

Accident Analysis and Prevention 32 (2000) 575-581



www.elsevier.com/locate/aap

Influence of drivers' comprehension of posted signs on their safety related characteristics

Hashim Al-Madani *

Department of Civil and Architectural Engineering, University of Bahrain, PO Box 32038, Bahrain

Received 22 September 1997; received in revised form 19 May 1999; accepted 16 June 1999

Abstract

The paper studies the relationship between drivers' understanding of posted signs in three of the Gulf Cooperation Council (GCC) states, Bahrain, Qatar and the United Arab Emirates (UAE), and some of their safety related characteristics. These characteristics are driving experience, accident involvement, experience per accident, citations received in the last 3 years on speed limit violations, and seat belt usage. A total of 28 posted signs were investigated. These were categorized as warning and regulatory. To achieve the above goals a questionnaire, specially prepared to collect the necessary data, was distributed to over 6000 drivers in the three states. Over 2820 (47%) responded back. Comprehension of posted signs for drivers with high years of driving experience proved to be significantly better than those with lesser experience. However, the results revealed no significant influence on their accident involvements, even when the effect of age is incorporated; experience per accident ratios, or speed citations. Further, the seat belt usage is also found to increase with understanding of posted signs. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Warning signs; Regulatory signs; Understanding; Comprehension; Accident; Seat belt; Speed; Citations; Experience

1. Introduction

Posted road traffic signs are the most commonly used traffic control devices. Their main function is to provide the road users, specially the drivers, with the important navigational messages. They serve other needs, as well, as will follow. However, questions such as: does better understanding of such signs mean less accident involvement?; is there any relationship between drivers' understanding of posted signs and their speed limit citations?; does understanding of such signs increase with driving experience and how is the drivers seat belt usage related to their knowledge of posted signs?, are investigated in this study.

Many accidents occur because the driver is suddenly confronted by the unexpected. The driver should, therefore, be warned by means of traffic signs, as much as possible, for any abnormal driving situations ahead (Pignataro, 1973). These signs convey messages in terms of words or symbols. Signs are, therefore, essential where special regulations apply at specific places or at specific times, where hazards are not self-evident. According to US Department of Transportation (1989), improvement in traffic signs at intersections lead to 34% reduction in fatal accidents and 93% in injury related accidents in the United States. In fact the effectiveness, as per benefit/cost ratio, appears to be the highest compared with traffic channalization facilities, sight distance, markings, illumination and traffic signal improvement. The improvement in the posted signs include the location and the illumination.

Although traffic signs are very uniform all over the world, many countries have issued their own sign manuals. Traffic signs, however, are most effective when they satisfy the following fundamentals: fulfill a need, command attention, convey a clear and simple meaning, command respect of the road users and give adequate time for proper response (Institute of Transportation Engineers, 1992). The subject of this investigation is related to the third fundamental parameter, namely conveying a clear meaning to the users.

One of the earliest studies on posted signs was that of Riegelneier (1942) on rehabilitation of signs. Roadway

^{*} Tel.: +973-681234; fax: +973-684844.

posted signs, in fact, were evaluated by a wide range of techniques. In the 1940s and early 1950s many of the researches in this field were technical related studies, such as those related to impact assessment, cost estimation, accident evaluation and illumination effectiveness. In the early 1960s researchers started to give more weight to human related studies, particularly the motorists behavior. Hakkinen (1965), for example, directly assessed the influence of road signs on drivers' behavior by measuring their sign recall with such measures as speed reduction. Other investigators measured the visibility of the signs and drivers' recognition at different approaching speeds, taking into consideration different social and psychological backgrounds of the drivers (Johansson and Rumar, 1966; Johansson and Backlund, 1970). Others (Summala and Naatanen, 1974; Ells and Dewar, 1979; Drory and Shiner, 1982), tested the effect of illumination and brightness of the signs on both users response and drivers' reaction time. However, studies of drivers' characteristics, particularly the safety related ones, with respect to their understanding of the informational values of the signs and how well do such signs guide drivers are not, yet, extensively covered.

