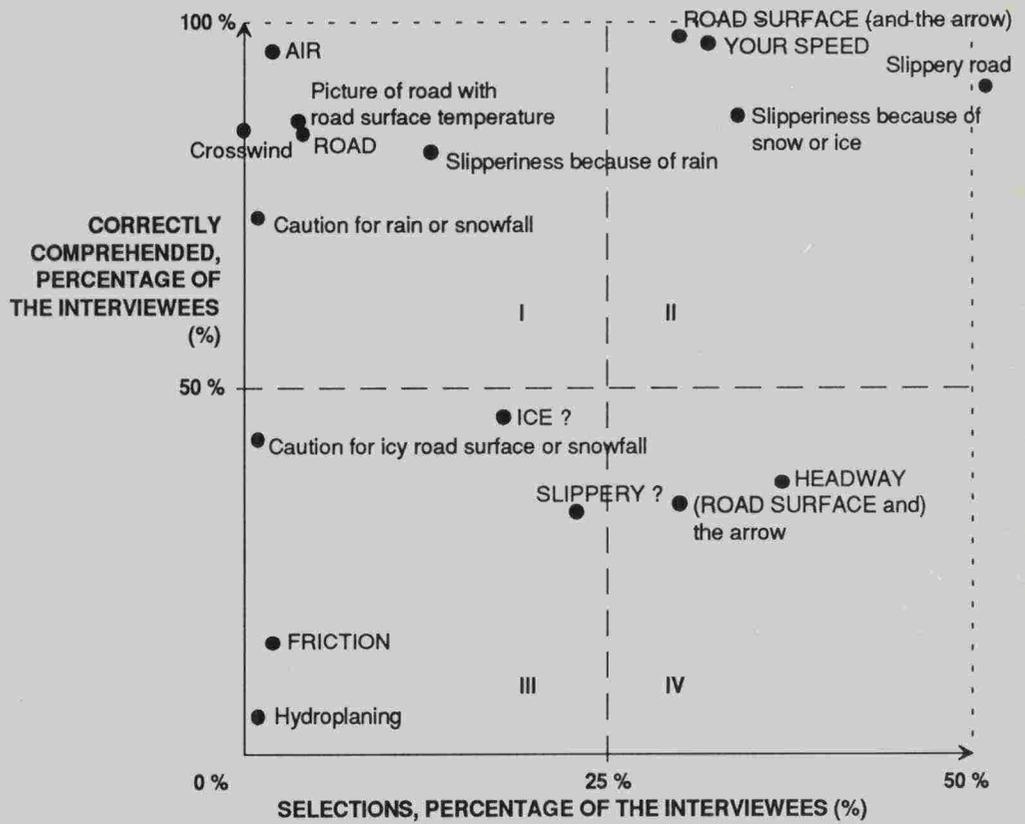




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Traffic Management Research Programme

Comprehension of Variable Message Signs for Road Conditions



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Key words: comprehension, preference, road condition, numerical message, symbolic message, verbal message, variable message sign, driver behaviour

Abstract

This interview study investigated how different variable message signs (numerical, symbolic and verbal messages) for poor road conditions are comprehended. The study also investigated what kind of slippery road condition information road users prefer; what they think about variable message signs for poor road conditions; and potential in-vehicle displays that would show similar messages. The main part of messages were imaginary variable message signs along the roads. One hundred and thirty-one drivers of different ages were interviewed at service stations in different parts of Finland.

The studied messages can be roughly distributed into four classes by comprehension and preference. The classes are: (1) comprehensible and preferable messages, (2) comprehensible but less preferable messages, (3) preferable but less comprehensible messages, (4) messages that are both less comprehensible and less preferable.

The most comprehensible and preferable messages were symbolic cautions representing slippery road, slipperiness because of snow or ice, and a verbal/numerical message describing "ROAD SURFACE" as text and temperature in degrees Centigrade. The following messages were comprehensible but less preferable: symbolic messages representing slipperiness because of rain, crosswind, caution for rain or snowfall, verbal/numerical messages indicating air temperature ("AIR"), road temperature ("ROAD") and a picture of the road (with a temperature message). Verbal/numerical messages such as "HEADWAY" (and recommended minimum value in meters) and "ROAD SURFACE", with the arrow that shows the temperature and whether it is falling or rising, were preferable but less comprehensible. Symbolic messages representing caution for hydroplaning, icy road surface or snowfall, and verbal/numerical messages such as "FRICTION" (and value), "ICE ?" and "SLIPPERY ?" were both less comprehensible and less preferable.

The implication of this study is that only comprehensible and preferable messages should be used. The use of comprehensible but less preferable messages is also possible, but they require special justification. If preferable but less comprehensible messages are used, information about their meaning must be provided in a more effective way. On the other hand it should be examined whether those messages could be showed in a more intelligible form. Finally, less comprehensible and less preferable messages are not recommended.

Almost all interviewees preferred to have these variable message signs for poor road conditions along the roadside. More than half of the interviewees considered information on the local road condition to be more necessary than information on road conditions for long distance. Sixty three percent of the interviewees would like to have an in-vehicle display that would show similar messages. Furthermore, 95% of them would also be willing to pay for this device, with 43% of them willing to pay up to FIM 1,000 or more to have it installed.

Asiasanat: ymmärrettävyys, arvostus, keliviesti, kuljettaja, numeerinen viesti, symboliviesti, tekstiviesti, muuttuva liikennemerkki

Tiivistelmä

Haastattelututkimuksessa selvitettiin erilaisten tiellä vallitsevasta kelistä ker-
tovien numeeristen-, teksti- ja symboliviestien ymmärrettävyyttä. Lisäksi
selvitettiin minkälaisia keliviestejä kuljettajat arvostavat liukkaudesta tie-
dotettaessa, mitä mieltä he ovat tienvarressa esitettävistä keliviesteistä ja
autoon mahdollisesti saatavista visuaalisista keliviesteistä. Pääosa vies-
teistä oli kuvitteellisia tienvarressa sijaitsevia muuttuvia liikennemerkkejä.
Tutkimuksessa haastateltiin 131 eri ikäistä autoilijaa eri puolilla Suomea si-
jaitsevilla huoltoasemilla.

