EVALUATING THE COMPREHENSIBILITY OF VISUALIZED INFORMATION FOR THE TRANS-EUROPEAN ROAD NETWORK (TERN)

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ABSTRACT

The IN-SAFETY (Infrastructure and Safety) Project focuses on the pre-requisites of a successful implementation of Intelligent Transport Systems (ITS) in order to enhance the self-explanatory nature of roads. The European driver has to cope with more and more complex traffic environments, including vertical and horizontal signing; frequently supported by telematics.

Due to the complexity of road information there is a strong need to support the driver with homogenized pictorial messages. The readability and understandability of pictorial messages on a VMS (Variable Message Sign) was analyzed by evaluation criteria and methods of ISO 9186 "Test methods for judged comprehensibility and for comprehension". This paper discusses as well the evaluation and the results of the Comprehensibility Judgement Test, done in Austria, Hungary, and Czech Republic and Spain. For 33 referents a total of 243 variants were tested. In total, 825 voluntary drivers participated in the study. 28 referents reached a median value of judged comprehensibility exceeding 85. In 104 cases thresholds for immediate acceptance have been exceeded. Among them 56 variants were proposed for a redesign in order to enhance chances for positive results when applying the following Comprehension Test.

INTRODUCTION

Intelligent Transport Systems

Transportation is a driving force behind economic development and the well-being of all people around the world. Modern life demands growing mobility. Frequently, it is secured through ever-increasing use of private cars, burdening on a transport infrastructure that is already heavily stretched. Despite major expenditures on new road infrastructures, traffic congestion continues to rise. Past gains in road safety and environmental improvements are decreasing. Such problems can not be solved by simply building more roads or by relying on past approaches. Innovative efforts are clearly needed on a broad front. Among those is the concept – and the practice – of Intelligent Transport Systems (ITS). ITS can open up new ways of achieving sustainable mobility in the communications and information society. However, infrastructure improvements and enforcement campaigns are not expected to significantly contribute towards the 50% reduction of road fatalities, as is the target by the EU for 2010. The use of new technologies may become the catalyst towards achieving this goal.

THE PROJECT

The IN-SAFETY Project focuses on the pre-requisites of a successful implementation of ITS and aims to use intelligent, intuitive and cost-efficient combinations of new technologies and traditional infrastructure best practice applications in order to enhance the self-explanatory nature of roads.

SELF-EXPLANATORY ROADS

Self-explaining roads are roads with a design that evoke the correct expectations from road users [1]. This can be induced by correct categorisation of the road scene by the road users according to existing schemata [2].
The European driver has to cope with more and more complex traffic environments, including vertical and horizontal signs.
In some cases, this may lead to an excessive workload imposed on the driver, including:

- Striving to read the VMS (Variable Message Sign) message, while seeking the route in an unfamiliar environment (often in a foreign language and even with unfamiliar signs);
- Attempting to detect the required relevant piece of information among an abundance of information sources (e.g. in-car navigation system, Traffic Management and Information Centre or radio announcements, VMS signs, road signs,

ADAS [advanced driver assistance systems] messages, etc.).

Thus, there is a considerable need for a self-explaining road environment, preferably in a personalised fashion, which would offer intuitive guidance to the driver and information when this is needed, related to the driver's particular needs (route, disabilities, preferences, etc.) and if possible, in the driver's own language.

The concept of self-explaining roads includes [3]:

- offering the driver information on the main traffic function of the road
- allowing sufficient time for adjusting the speed when approaching a new situation (e.g. curve)
- offering roads with a safe field of vision
- and respecting the driver's expectancies and orientations

In this context, the readability and understandability of variable message signs (VMS`s) are of at most importance. The number of VMS`s in the European countries is growing fast. The drivers have to cope with an increasingly large variety of pictograms and textual messages, which even might deviate from the fixed signs as well. "During several decades now, much international and European R&D has been done, and actually is still continuing, on development and best use of Variable Message Signs, but there is no sound set of basic European recommendations for the benefit of the road authorities." [4] The main conclusion derived from the literature review is that given the diversity in practice, there is astrong need to support the driver with homogenized pictorial messages along his way on the Trans European Road Network.