Jabbar and Nagvi (1992) found that drivers commit significant errors in detecting symbolic signs compared with alphanumeric ones. Therefore, to incorporate users' comprehension, modifications to certain signs might be necessary. Alphanumeric signs are better when compared with symbolic ones, so are warning signs compared with regulatory signs (Dewar et al., 1976) because the drivers regard them to be more serious. However, this was not true when 'head room hazard' sign was considered. Galer (1980) found that 21% of the long truck drivers did not understand such signs. Laboratory tests showed that drivers perceive the word 'danger' to indicate the highest level of alert compared with 'caution' and 'warning'. When such words were posted with different backgrounds, the greatest impact was found for 'danger' with a red background (Chapanis, 1994).

Fisher (1992) measured the informational value of road traffic signs by questioning drivers at road blocks. He found drivers' memory for road signs to be typically poor. Further, he strongly recommended not to assess the effectiveness of road signs in terms of drivers recall. In fact, they should be assessed in terms of their ability to sensitize the driver to hazards, regardless of those who ignore such signs. However, Book and Bergstrom (1993) tested the correlation between amount of reduction in frequency of sign occurrence and the complete elimination of sign. He found a strong correlation between the two, but for the higher experience group of drivers only.

Otani et al. (1992) found that drivers over 60 years old indicate higher risk in ignoring the warning signs.

This may be indicative of some sort of overconfidence in them. Richard and Heathington (1988) made a survey of motorists' comprehension of rail road grade crossing traffic control devices (signs and signals). Their results indicated that very young drivers (under 19 years) and elderly drivers (over 54 years) face difficulties in understanding and recognizing such devices. Significant differences between novice and experienced drivers were also observed. Drivers who disregard, even plausible, speed limits face more serious accidents and more traffic violations than those who observe the limits. Typical observers of speed limits are females aged between 40 and 60 years. Typical non-observers are males, between 25 and 40 years (Schmidt, 1982). Factors associated with compliance and noncompliance with traffic regulations, as safe driving practice and observation of regulatory signs, was investigated by Hofner (1982). Their results contradicted, at least age wise, with Otani et al. (1992). Hofner found compliers to be conscious (safety wise), either under 30 or over 60 years old, drove medium power cars, had less driving experience and fewer traffic fines than noncompliers. Typical non-compliers who tended to take risks, were between 45 and 55 years, were executives or self-employed and drove high power cars. Both groups, however, provided similar ratings for different traffic violations.

2. Aims

This study examines the influence of drivers' understanding of posted signs on some of their safety related characteristics in three of the Gulf Cooperation Council (GCC) states; Bahrain, Qatar and UAE. These characteristics include experience, accident involvement because of drivers' own fault, experience per accident ratio, speed citations received by the drivers in their latest 3 years of driving and seat belt usage. More details on experience per accident ratio is discussed latter. To achieve the above goals the following hypotheses are tested:

- 1. If traffic sign knowledge is important for safety then drivers with good understanding of posted signs should be less involved in accidents compared with those with less understanding.
- 2. Experienced drivers are expected to know the posted signs better than novice ones; for obvious reasons as higher exposure rate. Findings by Richard and Heathington (1988), as has been mentioned earlier, support this statement. Consequently, one may fairly hypothesise that as drivers' experience increase so do their understanding of posted signs.
- 3. Drivers with good understanding of posted signs are less involved in speed violations compared with those with less understanding.

4. If comprehension of signs is important for drivers' safety then drivers with good understanding of traffic signs should more frequently use their seat belts compared with those with less understanding. In other words, safe drivers attend to signs, understand them and wear seat belts.

3. Methodology

The method adopted here involved questionnaires to be filled by the drivers who were selected randomly based on stratified random sampling technique (Stopher and Meyburg, 1979; Steven, 1992; Ortuzar and Willumsen, 1996). The stratification was based on occupation. The proportion of the various occupations, countrywise, was first obtained. Accordingly, the questionnaires were distributed to the various related institutions. The various occupations were classified into twelve groups.