Ymmärrettävyytensä ja kuljettajien arvostuksen perusteella tutkitut viestit
voidaan jakaa karkeasti neljään ryhmään: (1) helposti ymmärrettävät ja kul-
jettajien arvostamat viestit, (2) helposti ymmärrettävät viestit, joita kuljettajat
eivät arvosta, (3) huonosti ymmärrettävät, mutta kuljettajien arvostamat
viestit, (4) huonosti ymmärrettävät viestit, joita kuljettajat eivät myöskään ar-
vosta.

Helposti ymmärrettäviä ja kuljettajien arvostamia viestejä olivat symboliset
viestit liukas ajorata, lumesta tai jäältä johtuva liukkaus ja
teksti/numeroviesti tienpinnan lämpötila "TIEN PINTA" -tekstillä (ja lämpötila
asteina). Helposti ymmärrettäviä viestejä, joita kuljettajat eivät suosineet oli-
vat symboliset viestit vesisateesta johtuva liukkaus, sivutuuli, vesi- tai lumi-
sateen aiheuttama vaara ja teksti/numeroviestit ilman lämpötila ("ILMA"
-tekstillä) ja tienpinnan lämpötilat (tienpinnan lämpötila -kuva ja tienpinnan
lämpötilanäyttö "TIE" -tekstillä). Huonosti ymmärrettäviä, mutta kuljettajien
arvostamia viestejä olivat teksti/numeroviestit "TURVAVÄLI" ja tienpinnan
lämpötilanäyttö lämpötilan muutossuunnan osoittavan nuolen osalta.
Huonosti ymmärrettäviä viestejä, joita kuljettajat eivät myöskään ar-
vostaneet olivat symboliset viestit vesiliirto, jäisestä tien pinnasta tai lumisa-
teesta aiheutuva vaara (lumikide), teksti/numeroviesti "KITKA" sekä
tekstiviestit "JÄÄTÄ ?" ja "LIUKAS ?"

Tutkituista keliviesteistä voitaneen suosittaa niiden keliviestien käyttöönot-
toa ja käyttämisen jatkamista, jotka ymmärrettiin helposti ja joita myös ar-
vostettiin. Helposti ymmärrettyjä viestejä, joita ei juuri arvostettu voidaan
käyttää ymmärrettävyytensä puolesta, mutta koska kuljettajat eivät pidä nii-
tä erityisen tärkeinä, on käytön oltava erityisen perusteltua. Huonosti ym-
märretyt, mutta suositut viestit vaativat puolestaan huolellista tiedottamista,
jos niitä otetaan käyttöön. Toisaalta tulisi tutkia, voidaanko näitä viestejä
esittää ymmärrettävämmiin jollain muulla tavalla. Huonosti ymmärrettyjä
viestejä, joita ei myöskään arvostettu, ei ole tarkoituksenmukaista käyttää.

Lähes kaikki haastatellut pitivät tienvarren keliviestejä tärkeinä. Yli puolet
haastatelluista piti lähialueen paikallista kelitietoa tärkeämpänä kuin tiedo-
tusta pitkälle tieväliille. Peräti 63 % halusi vastaavanlaisia muuttuvia keli-
viestejä autonsa sisään. Näistä 95 % oli myös valmis maksamaan
tällaisesta laitteesta ja heistä jopa 43 % 1 000 mk tai enemmän.

Haastattelututkimus on osa diplomityötä Kelitiedotus ja tienvarressa esitet-
tävien keliviestien ymmärrettävyys (Kosonen 1993).

Preface

Poor weather and road surface conditions are one of the main transport problems in Finland. Annually about one third of injury accidents occur on wintry road surface conditions (icy, snowy or slushy road). Weather and road surface condition monitoring and information is thus currently widely seen as a main application of transport telematics in Finland. Work on research and development has been done since the early 80's resulting in good knowledge in this field. A network of nearly 200 road weather observation stations covers the whole country.

FinnRA's national Traffic Management Research Programme focuses on these issues. Within the research programme, the monitoring of the prevailing road conditions and road weather forecasting will be improved. Also the impact of road weather information on drivers' behaviour, and drivers' reactions and understanding towards weather controlled variable message signs (VMS) will be studied in-depth. The main results of the research programme will be published also in English.

This interview study has been done for the Traffic Management Research Programme in 1993 as part of a Master of Science Thesis. At the moment the following field studies are in progress: study on the effects of slippery road warning VMS on road user behaviour, and a study on the effects of weather and road condition warning VMS and automatic weather controlled speed limits on traffic flow and road user behaviour on a motorway.

Helsinki, December 1994

*Finnish National Road Administration
Traffic Management Research Programme, Project Manager*

Kari Karessuo

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1 INTRODUCTION

Information on road conditions has been mainly studied as a part of winter maintenance. The problem has been communication between meteorologists and road maintenance officials, while aiming at timely and economical winter maintenance. However, information on road conditions is an important part of driver information too, and a part of a dynamic traffic management system.

In Finland road users can get information on road conditions by: radio, television, teletext, service telephone, displays along the roadside (speed and temperature displays), and by 'Road info' monitors (mainly at service stations). There are also some variable speed limits (speed limit is changed when conditions are changed), and information signs that warn about the hazards of poor road conditions. Information on road conditions are produced by the Meteorological Institute (weather forecasts and possible warnings) and the Finnish National Road Administration (road reports and forecasts based on information from road weather stations). Information on road conditions is still mainly local, and in many places still in it's testing stage.

In Finland it has been found that road users can not estimate the prevailing slipperiness of the road surface, and they tend to estimate the road conditions to be better and less slippery than they really are. (Heinijoki et al. 1990)

This study was designed to compare the comprehension of different variable message signs for poor road conditions. Messages that are easy to understand and are surely understood are the basis of successful information. The studied messages were based on messages of road temperature displays that are used along the roadside in Finland.