Generally it is recommended to use pictograms and symbols as much as possible, in order to avoid the language problem. [5] According to Luoma and Rämä (2001) they have many advantages over commonly used text passages: "For example, pictograms are more legible for a given size and hence cost. They are more easily recognised when their information is degraded due to poor condition of the sign, poor eyesight of the observer or poor environmental visibility; when drivers are familiar with both pictograms and text messages they can extract information more quickly from the former than the latter; words and abbreviations in foreign languages are not as well understood as the pictograms; and drivers who are poor readers and who therefore have difficulty understanding text messages are able to comprehend pictograms" [6]. Foster (2001) argues in a similar way: "Symbols can express a message in a compact form, may be more noticeable in a 'busy' environment than a written message, have more impact than words and ...be understood more quickly than (written) messages." [7]

METHODOLOGY

Several stages were used to select and design pictograms for the study.
1) Collection of the information needed concerning the standardization of a graphical symbol.
2) Collection of a set of existing and proposed variants for each pictogram.
3) Pre-testing variants using the Comprehensibility Judgement Test to eliminate incomprehensible solutions, done in two countries. (Austria and Hungary)
4) Comprehensibility Judgement Test, done in 4 countries. (Austria, Czech Republic, Hungary and Spain) [8].
Further steps will be:
5) Comprehension Test, done in three countries (Austria, Czech Republic and Hungary).
6) Evaluating comprehensibility of variants under conditions of impaired vision.
7) Acceptance as a standard graphical symbol to be included in the draft to the EC.

In each stage, designs are drafted and submitted to testing, resulting in a reduction of variants and gain of insights on how the remaining pictograms are improved, if necessary.

There are two main factors to guarantee a high quality standard of pictograms to be developed for VMS:

Experts
Reknowned design consultancies with experience in this particular field participate in the project by delivering pictogram designs. Additionally, a Design Panel formed by well experienced designers provide constructive critique and guidance. Finally, psychologists assist the designers regularly in providing their insights.

ISO Tests
Evaluation criteria and methods for testing follow the ISO 9186 'Test methods for judged comprehensibility and for comprehension' [9]. These methods are employed to verify the validity of re-designed and newly developed pictograms. The cognitive value of the pictograms is estimated both under regular and impaired visibility conditions. The results of the comprehension test on animated pictograms are compared to those of static pictograms.

COMPREHENSIBILITY JUDGEMENT TEST

The objective of the comprehensibility judgement test is to reduce the number of pictogram variants that are to be submitted to a subsequent comprehension testing.

Signs

For 33 referents a total of 243 variants were tested. Table 1 shows all the referents tested in the comprehensibility judgment test (see column Referent). There are four sets of referents.

Table 1.
Referents tested at Comprehensibility Judgement Test

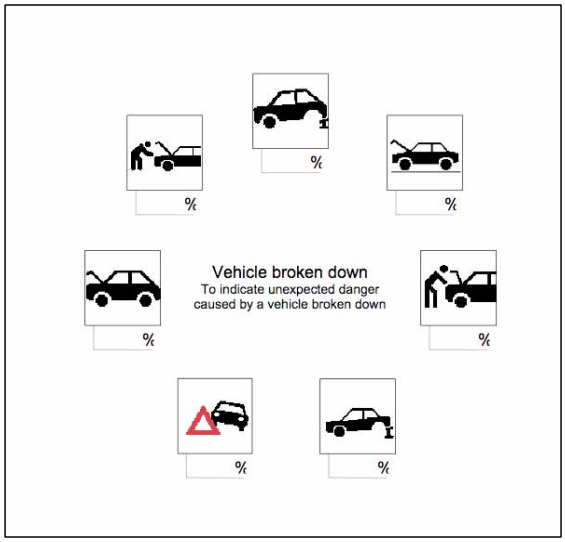
Referent	Variants	Sets			
		1	2	3	4
Road ahead closed	6		6		
Pass ahead is closed	6	6			
Tunnel ahead is closed	11			11	
Bridge ahead is closed	8				8
Next exit closed	4	4			
Take next exit	3				3
Dedicated lanes for lorries	5	5			
Flooded road	6		6		
Fog	16	16			
Freezing Fog	10			10	
High wind	6	6			
Road temperature	6				6
Accident has happened	18		18		
Vehicle broken down	7	7			
Oncoming illegal traffic	7			7	
Pedestrians on road	5				5
Horse on road	3	3			
Cow on road	3		3		
Deer on road	3			3	
Elk or reindeer on road	2				3
Speed camera/radar	14				14
Last exit before control point	11			11	
Toll road ahead	5		5		
Park & Ride	12		12		
Tram	12	12			
Ferry boat	5			5	
Picnic / rest area	7				7
Internet	1			1	
Mobile phone	6		6		
Fines doubled	6			6	
Switch off engine	10				10
Switch on Hazard Light	6		6		
Underground trains depart every 15 minutes	4				4
Total number of variants	243	59	62	61	61

Procedure

The Comprehensibility Judgement Test is a paper-and-pencil test that is conducted “in order to determine the variants judged highest on comprehensibility” [9]. Studies by Zwaga (1989) [10] and Brugger [11] support the validity of this procedure to identify promising variants within a larger set of variants.