The questionnaire involved short-answer and multiple-choice questions. The short-answer questions were designed to identify the drivers' traffic and safety related characteristics satisfying the above goals and the multiple-choice questions evaluated drivers' comprehension of posted traffic signs. The questionnaire included 28 multiple-choice questions on different posted signs, printed in colors, both in Arabic and English; 18 on regulatory signs, e.g. speed, weight and height limits; parking, turning and overtaking prohibitions; and directional movements, and ten on warning signs, e.g. staggered junction, road narrowing and splitting, turnings and diversions. The suitability of the questionnaire was approved by language and educational experts, before being distributed. The understanding scores were considered as percentages of signs answered correctly to the total number of questions in each category. The scores were statistically tested against drivers' accident involvement, years of driving experience, speed citations received in the past 3 years, frequency of seat belt usage and experience per accident. The latter fairly combines the effect of both the driving experience and the driver's accident involvement. Therefore, comparsion between the drivers can be made on a more rational bassis. The prameter can be determined by simply dividing driver's years of experience over driver's accident involvement. However, the reciprical of the parameter is first determined. This to avoid the presence of infinite values resulting from the division process of experience by accident involvement for the drivers with no accidents. Influence of age on accident and experience was also considered. The investigated characteristics were subdivided into uniform groups, as will be discussed later. The average scores representing drivers' understanding of both regulatory and warning signs were then determined for the different groups.

Analysis of variance, using Scheffe's technique, was then performed in order to test the hypotheses. The procedure evaluated the significance of the difference at 0.05 level, between the score of the drivers in the various groups.

4. Data collection

The questionnaire was distributed to over 6000 drivers; 1400 drivers in Bahrain, 2200 drivers in Qatar and 2400 drivers in Abu Dhabi, to represent the UAE. Over 970 drivers in Bahrain (Al-Madani and Abdul-Ghani, 1995; Al-Madani et al., 1996), 1000 drivers in Qatar and 850 drivers in the UAE, responded back. A response rate of 47% was achieved. This represented over 0.05% of the total number of vehicles registered in each state. This is equivalent to over one million questionnaires that would be required for the United States (Economic Commission for Europe, 1994) as per this response rate. Both the response and the response rate are thought to be sufficient, as many studies (e.g. Dean, 1981; Steven, 1992) consider samples as high as 500 to be representative for any large populations if properly distributed according to a known statistical technique. Moreover, Hofner (1982), for example, ended up with a 39% response rate when he investigated compliance and non-compliance with regulatory signs. However, Schmidt (1982) successfully ended up with 67%.

All the necessary data, including the accident involvements, are from drivers self-response to the questionnaires. The reduced data were analyzed using statistical software called Statistical Package for Social Sciences (SPSS, 1996).

5. Results and discussion

Scores representing drivers' understanding of signs were statistically tested based on the previously mentioned characteristics.

5.1. Posted signs by driving experience

The results (Table 1) showed an increasing trend of drivers comprehension of various posted signs with the experience. Drivers in Bahrain and Qatar are comparable in their understanding capabilities towards posted signs, while those in UAE were slightly better. This might be because of the fact that drivers in the UAE are required to pass a written test on various traffic signs before being awarded a driving license, while drivers in Qatar and Bahrain are not.

Regardless of the above findings, the hypothesis that the understanding of posted signs increases with the experience is rejected, because the score did not increase significantly in all the corresponding groups. Nevertheless, the hyposesis is still valid when only the two extreme cases are compared, i.e. those with at least 2 decades of experience with those with at most 5 years of experience, at 0.0001 level of significance.

Because experience and age are correlated highly in motorized countries, age and experience were also compared in this study, for all the three states. The results showed that age and years of experience (since licencing) are highly correlated. The correlation, at 0.01 significance level, varried between 0.56 and 0.72 for the three states.

An attempt was also made to separate age and experience effects on comprehension of signs. This was performed by dividing the drivers in the highest experience group, those with at least 20 years of experience, into two groups as follows: those who obtained their driving licences within 15 years after the minimum permissible driving age (18 years) and those who obtained them afterwards. The drivers in the former group scored 64.5 and 61.1% in the warning and the regulatory signs, respectively. Those in the latter group scored 68.9 and 62.4%, respectively. However, the *t*-test indicated no significant differences

Table 1

Drivers' understanding of posted signs by driving experience

between the two groups in any of the two categories of the signs.