2 METHODS AND MATERIALS

First, this study investigated how drivers understand different messages for poor road conditions when displayed along the roadside. A number of numerical, verbal and symbolic messages were chosen to be studied. Some of the studied messages were similar to present traffic signs. The black background of the messages indicated that they were meant to be displayed in variable message signs (meaning the message or part of it can be changed when the weather changes or, the sign can be switched off when it is not needed).

Second, the study investigated what kind of information on slippery road conditions drivers prefer. Third, the study investigated what they think about variable message signs for poor road conditions along the roadside, and potential in-vehicle displays that would show similar messages.

This study was carried out at service stations in order to get a relatively wide sample of drivers with minor arrangements. First, a driver was told that the study was designed to compare the comprehension of different imaginary messages for poor road conditions. The signs were supposed to be situated along the roads like normal traffic signs. In addition, it was explained that the signs were supposed to be variable. A picture of a currently used speed/road temperature sign was shown to the driver to ensure that he or she understood the concept of variable message signs.

Next, the pictures were shown to the driver one at a time and he or she was asked to describe what each of the pictures stands for, and how he or she understood the picture in question.

Messages of the study were based on currently used messages of road temperature. In addition, there were three other verbal/numerical messages for road conditions, and two verbal messages that were designed just for this study. All symbolic messages except for two have been accepted by the COST 30 committee to be used in variable message signs (EUCO-COST 30, 1981).

The studied messages are shown in figures 1 through 3. The pictures were made on the black background to easily indicate as variable message signs. The size of signs were about 14 cm x 14 cm, except for verbal messages which were a bit smaller. All signs were made on paper and on a white background.

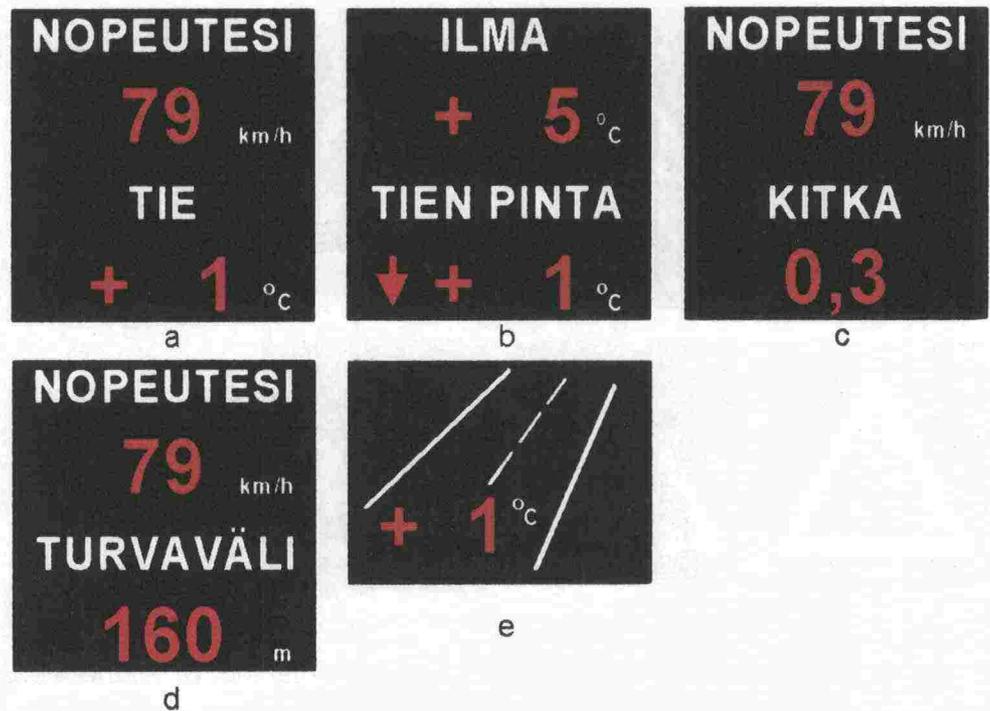


Figure 1: Studied verbal/numerical messages: a) "YOUR SPEED" and "ROAD", b) "AIR" and "ROAD SURFACE", c) "YOUR SPEED" and "FRICTION", d) "YOUR SPEED" and "HEADWAY", e) Picture of the road with road surface temperature.

The messages showed in figure 1 were considered to have the following explanations:

- a) "YOUR SPEED" and "ROAD": this sign shows the speed of a car while it is approaching the sign, and the temperature of the road surface near the sign.
- b) "AIR" and "ROAD SURFACE": this imaginary sign shows the temperatures of the air and the road surface near the sign. The arrow in front of the road temperature shows whether the temperature is falling or rising.
- c) "YOUR SPEED" and "FRICTION": this imaginary sign shows the driving speed and the friction of the road surface near the sign.
- d) "YOUR SPEED" and "HEADWAY": this imaginary sign shows the driving speed and recommended headway (in meters) caused by the driving speed and the road condition near the sign.
- e) Picture of the road with the road surface temperature: this imaginary sign shows the temperature of the road surface near the sign.

