations of their meaning or typically overlearned, they are well comprehended. On the other hand, the design of less common signs and signs unique to an individual country should involve good representation and scientific evaluation before it is let loose on the motoring public. In some cases, where a good representation cannot be found, and education to all the motoring public cannot be assured, it is probably best to use a verbal sign rather than a symbolic sign (Evans 1991).

When the sign design is completely arbitrary, then drivers who have not been exposed to it as a part of their driver education cannot be expected to comprehend it. This was shown to be the case in Signs S12 (Termination of Road) and S26 (End Priority Road). The Termination of Road sign is used in Canada but not in the remaining three countries. Consequently, only the Canadian respondents showed any significant levels of understanding of this relatively infrequent and arbitrarily-designed sign. In contrast, S26 (End of Priority Road) has an arbitrary code used in Europe, and consequently very familiar to the Finnish and Polish drivers. Accordingly, while most of those drivers identified the sign perfectly, most of the Israeli and Canadian drivers did not comprehend it at all. In contrast, signs that are unique in their details but similar to other signs conveying similar messages, such as the Railroad Crossing with Lights sign (S1) that is unique to Australia, was still identified at a partially correct level or better by most drivers in all four countries.

Above and beyond the differences in signs and their uniqueness or commonality to specific countries, it is still possible that there are true cultural differences among countries. This has been demonstrated in the comprehension of vehicle control and display symbols with respondents from France, Germany, UK, and the USA (Heard 1974). This argument is also supported by previous research on sign 'registration' in which drivers are asked to recall the last sign they passed. Although such recall is typically not high, comparable studies show that recall levels may be three to four times as high in Sweden (Johansson and Rumar 1966) and Finland (Hakkinen 1965) as they are in Israel (Shinar and Drory 1983) or Yugoslavia (Milosevic and Gajic 1986). Thus the generally poor sign comprehension of Canadian drivers and the generally good comprehension of Polish drivers may be due to differences in importance of road signs among different cultures. In particular, we have no explanation for the poor performance of the Canadians other than it may also be due, in part at least, to the fact that drivers seem to encounter fewer signs in Canada than in Europe or Israel, and Canadian drivers drive less in Europe where most of these sign symbols are used.

Finally, it is important to address the issue of sign comprehension by the different groups of drivers. Novice drivers who were recently tested on the signs did not perform significantly better (even on the local signs) than experienced drivers, and problem drivers did not perform any worse than other drivers. While the former finding may be unexpected, there is no reason to expect that problem drivers would have worse comprehension. These drivers are typically identified as 'problems' because they violate speed limits, run red lights, and fail to come to complete stop at

stop signs—behaviours that are more closely associated with risk-taking actions than with lack of comprehension of the driving environment.

One group of drivers that do merit particular attention are the older drivers. While there were no conspicuous differences among the other groups of drivers, in Finland and Israel (and to a small extent in Canada), elderly drivers did not do as well as the other drivers, and had relatively more opposite responses than younger drivers. This is despite the fact that they have been exposed to the road signs for more years than the other groups. Previous research (e.g. Dewar *et al.* 1994) also noted poorer sign comprehension by older drivers. Three different reasons may account for their poorer comprehension levels. First, it is possible, that as these drivers restrict their driving to familiar environments, and to daylight hours, they encounter the less frequent signs much less than drivers who drive in a variety of environments. Second, because of their intimate familiarity with their routes (and tendency not to travel on less familiar ones), they do not need to allocate much attention to the signs (that are essentially permanent fixtures of a familiar environment), and can devote their limited attention to the traffic instead. Third, it is likely that some of the signs in use today were introduced after their initial licencing, and so the elderly drivers never learned them in any formal manner. The relevance of the last explanation is supported by Lajunen *et al.*'s (1996) finding that signs introduced after licencing are less known than pre-existing signs.

5. Conclusions and recommendations

The results of this study lead to the following conclusions:

(1) Sign comprehension varies greatly among drivers in different countries—even when encountering signs used in all countries.
(2) Comprehension of locally used signs is much higher than that of non-local signs.
(3) Of the different driver groups evaluated, older drivers tend to do less well at sign comprehension than other drivers, including novice drivers and repeat violators.
(4) Comprehension varies widely among signs. Though not designed to test this issue directly it appears that signs that conform to good ergonomic design principles are more likely to be fully comprehended than signs that violate these requirements.