5.2. Posted signs by accident involvement

Results of drivers' understanding of posted signs versus accident involvement of their own faults (Table 2) revealed the existence of no significant difference in the drivers' scores, representing understanding of posted signs, between any two accident involvement groups. This means that drivers' better understanding of posted regulatory and warning signs has no significant influence in reducing their accident involvement because of their faults. In other words, drivers with high accident involvement are, statistically, as good as those with no accident involvement in cognition traffic signs. Moreover, similar results were observed when drivers understanding of such signs was tested versus their total accident involvement, i.e. of their faults and otherwise, in the three states.

Regardless of the insignificant difference, the scores from the regulatory signs showed a descending tendency with the accident involvement. Moreover, drivers involved in at least three accidents scored the lowest comprehension of both warning and regulatory signs.

State	Group	1 0-5	$-\frac{2}{6-10}$	$-\frac{3}{11-20}$	$-\frac{4}{20+}$	F-test	Significance level	Groups differed significantly
	Years of experience							
UAE	Sample size	93	123	334	202	_	_	_
	Warning signs (%)	57.00	61.90	66.10	60.20	9.302	0.000	1&3,4; 2&4
	Regulatory signs (%)	56.80	59.40	61.80	64.00	4.992	0.002	1&4
Qatar	Sample size	185	215	395	138	_	_	_
	Warning signs (%)	55.30	58.10	58.00	61.8	3.375	0.018	1&4
	Regulatory signs (%)	56.00	58.30	58.40	58.6	1.595	0.189	None
Bahrain	Sample size	218	281	309	114	_	_	_
	Warning signs (%)	56.16	54.47	58.37	66.43	7.2	0.001	4&1, 2, 3
	Regulatory signs (%)	58.3	56.3	58.6	59.5	1.4	0.230	None

Table 2

Drivers' understanding of posted signs by accidents involvement because of drivers' fault

State	Group	1	2	3	4	F-test	Significance level	Groups differed
	Life time accident involvements	None	One	Two	Three or more		_	significantiy
UAE	Sample size	553	216	63	16	_	_	_
	Warning signs (%)	65.17	64.95	65.24	61.87	0.126	0.930	None
	Regulatory signs (%)	61.36	60.65	85.82	57.33	0.897	0.465	None
Qatar	Sample size	569	273	75	22	_	_	_
	Warning signs (%)	57.77	59.19	60.53	58.37	0.821	0.512	None
	Regulatory signs (%)	57.34	58.27	57.56	55.58	0.918	0.453	None
Bahrain	Sample size	528	272	87	23	_	_	_
	Warning signs (%)	58.37	56.55	57.40	57.08	1.4	0.226	None
	Regulatory signs (%)	57.9	58.5	56.1	59.92	1.2	0.295	None

Table 3								
Drivers'	understanding	of	posted	signs	bv	speed	tickets	

State	Group	1	2	3	4	F-test	Significance level	Groups differed significantly
	Speed citation received (3 years)	0	1–2	3–6	>6		-	
UAE	Sample size	438	250	84	16	_	_	_
	Warning signs (%)	66.76	65.68	60.00	60.63	3.274	0.020	None
	Regulatory signs (%)	62.98	59.60	56.08	45.83	10.478	0.000	1&4, 2&4
Qatar	Sample size	673	144	18	5	_	_	_
	Warning signs (%)	59.49	57.50	61.67	62.00	0.687	0.559	None
	Regulatory signs (%)	58.27	57.48	56.79	56.67	0.203	0.894	None
Bahrain	Sample size	798	94	6	1	_	_	_
	Warning signs (%)	57.72	56.70	55.00	50.00	0.151	0.929	None
	Regulatory signs (%)	58.02	58.45	59.26	50.00	0.109	0.955	None

Yet, no significant difference was observed with any accident group. Nevertheless, drivers in this group may be considered for safety rehabilitation programs. However, this does not mean that authorities should ignore posted signs' improvements or drivers' education programs, because the main aim of the posted signs is to instruct the drivers. In fact, Ofusu et al. (1988) encouraged such programs to improve drivers' behaviour because the rapid motorization has not been paralleled by proper development in drivers' education. In brief, comprehension of posted signs has no influence on their accident involvement.