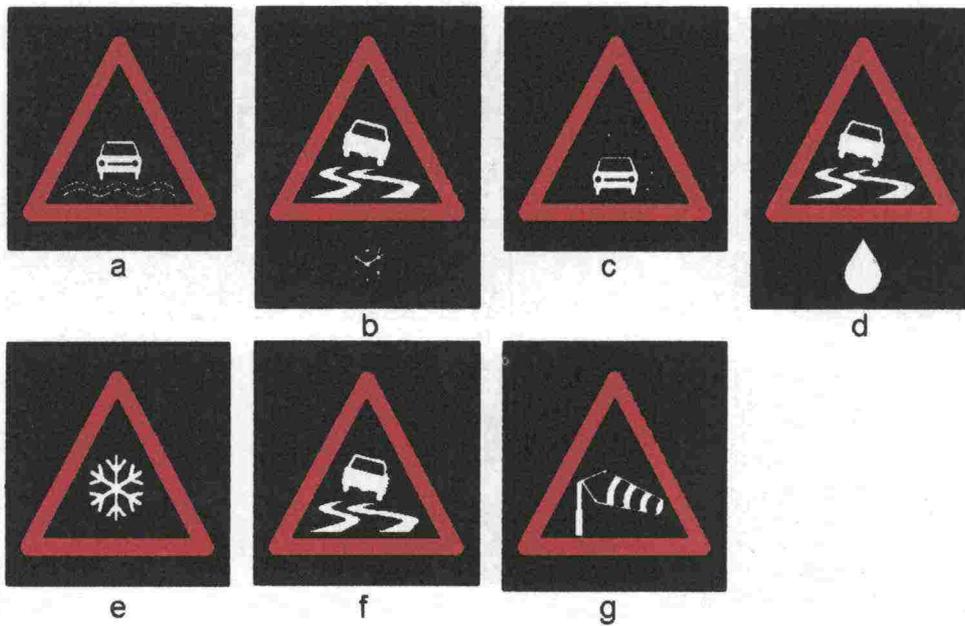


Figure 2: Studied symbolic messages: a) Hydroplaning, b) Slipperiness because of snow or ice, c) Caution for rain or snowfall, d) Slipperiness because of rain, hydroplaning, e) Caution for icy road surface or snowfall, f) Slippery road, g) Crosswind. Messages a, b, c, f and g have been accepted by COST 30 committee (EUCO-COST 30, 1981).

The imaginary sign "SLIPPERY ?" was considered to tell that the road surface may be slippery or it is slick in spots. The imaginary sign "ICE ?" was considered to tell that the road surface is possibly icy, or icy in some places.



Figure 3: Studied verbal messages: "SLIPPERY ?", "ICE ?"

These signs were shown to the driver in the same order that they are shown in figures 1 through 3. The details of the pictures were also asked about if the answers did not cover them (for example the arrow with the road temperature).

Third, the speed/friction combinations were given to the driver (figure 4). He or she was asked to compare the combinations, tell what the situations shown in the pictures mean and what the values tell about the slipperiness of the road surface. The given values 0.1, 0.3, and 0.5 represented a wide range of slipperiness as follows. The road surface is very slippery when the friction coefficient is 0.1. The friction coefficient 0.3 might represent moderate road conditions during wintertime. And when the friction coefficient is 0.5 the road conditions are almost like those of summer, when the road surface is not slippery at all.

METHODS AND MATERIALS



Figure 4: Compared speed/friction combinations.

Different headway values were compared correspondingly (figure 5). When the driving speed is about 80 km/h and the recommended headway value is 80 m, then the weather is supposed to be summery, and the road surface is not slippery at all. If the driving speed is the same as before, but the recommended headway value is 160 m, then the situation can be supposed to represent moderate road conditions during wintertime, or a wet surface during summertime. The road surface is slippery when the recommended headway value is 250 m while driving speed is about 80 km/h.



Figure 5: Compared speed/headway combinations.

Fourth, the considered meanings of the messages (figures 1 through 3) were explained to the driver. He or she was asked how he or she would like to be informed with these messages. The driver was asked to answer by forming a message combination for poor road conditions, what he or she would prefer by joining pieces of the messages together (figure 6).

Another set of the messages were made just for this task. The size of the pictures was smaller (about 10 cm x 10 cm) in order to handle them easily as pieces of puzzle. The driver was asked to keep in mind that the message combination should be suitable to be used along the roadside, and it would be changeable as the road conditions change. The driver was allowed to select three or less messages for his or her message combination.

Private and professional drivers of different ages were chosen to be interviewed when they drove to a service station. Consequently, it was a discretionary sample of drivers. Of the 131 drivers chosen, 82% were men. The mean age of the drivers was 40 years, ranging from 20 to 74 years. About 85% of the drivers used a car or van most during the last year, while 15% drove a truck or bus.

Table 1: Percentage of drivers by their major vehicle type.

Percentage of drivers (%)	Drivers	Percentage of drivers (%)
Passenger car	103	79
Van	8	6
Truck	4	3
Trailer truck	15	11
Bus	1	1
Total	131	100

The driver was asked to estimate how many kilometres he or she had driven during the last year. The mean of driven kilometres was 46,600 km/year, but the median of kilometres was only 30,000 km/year. Table 2 shows driven kilometres per year by four categories.

Table 2: Percentage of drivers by kilometres they have driven during the last year.

Kilometres per year	Drivers	Percentage of drivers (%)
- 14,999	19	14
15,000 - 29,999	35	27
30,000 - 49,999	35	27
50,000 -	42	32
Total	131	100

Table 3 shows how often drivers had seen speed/temperature displays along the roadside. Almost half the drivers had seen temperature displays along the roadside at least once.

Table 3: Percentage of drivers by how often they had seen speed/temperature displays along the roadside.

How often	Has seen temperature displays (%)	Has seen speed displays (%)	Has seen temperature and/or speed displays (%)	N
Once a week	12	6	18	23
Seldom	36	24	60	79
Never			22	29
Total	48	30	100	131

3 RESULTS

The comprehension results for each poor road condition message are presented first in the same order the messages were shown to the drivers. Next are provided the selections of message combinations for poor road conditions followed by a combination of comprehension and selecting results. Finally there are treated preference of information on road conditions.

The answers were classified into the four following categories: correct, partly correct, incorrect, and do not know. An answer was classified as correct if the driver explained the content of the message so well that one can be relatively sure that the message was comprehended. Partly correct answers either lacked some essential part or were partly wrong. A wrong answer indicated a clear misunderstanding.

The mean for correct answers was 64%, and the percentage of correct answers ranged from 5% to 98%. The mean for correct and partly correct answers was 85% and percentage ranged from 28% to 100%. Distributions of correct and partly correct answers are presented in figure 7.