These general conclusions lead directly to the following recommendations:

(1) Signage should be standardized across countries as much as possible, so that the number of signs unique to a country will be kept to a minimum. In particular countries that honour each other's driving licence, should strive for common standardized signs.
(2) All signs—with the exception of those that are already well comprehended even though their design is arbitrary—should conform as much as possible to good ergonomic design principles. When there is concern that the symbol sign may not be comprehended by a significant percent of the user population, it might be good to consider text in the sign as an additional cue.
(3) Signs that are unique to specific countries (e.g. non-local signs in our study) should either be easy to interpret by drivers not previously familiar with these

signs, or have their meaning spelled out in text in one of the more common languages (e.g. English, which is a language that many tourists know, at least at a rudimentary level).

(4) An international committee (like the 'Vienna Conference') should be reestablished to evaluate both current signs in different countries as well as proposed new signs. Initial international efforts towards where to place ('site') signs have been made (ECMT 1996), but much more work needs to be done. For example, presently we don't even have acceptable criteria as to what level of comprehension should be required to constitute a good sign symbol.

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References

Al-Yousifi, A. E. 1999, Investigation on traffic signs to improve road safety. *Proceedings of the 10th International Conference on Traffic Safety on Two Continents*. Malmo, Sweden, Sept. 20–22.

Al-Yousifi, A. E. 2000, Better signs for better road safety. *Proceedings of the 11th International Conference on Road Safety on Three Continents*. Pretoria, South Africa, September 20–22.

Bowman, B. L. 1993, Supplemental advance warning devices. NCHRP Synthesis of Highway Practice. No. 186.

Dewar, R. 1988, Criteria for the design and evaluation of traffic sign symbols, *Transportation Research Record*, **1160,** 1–6.

Dewar, R. E. and Ells, J. G. 1977, The semantic differential as an index of traffic sign perception and comprehension, *Human Factors*, **19,** 183–190.

Dewar, R. E., Kline, D. W. and Swanson, H. A. 1994, Age differences in comprehension of traffic sign symbols, *Transportation Research Record*, **1456,** 1–10.

Dudek, C. L., Huchingson, R. D., Trout, N. and Chester, D. 1996, International tourist guidance needs and understanding of selected guide signs in Florida, *Transportation Research Record*, **1550,** 37–47.

ECMT. 1974, European rules concerning road traffic signs and signals, *European Conference of Ministers of Transport*, Paris.

ECMT. 1996, Siting of road signs and signals: first steps towards a common practice. Unpublished survey data, *European Conference of Ministers of Transport*, Group on Road Traffic Signs and Signals, Paris.

Evans, L. 1991, *Traffic Safety and the Driver*. New York: Van Nostrand Reinhold.

Hakkinen, S. 1965, Perception of highway traffic signs. Report No. 1, The Central Organization for Traffic Safety in Finland.

Heard, E. A. 1974, Symbol Study—(SAE Paper 740304. Warrendale, PA: Society of Automotive Engineers.

Johansson, G. and Rumar, K. 1966, Drivers and road signs: a preliminary investigation of the capacity of car drivers to get information from road signs, *Ergonomics*, **9,** 57–62.

Jones, R. W. 1992, Older drivers say . . . Stop signs of confusion, *Traffic Safety*, **11**(6), 6–9

Lajunen, T., Hakkarainen, P. and Summala, H. 1996, Ergonomics of road signs: explicit and embedded speed limits, *Ergonomics*, **39,** 1069–1083.

Leppikangas, K. and Summala, H. 1999, Suomalaisten ja venäläisten kuljettajien liikennemerkkituntemus. Ministry of Transport and Communications, Report No. B11/99. Helsinki, Finland.

Milosevic, S. and Gajic, R. 1986, Presentation factors and driver characteristics affecting road-sign registration, *Ergonomics*, **29,** 807–815.

Ott, R. L. 1993, *An Introduction to Statistical Methods and Data Analysis* (p. 786). 4th edition, Duxbury Press, Belmont, CA.

Paniati, J. F. 1989, Redesign and evaluation of selected work zone sign symbols, *Transportation Research Record*, **1213,** 47–55.

Picha, D. L., Hawkins, H. G. Jr. and Womack, K. N. 1995, Motorist understanding of alternative designs for traffic signs. Final Report to the Federal Highway Administration. Texas Transportation Institute, Texas A&M University, College Station, TX.

Picha, D. L., Hawkins, H. G. Jr., Womack, K. N. and Rhodes, L. R. Jr. 1997, Driver understanding of alternative traffic signs, *Transportation Research Record*, **1605,** 8–16.

Shinar, D. and Drory, A. 1983, Sign registration in daytime and nighttime driving, *Human Factors*, **25,** 117–122.

Summala, H. 1998, American drivers in Europe: different signing policy may cause safety problems at uncontrolled intersections, *Accident Analysis and Prevention*, **30,** 285–289.

Swanson, H. A., Kline, D. W. and Dewar, R. E. 1997, Guidelines for traffic sign symbols, *ITE Journal*, **67**(5), 30–35.