When lifetime accident involvements are considered, the age and licence age (experience), are to be given due consideration because experienced drivers are compared with less experienced ones in each accident category. Although accidents caused by drivers' own fault are partially because of random variance, the argument is still true because they increase with time. Therefore to incorporate the influence of age on understanding of signs in each accident category, analysis of variance was carried out at 0.05 level of significance. The test was performed for the following age groups: (i) less than 24 years; (ii) 25-34 years, (iii) 35-44 years; (iv) 45-54 years, and (v) over 54 years. When drivers with either one or no accident involvement are considered, the results indicated that drivers in age groups between 35 and 54 years understand warning and regulatory signs significantly better than those in younger ages. When those with only two accidents are considered, drivers between the age of 35 and 44 understand the sign significantly better than those between 25 and 34 years. Finally, when those with three or more accidents are considered no significant difference between any two age groups was observed.

As a result of the above findings one can conclude that middle age drivers, i.e. those between 35 and 54 years, with up to two accident involvements understand the posted signs significantly better than younger ones. Age has no significant influence in improving drivers' comprehension of sign for those with higher accident involvement. Furthermore, drivers' comprehension of posted signs are compared as per their accident involvement considering each age category separately. For example drivers' understanding of traffic signs, for those in age group between 16 and 24 years, is compared for those with 0,1,2 and 3 or more accidents. This is to identify level of understanding of safe drivers compared with less safe and risky ones. In order to enlarge the sample size in the various subcategories, the data for all the three states were considered as one group. The results indicated no significant difference between any two accident groups in any age category. In other words, risky drivers are as good as less risky ones in understanding the traffic signs.

5.3. Posted signs by experience per accident ratio

In order to consider the combined effect of both drivers' accident involvement and their experience on their understanding of posted signs, 'experience per accident ratio' is used. This ratio properly takes care of the cumulative effect of the accidents with years of experience. It is not fair, for example, to compare the understanding level of a driver who was involved in a single accident in 20 years of driving to that with 5 years. Drivers' comprehension of posted signs were tested for the drivers with the following years of experience per accident involvement: under 3, 3-5, 5-7, 7-10, 10-15 and over 15. The results, considering drivers total accident involvements and accidents because of their own faults, indicated no significant differences between any two groups. However, drivers in the groups with high experience per accident ratios were generally better than those in low groups.

5.4. Posted signs by speed citations

Drivers' scores, representing understanding level, were tested based on number of speed tickets received by the drivers in their latest 3 years of driving. The results (Table 3), generally, revealed no significant differences between the various speed ticket groups. In other words, all the groups are statistically similar. The scores in the various posted signs, excluding the warning signs in Oatar, decreased with the increase in number of speed tickets received. The results, therefore, reject the hypothesis stated earlier. Therefore, drivers with good understanding of signs are not necessarily less involved in speed citations compared with those with less understanding. It is, however, worth mentioning that drivers with over six speed violations scored low in understanding the regulatory signs, one of which is the speed limit sign. While only 9% of the drivers in Bahrain do not know the speed limit signs, in UAE and Qatar the figures are 19 and 23%, respectively. This might be because of the higher average years of education per capita as well as higher literacy level in Bahrain compared with UAE and Qatar. However, further investigation is still necessary to check both the adequacy of such for the problematic signs group of the drivers, those with high number of tickets and low comprehension of signs, and the behavioral aspects of such drivers. This will be of interest to both the designers and the manufacturers of the coming generation of signs.

Another point to be mentioned here is that drivers with high number of speed violations in Qatar showed quite high understanding of posted signs, at least towards the warning signs. This may indicate a serious irresponsible driving behavior when compared with the drivers in Bahrain and UAE where similar rules are applied, but with tougher enforcements. Nevertheless, UAE and Bahrain, are comparable in police enforcement, yet drivers in UAE clearly receive higher number of speed citations than those in Bahrain. This might be attributed to more affluence in the UAE where the average per capita income is almost twice that in Bahrain (Al-Madani and Al-Sada, 1998). Therefore, in addition to citations, enforcement of more punitive measures are desirable.