RESULTS

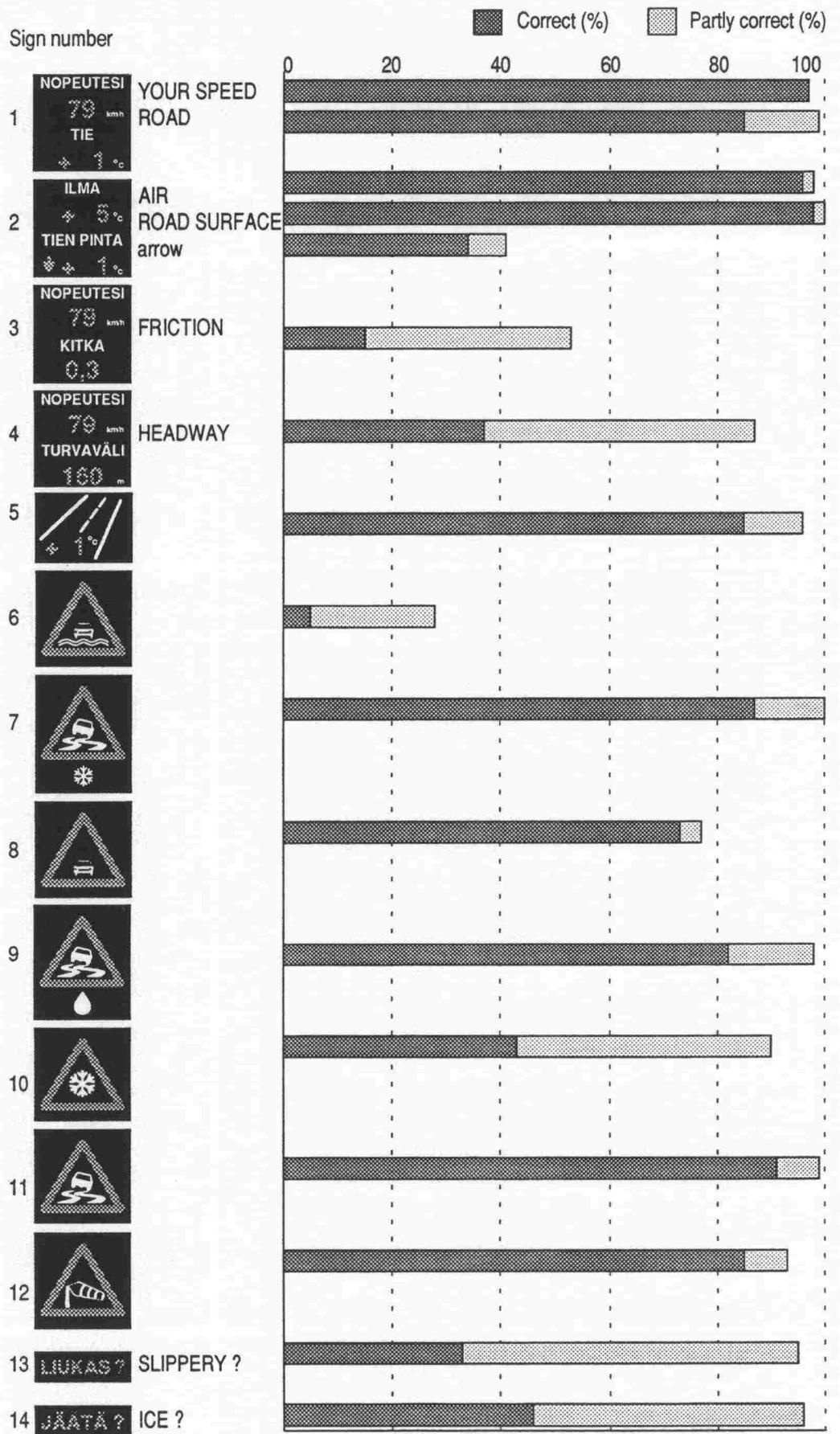


Figure 7: Drivers comprehension of different messages for poor road conditions.

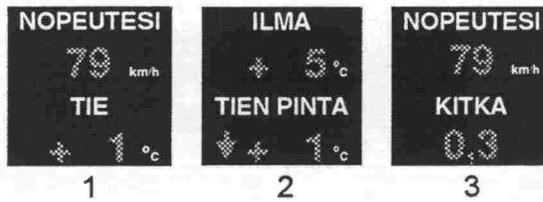


Figure 8: Signs 1, 2 and 3.

Ninety-seven percent of the drivers comprehended the speed display showed in the first sign correctly and the remaining 3% of the answers were incorrect. The following answers were considered to be incorrect: speed-limit, speed-limit required by road conditions. The road temperature was comprehended correctly by 85% of the drivers, partly correct by 14%, and incorrectly by 1%. Answers were interpreted to be correct if the temperature of the road surface was mentioned and even if there was no mention of the local temperature, or temperature at one point. The partly correct answer was the road temperature without mention of the road surface. Air temperature was an incorrect answer.

The air temperature in the second sign was correctly comprehended by 96% of the drivers. Two percent of the answers were partly correct, and 2% of the drivers were not able to explain the air temperature. Of the partly correct answers there was an allusion made to the air temperature without actually mentioning air temperature. The temperature of the road surface was correctly comprehended by 98% of the drivers, with the remaining 2% being partly correct. The arrow was correctly comprehended by only 34% of the drivers. The following answers were partly correct (7% of the answers): it might be colder; temperature of road surface might be less than +1 and temperature is falling toward road surface. Forty-seven percent of the drivers responded with the following incorrect answers: the arrow points to the road surface, or it points to the temperature on the road surface; the arrow indicates something about oncoming traffic; to keep an eye on the road surface; the arrow helps to discern temperatures of air and road surface; the temperature of the road surface below the sign or near the sign. The remaining 12% of the drivers were unable to explain what the arrow stands for.