The test material used in the Comprehensibility Judgement Test is based on test-booklets. The booklets contain one series, starting with the title page, followed by the symbol pages in randomized order. In the centre of each page, the name of the referent, its function, and its field of application are presented. The symbol variants are placed in circular or oval arrangement around the text. The participant's task is to judge the comprehensibility of each variant by indicating the percentage of the population that she or he expects will understand its meaning. The last page in that booklet is a page where the respondent has to fill in his or her own socio-demographic data such as age, years of driving experience, number of km driven per year and education.

Figure 1.
Testsample of the Comprehensibility Judgement Test



Each participating country conducted the test with at least 50 respondents for each set. The sample of respondents resembles the eventual user population in terms of age, sex and educational level. Persons with severe visual impairment (no correction possible) were not allowed as subjects. The sample preferably consisted of respondents who could be expected to be familiar with the referents and therefore each respondent should have a driving license.

The comprehensibility judgement test began with a verbal instruction on the project while the test-booklet is shown. This verbal instruction consisted of the following message given to the participants: 'We are studying the comprehensibility of symbols used on highways. We will tell you what the symbols are supposed to mean, and we ask you to judge the percentage of drivers in xxx (xxx has to be replaced by the name of your country) that you expect would understand the intended meaning. When judging the comprehensibility, please keep in mind that all symbols regarding some kind of warning will be presented with a warning triangle or flashing lights when used in a real traffic situation.'

Respondents

The interviews were conducted in Austria, the Czech Republic, Hungary and Spain. In total, 825 voluntary drivers participated in the study. Gender, age and driving experience of drivers are summarized in Table 2. The average age of the respondents was 37, 5 years. The number of female and male respondents was nearly balanced. Concerning the educational level of the participants the university level was prevailing, the driving experience was rather balanced again with 10.00 km /per year in average.
Also total values are calculated (see last row).

Table 2.
Sample characteristics

		Austria	Czech	Hungary	Spain	Total
Number of Respondents		206	200	200	219	**825**
Average age (in years)		35,9	39,5	43,8	31,2	**37,5**
Gender	Men	55,3 %	70,0 %	72,0 %	34,7 %	**57,5 %**
	Women	44,7 %	30,0 %	28,0 %	65,3 %	**42,5 %**
Education	Primary	24,3 %			2,3 %	**6,7 %**
	Secondary	49,5 %	12,0 %	37,5 %	12,8 %	**27,8 %**
	University	26,2 %	88,0 %	62,5 %	84,9 %	**65,6 %**
Driving experience. Average distance (km/year)		12.300	7.700	10.000*)	10.000*)	**10.100** *)
Years		14,8	15,9	19,2	11,4	**13,5**

DISCUSSION AND CONCLUSIONS

The mean and median values of the responses obtained were studied and the best variants differing significantly in detail and also regarding aspects of readability were proposed for further testing. See Table 3 for the total means of the tested variants and Table 4 for a results sheet example.