5.5. Posted signs by seat belt utilization

Drivers' understanding of posted signs were tested for the following seat belt utilization categories: those who always fasten them, those who sometimes fasten them and those who occasionally fasten them. Sometimes putting on seat belt was defined to be less than frequent (almost always) and greater than occasional (very little). The results (Table 4), revealed significant differences in understanding of the posted signs between the various seat belt utilization groups. It was indicated that as drivers' awareness of posted signs increases so does their seat belt usage. This, therefore, confirms the hypothesis stated earlier.

6. Conclusions and recommendations

Drivers' knowledge of posted signs showed significant improvement with the seat belt usage. However, drivers better comprehension of signs does not mean less accident involvement, of their fault. This is true even when age is incorporated when accidents are considered. Driving experience, since licensing, showed better understanding among only highly experienced drivers compared with novice ones. Moreover, those with very good experience per accident ratios did not prove to be better than those with bad ratios in understanding the signs. Similarly, those with no speed citations or with low number of citations were not significantly better than those with high number of citations.

As a result of the above findings, one can not agree with the commonly used assumption that knowledge of posted signs certainly improves safety. Therefore safety campaigners are recommended to be more conservative in spending on programs related to drivers' understanding of posted signs in order to improve the safety. Yet, agencies that have responsibility for drivers' licensing and for developing the handbooks should be adequately supported; because traffic signs fulfill other driving navigational needs. These agencies should certainly include some programs to improve the driving behaviours.

Group	1	2	3	F-test	Significance level	Groups differed significantly
Seat belt usage	Always	Sometimes	Occasionally			
Sample size	306	314	172	_	_	_
Warning signs (%)	73.59	62.48	57.33	53.508	0.000	All
Regulatory signs (%)	65.70	59.38	57.36	20.723	0.000	1&2,1&3
Sample size	161	359	430	_	_	_
Warning signs (%)	66.46	59.53	54.14	33.943	0.000	All
Regulatory signs (%)	63.53	58.82	54.88	26.714	0.000	All
	Group Seat belt usage Sample size Warning signs (%) Regulatory signs (%) Sample size Warning signs (%) Regulatory signs (%)	Group1Seat belt usageAlwaysSample size306Warning signs (%)73.59Regulatory signs (%)65.70Sample size161Warning signs (%)66.46Regulatory signs (%)63.53	Group12Seat belt usageAlwaysSometimesSample size306314Warning signs (%)73.5962.48Regulatory signs (%)65.7059.38Sample size161359Warning signs (%)66.4659.53Regulatory signs (%)63.5358.82	Group 1 2 3 Seat belt usage Always Sometimes Occasionally Sample size 306 314 172 Warning signs (%) 73.59 62.48 57.33 Regulatory signs (%) 65.70 59.38 57.36 Sample size 161 359 430 Warning signs (%) 66.46 59.53 54.14 Regulatory signs (%) 63.53 58.82 54.88	Group 1 2 3 F-test Seat belt usage Always Sometimes Occasionally Sample size 306 314 172 - Warning signs (%) 73.59 62.48 57.33 53.508 Regulatory signs (%) 65.70 59.38 57.36 20.723 Sample size 161 359 430 - Warning signs (%) 66.46 59.53 54.14 33.943 Regulatory signs (%) 63.53 58.82 54.88 26.714	Group123 F -testSignificance levelSeat belt usageAlwaysSometimesOccasionallySample size306314172-Warning signs (%)73.5962.4857.3353.508Regulatory signs (%)65.7059.3857.3620.723Sample size161359430-Warning signs (%)66.4659.5354.1433.943Regulatory signs (%)63.5358.8254.8826.714

Table 4 Drivers' understanding of posted signs by seat belt usage

* Bahrain is not included because the seat belt part was not included when the study first started in Bahrain.