Comprehension of the friction value was investigated with the third sign. Answers that explained both the weather when this sign could be used, and explained the friction were accepted to be correct. Fifteen percent of the answers were correct. They were as follows: quite slippery road conditions, friction between road and tire; friction coefficient of road, slippery; friction is quite low so it might be slippery. The following answers were partly correct (38% of the answers), for instance: friction between tire and road surface; friction of road surface; it can be slippery. The following answers were incorrect: weight of a car in relation to something; dry road surface and good adhesion (3% of the answers). Forty-four percent of the drivers were not able to explain what the friction stands for.

RESULTS

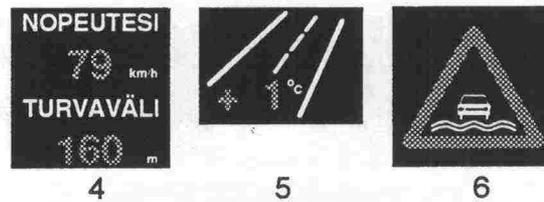


Figure 9: Signs 4, 5 and 6.

Answers indicated that 37% of the drivers comprehended correctly the recommended minimum distance (headway) that should be kept between their car and the car in front of them. In addition, they indicated that it depends on road conditions, variations in traffic, and their driving speed. Partly correct answers lacked some factor such as road conditions or other disturbance (50% of the answers). Of the remaining responses 11% were incorrect, and 2% of the drivers were not able to explain what headway stands for.

The picture of the road with the road surface temperature (sign 5) was correctly comprehended by 85% of the drivers. Eleven percent of the answers were partly correct and 2% of the answers were incorrect. Two percent of the drivers were not able to explain what that picture stands for. For instance the following answers were considered to be partly correct: the road is quite slippery if there is slush on it; slick in spots and +1 degree above zero. The following answers were incorrect: straight road; good bituminous road; air temperature.

The hydroplaning symbol (sign 6) was comprehended correctly by 5% of the drivers, partly correct by 23% and incorrectly by 66% of the drivers. Six percent of the drivers were not able to explain what this symbol stands for. Partly correct answers explained that the sign represents a rutted road and the situation will be difficult especially when it rains. If the ruts are full of water there will be a danger of hydroplaning. The following answers were incorrect: warning of deep ruts; rutted road; worn road surface at places; rough road; damages by frost; ruts on ice that covers road surface at winter; difficult road conditions; road has not been scraped for ages and there are bad bumps.



Figure 10: Signs 7, 8, 9 and 10.

Sign number 7, slipperiness because of snow or ice, was correctly comprehended by 87% of the drivers, and remaining 13% of the answers were partly correct. An indication of slippery road and the cause of slipperiness, either snow or/and ice, were required for correct answer. For instance, the following answers were partly correct: slipperiness caused by weather; icy

road; temperature is below zero and there are slippery road conditions; really slippery; slippery and a bend; wintry and slippery road conditions.

Sign 8 represents a caution for rain or snowfall. Those answers which mentioned snowfall and/or rain were accepted to be correct. Seventy-three percent of the answers were correct and 4% were partly correct. For instance, the following answers were partly correct: rain or avalanche (stones); rain or fog. The following answers were incorrect: caution for avalanches from right; oncoming traffic splashes mud; caution for fog; blowing snow; stones or avalanche; poor visibility and slushy road (8% of the answers). Fifteen percent of the drivers were unable to explain what this sign stands for.

Sign 9 represents a caution for slipperiness because of rain. Correct answers explained that slipperiness is caused by rain or water, or that there is a danger of hydroplaning (82% of the answers). The following answers were partly correct: slippery road surface; water at some places; wet road surface; slippery road and oil on road; supercooled water; icy road and rain (16% of the answers). Two percent of the answers were incorrect: caution for drunken drivers; temperature is plus/minus zero.

Sign 10 represents a caution for icy road surface or snowfall and 43% of the answers were correct, 47% were partly correct and 4% of the answers were incorrect. For instance the following answers were considered to be correct: caution for snowfall or whirling snow; newfallen snow and surprising snowdrifts; snowy, unploughed road; ice and snow on road surface; general caution for ice; caution for slippery road caused by snowfall. In partly correct answers the symbol was understood to represent snow or ice but these answers lacked any mention of inconvenience or danger to traffic. The following answers were incorrect: caution for cold weather; reindeers or elks at road; ahead the weather will be colder; cold weather. Six percent of the drivers were unable to explain what this sign stands for.

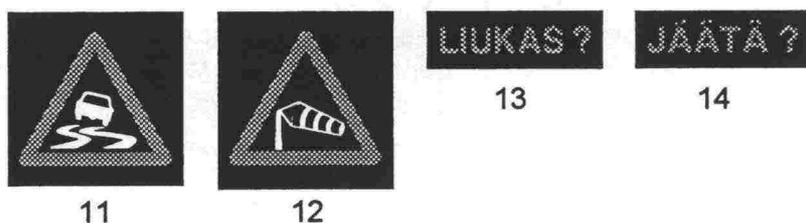


Figure 11: Signs 11, 12, 13 and 14.

The symbol representing slippery road (sign 11) was correctly comprehended by 91% of the drivers, 8% of the answers were partly correct, and 1% was incorrect. For instance the following answers were accepted to be correct: caution for slippery road; slippery road; the sign represents slippery road; the road surface is slippery. The following answers were partly correct: slippery in the rain; slippery if road is rutted; slippery, just made asphalt surface; icy road. A bend was an incorrect answer.

The symbol representing crosswind (sign 12) was correctly comprehended by 85% of the drivers. Eight percent of the answers were partly correct, and 5% were incorrect. Two percent of the drivers were unable to explain what this symbol stands for. Caution for strong wind, crosswind, wind and

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windy place were accepted to be correct answers. Wind gauge, air sock and wind direction were partly correct answers. The following answers were incorrect: landing place for airplanes; something about gas; caution for road marking; someone drives aside; some danger somewhere above.