Table 3.
Total means of the tested variants

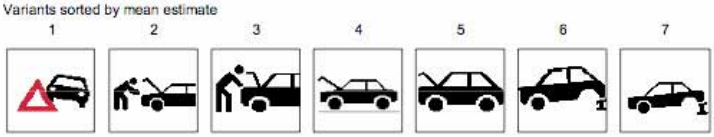
Referent	Number of Variants	Total means and medians of Variants 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Road ahead closed	6	88	85	72,5	70,6	68,8	56,6												
Pass ahead is closed	6	57,5	41,3	30	29,4	22,5	20,6												
Tunnel ahead is closed	11	68,8	65	65	55,5	51,9	51,3	50,0	46,9	48,8	30,0	30,9							
Bridge ahead is closed	8	62,5	59,4	56,3	42,5	38,8	34,4	25,0	23,8										
Next exit closed	4	83,1	84,4	68,8	57,5														
Take next exit	3	90,0	86,3	63,8															
Dedicated lanes for lorries	5	86,3	82,5	66,3	65,0	53,1													
Flooded road	6	68,8	53,8	50,0	40,0	35,0	30,0												
Fog	16	60,0	57,5	42,5	41,3	30,0	26,3	29,4	13,4	9,4	8,8	7,4	5,0	5,8	1,3	1,5	1,8		
Freezing Fog	10	86,3	62,5	47,5	50,0	30,6	30,0	28,9	25,1	22,5	20,0								
High wind	6	87,5	85,0	82,5	78,8	76,9	76,9												
Road temperature	6	88,8	87,5	45,0	41,3	40,0	30,0												
Accident has happened	18	77,5	77,5	76,3	47,5	38,8	43,8	43,3	38,6	41,9	38,8	38,4	37,5	35,0	25,6	31,3	32,5	28,8	15,0
Vehicle broken down	7	82,5	66,3	64,4	50,0	47,5	45,0	45,0											
Oncoming illegal traffic	7	31,9	36,3	38,1	12,5	3,1	4,4	5,0											
Pedestrians on road	5	87,5	77,5	70,6	60,6	36,9													
Horse on road	3	90,0	80,0	74,4															
Cow on road	3	95,4	85,6	81,9															
Deer on road	3	98,1	83,1	80,6															
Elk or reindeer on road	2	90,0	72,5																
Speed camera/radar	14	96,8	98,6	40,0	42,5	40,0	36,3	36,4	33,8	31,3	34,4	35,0	14,0	10,6	5,0				
Last exit before control point	11	90,0	37,5	33,8	30,0	27,5	27,5	27,5	25,0	18,8	20,6	10,0							
Toll road ahead	5	94,5	88,8	55,5	52,5	33,1													
Park & Ride	12	62,5	60,0	58,8	54,4	51,3	49,4	48,8	45,6	42,0	36,3	35,0	32,5						
Tram	12	86,3	84,4	76,9	67,5	60,0	53,8	46,3	46,8	43,8	41,3	32,5	30,0	22,5					
Ferry boat	5	89,4	42,5	39,4	35,0	31,1													
Picnic / rest area	7	90,6	85,6	82,5	74,9	76,3	53,8	43,8											
Internet	1	92,5																	
Mobile phone	6	81,4	80,0	77,5	60,8	60,6	57,5												
Fines doubled	6	55,0	51,9	27,5	27,5	13,1	10,8												
Switch off engine	10	62,5	57,5	54,4	43,8	33,8	34,3	30,6	26,9	24,9	3,4								
Switch on Hazard Light	6	85,0	73,8	72,5	38,8	22,5	17,5												
Underground trains depart every 15 minutes	4	78,8	80,6	71,9	35,0														
Total number of variants	243																		

3.14 Vehicle broken down

Internal numbering 2.3.3

Function as presented for testing:
To indicate unexpected danger caused by a vehicle broken down

Variants sorted by mean estimate



Austria	Median	80,0	72,5	70,0	50,0	50,0	50,0	50,0
	Mean	76,2	66,7	62,1	49,1	47,8	45,3	44,8
Czechia	Median	70,0	70,0	67,5	50,0	50,0	50,0	50,0
	Mean	66,3	65,1	62,6	44,4	45,0	48,5	48,1
Hungary	Median	90,0	62,5	60,0	50,0	40,0	40,0	40,0
	Mean	77,9	62,1	60,8	43,2	42,3	40,5	40,1
Spain	Median	90,0	60,0	60,0	50,0	50,0	40,0	40,0
	Mean	72,7	58,0	53,4	49,1	46,8	43,0	43,7
Total	**Median**	**82,5**	**66,3**	**64,4**	**50,0**	**47,5**	**45,0**	**45,0**
	Mean	**73,3**	**63,0**	**59,7**	**46,5**	**45,5**	**44,3**	**44,2**

The 3 variants judged most comprehensible reached far better scores than the rest.

Proposal:
Variants 1 and 3 (better readability expected than for variant 2) are proposed for further testing (Comprehension Test).

Comments from IIID:
Variant 3: Resembles the opening of a car´s boot. Modify to clarify the activity – inspection of the engine.

Table 4.
Results sheet example

According to recommendations of experts, further testing of comprehensibility using the Comprehension Test is not strictly necessary for variants with a mean or median value of judged comprehensibility exceeding 85, except if there are safety related requirements of higher comprehensibility.
If the best variant score is below 45 a redesign should be considered before continuing testing.
Of the total number of 243 variants 28 variants reached the score exceeding 85. In 104 cases the thresholds for immediate acceptance were exceeded. Among them 56 variants were proposed for a redesign in order to enhance chances for positive results when applying the following Comprehension Test. Only one referent proved to be unsuitable for visualization, oncoming illegal traffic, but even in this case a proposal for improvement was subsequently presented.
Nevertheless, it was agreed that additional testing procedures should be applied to guarantee successful application in real traffic applications.

OUTLOOK

The results of this Comprehensibility Judgement Test are a major achievement, generating valuable data on the potential for accurate comprehension of pictograms. Nevertheless, the results at present are to be regarded as a pre-selection for the next phase of testing where the comprehension of pictograms will be investigated in detail. In addition to the Comprehension Test, a screenbased Comprehension Test on Animated pictograms, in both regular and impaired visibility conditions, will be carried out. Only after successfully passing the upcoming Comprehension Test, the pictograms may be regarded understandable and worth of employment on the Trans-European Road Network.

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