References

- Al-Madani, H.M.N., Abdul-Ghani, A., 1995. Characteristics of drivers understanding of posted signs. Proceedings of the International Forum on Road Research, Bangkok, Thailand. Swedish National Road and Transport Research Institute, Sweden.
- Al-Madani, H.M.N., Al-Janahi, A.R., Abdul-Ghani, A., 1996. Motorists Conception of Posted Regulatory and Warning Signs, 29th ISATA International Symposium on Automotive Technology and Automation. Florence, Italy.
- Al-Madani, H.M.H., Al-Sada, I., 1998. Personal and social characteristics of the drivers towards posted signs. University of Bahrain and Swedish Road and Transport Research Institute, Safety on Roads: an International Conference (SORIC' 98), Bahrain.
- Book, A., Bergstrom, P., 1993. Road-sign utility as judged by drivers with different amounts of driving experience. Scandinavian Journal of Psychology 34 (2), 183–192.
- Chapanis, A., 1994. Hazards associated with three signal words and four colours on warning signs. Ergonomics 37 (2), 265–275.
- Dean, J., 1981. Basic Statistics for Social Research. Macmillan, New York.
- Dewar, R.E., Ells, J.G., Mundy, G., 1976. Reaction times as an index of traffic sign reception. Human Factors 18 (4), 381–392.
- Drory, A., Shiner, D., 1982. The effects of roadway environment and fatigue on sign perception. Journal of Safety Research 13 (1), 25–32.
- Economic Commission for Europe, 1994. Statistics of Road Traffic Accidents in Europe. United Nations, XXXLX, Geneva.
- Ells, J.G., Dewar, R.E., 1979. Rapid comprehension of verbal and symbolic traffic sign message. Human Factors 21, 161–168.
- Fisher, J., 1992. Testing the effects of road traffic signs' informational value on driver behavior. Human Factors 34 (2), 231–237.
- Galer, M., 1980. An ergonomics approach to the problem of high vehicles striking low bridges. Applied Ergonomics 11 (1), 43–46.
- Hakkinen, S., 1965. Perception of Highway Traffic Signs. Report 1, Helsinki, TALJA. Meddelar 4, 6–12.

- Hofner, K.J., 1982. Causes of traffic violations. Arbeiten-aus-damverkehrspsychologischen-Institute 19 (6), 47–58.
- Institute of Transportation Engineers, 1992. Traffic Engineering Handbook. In: Pline, J.L. (Ed.), Prentice Hall.
- Jabbar, A.S., Naqvi, S.A., 1992. A study of road signs. Derasat-Nafseyah, Riyadh 2 (3), 79–87.
- Johansson, G., 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.
- Johansson, G., Backlund, F., 1970. Drivers and road signs. Ergonomics 13, 749–759.
- Ofusu, J.B., Abouammoh, A.M., Bener, A., 1988. A study of road traffic accidents in Saudi Arabia. Accident Analysis And Prevention 20, 95–101.
- Ortuzar, J.B., Willumsen, L.G., 1996. Modelling Transport. John Wiley, New York.
- Otani, H., Leonard, S.D., Ashford, V.L., Bushore, M., 1992. Age differences in perception of risk. Perceptual and Motor Skills 74 (2), 587–594.
- Pignataro, L., 1973. Traffic Engineering: Theory and Practice. Prentice-Hall, Inc, New Jersey.
- Richard, H., Heathington, K.W., 1988. Motorist understanding of railroad-highway grade crossing traffic control devices and associated traffic laws. Transportation Research Record 1160, 52–59.
- Riegelneier, 1942. Rehabilitating Signs. Proceedings of the ITE.
- SPSS, 1996. 6.1 Syntex Reference Guide. SPSS Inc., USA.
- Schmidt, L., 1982. Observance and transgression of local speed limits. Arbeiten-aus-dam-verkehrspsychologischen-Institute 19 (6), 107– 116.
- Steven, K., 1992. Sampling. John Wiley and Sons, New York.
- Stopher, P.R., Meyburg, A.H., 1979. Survey Sampling and Multivariate Analysis for Social Scientists and Engineers. Lexington Books.
- Summala, H., Naatanen, R., 1974. Perception of highway traffic signs and motivation. Journal of Safety Research 6, 150–154.
- US Department of Transportation, 1989. Annual Report on Highway Safety Improvement Programs, USA.