Sign number 13, "SLIPPERY ?", was correctly comprehended by 33% of the drivers, partly correctly by 62% and 1% of the answers was incorrect. Four percent of the drivers were unable to explain what the sign stands for. For instance, the following answers were accepted to be correct: perhaps it is slippery; it is uncertain whether it is slippery or not; it might be slippery; it is likely that the road is slippery; the road might be slippery occasionally. Drivers with partly correct answers mentioned a slipperiness of the road, but they lacked information determining whether the slipperiness was conditional or local. Strong order to slow down was an incorrect answer.

Sign number 14, "ICE ?", was correctly comprehended by 46% of the drivers, partly correct by 50%, and 1% of the answers was incorrect. Three percent of the drivers were unable to explain what this sign stands for. For instance, the following answers were accepted to be correct: there might be ice; slippery at some places; it is likely that there is ice somewhere. In partly correct answers drivers mentioned a slipperiness of the road, and/or ice, but they lacked information determining whether the slipperiness or ice was conditional or local. Strong order to slow down was an incorrect answer.

Percentages were also counted by background variables. The percentage of correct answers given by 18 through 30 year old drivers was 68%, with 31 to 49 year olds it was 64%, and with fifty year olds and older it was 61%. The percentage of correct answers given by drivers who drove less than 15,000 km/year was 63%, with those who drive between 15,000 - 29,999 km/year it was 66%, with those who drive between 30,000 - 49,999 km/year it was 63%, and with those who drive 50,000 km/year or more it was 65%. The percentage of correct answers given by those who were interviewed in the south was 66%, and the corresponding percentage in the north was 62%. Consequently, the background variables did not have an effect on the percentage of correct answers.

The results of comparing different speed/friction combinations and different speed/headway combinations are presented in figure 12.

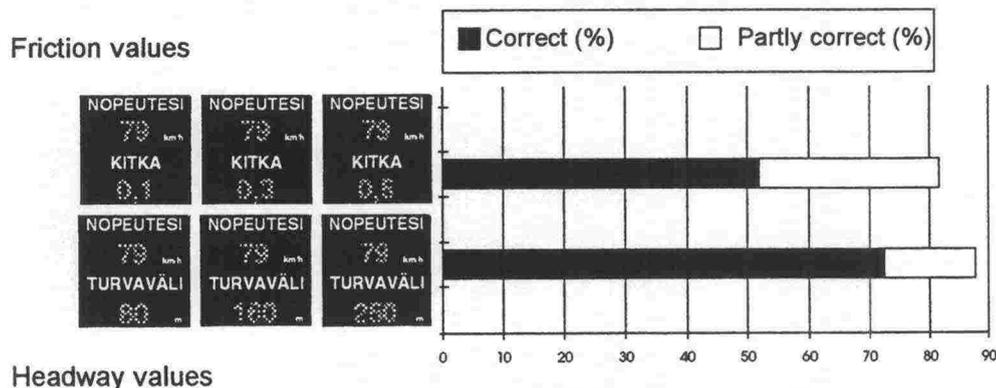


Figure 12: Comprehension of different friction and headway values.

The speed/friction combinations represented different situations which were explained correctly by 52% of the drivers and partly correctly by 30% of the drivers. Nine percent of the answers were incorrect and 9% of the drivers were unable to explain the situations. Those comparisons were accepted to be correct where drivers explained that road conditions are most slippery when the friction coefficient is 0.1, and that they are least slippery when the value is 0.5. It was not necessary to explain more about road conditions in the different situations. Those answers were accepted to be partly correct where drivers mentioned, for example, that the friction value 0.1 is the worst one or that there is least friction in that situation. Incorrect answers were when situations were in an incorrect order, in other words it was thought that the friction and grip will be better when the value of the friction coefficient decreases.

The speed/headway combinations represented different situations which were explained correctly by 73% of the drivers and partly correctly by 15% of the drivers. Ten percent of the answers were incorrect and 2% of the drivers were unable to explain the situations. Drivers with correct answers explained that road conditions are most slippery when the recommended headway is 250 metres, and that they are least slippery when the value is 80 metres. It was not necessary to explain more about road conditions in the different situations. Answers were accepted as partly correct where the drivers mentioned that longer headway is needed when it is slippery. But it was thought that headway value is the measured distance from one's own car to a car driving ahead. Drivers who mentioned that friction and slipperiness are changing but there were not defined the situations more closely also qualified as being partly correct. In incorrect answers the drivers said nothing about slipperiness, and the headway values were said to be measured, or it was said that road conditions are least slippery when the headway value is 250 metres.

The drivers were asked to make their own message combination for the slippery road conditions of the messages showed in the figure 6. They were asked to select 1 to 3 messages for their message combination. Most of the drivers did as was asked for, but some drivers wanted to select alternative messages to add to their combination, and usually that part was a symbol. For instance the slippery road symbol and its modifications were selected together, or both verbal messages. In the next table (table 4) all these selections are shown with overlaps.

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Table 4: Occurrence of messages in message combinations for poor road conditions.

Messages for poor road conditions	Number of times selected	Percentage of selections (%)	Percentage of drivers (%)
Slippery road	67	20	51
HEADWAY	49	14	37
Slipperiness because of snow or ice	44	13	34
YOUR SPEED	42	12	32
ROAD SURFACE and the arrow	39	11	30
SLIPPERY ?	30	9	23
ICE ?	23	7	18
Slipperiness because of rain	17	5	13
ROAD and the arrow	16	5	12
ROAD	5	1	4
Picture of road with road surface temperature	5	1	4
AIR	3	1	2
FRICTION	3	1	2
Caution for icy road surface or snowfall	1	0	1
Hydroplaning	1	0	1
Caution for rain or snowfall	1	0	1
Crosswind	0	0	0
Total	346	100	

The "selections" column indicates how many times each message was selected. Messages were counted both times when they occurred alone as one of the three parts of a message combination, and then again when it occurred as an alternative message. The column "percentage of drivers" shows the percentage of drivers that selected each message to their combinations for poor road conditions. These percentages better represent the superiority of messages than percentages of selections, because some drivers selected only one message, and others up to six messages to their message combinations.

Many drivers felt the messages they selected to their combination informed clearly about slipperiness, making it easy to understand and would awaken them to be more cautious in traffic.

The drivers might also choose the most important message(s) of their own message combinations for slippery road conditions. The results are shown in table 5. Messages have not been classified as to how many times different symbols or road temperatures were most important.

Table 5: The most important messages of the message combinations chosen for slippery road conditions.

	Number of times chosen most important	Percentage of times chosen most important (%)	Percentage of drivers (%)
Symbols	87	48	66
Road temperatures	33	18	25
HEADWAY	24	13	18
Verbal messages	23	13	18
YOUR SPEED	11	6	8
AIR	2	1	2
FRICITION	1	1	1
Total	181	100	

Those who chose a symbol as the most important message gave the following reasons: it shows straight and clearly whether it is slippery or not; it warns; it tells when and why it is slippery; it is clear, and attracts one's attention; it is a familiar message; it is faster to understand; it is illustrative. Those who chose a road temperature display as the most important message gave the following reasons: with temperature one can anticipate the situation, or when the road looks wet one knows whether it is icy or not. Road temperature was also considered to be a decisive factor for slipperiness and changes in weather were said to be seen from the temperature.

Those who chose a headway display as the most important message to tell about slipperiness gave the following reasons for that: it tells the extent of slipperiness; during a long drive one goes blind so that he do not notice how long headway should be in present road conditions; there is always danger of an accident if you drive in someone's bumper; one should know headway in different road conditions; it is important to keep headway; now it is said nowhere how long headway should be; it is a safety factor that is not understood by all. The following reasons were given for choosing verbal messages "SLIPPERY ?" and "ICE ?": it is the strongest order; many times you do not know whether it is slippery or not, this would be a good warning; it tells how serious the situation is; it is the clearest message; it attracts one's attention first.

There were not many differences between drivers who were interviewed in south Finland and in the north when they chose the most important messages. Only verbal messages and speed displays were chosen slightly more often in the north than in the south.

The main results of the comprehension of the messages for poor road conditions, and the selections that drivers made are combined and are presented in figure 13. Comprehension of both messages from the combination "ROAD SURFACE" and arrow were studied as separate messages. There was one message more representing temperature of road surface (in the figure 6 message set) than in the other message set (figures 1 to 3) from where comprehension of the messages were studied. On the selection axis the percentage of drivers represents how often each mes-

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sage was selected both alone, and in combination with other messages (compare with table 4).

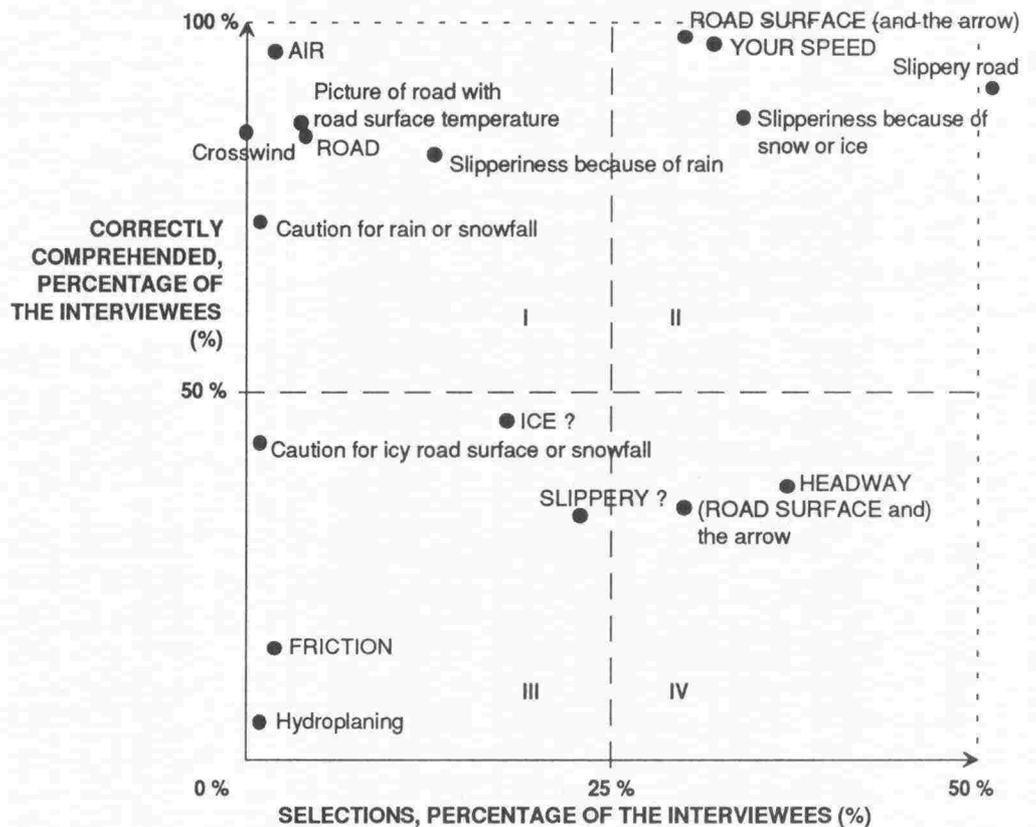


Figure 13: Comprehension of messages for poor road condition and selections made by drivers (in selections "ROAD SURFACE" and arrow formed one message, but they were studied as separate messages when comprehension was studied).

On the grounds of comprehension and selection results, the studied messages for poor road conditions can be roughly distributed into four classes according to figure 13:

- comprehensible, but less preferable messages (1st quarter)
- comprehensible and preferable messages (2nd quarter)
- less comprehensible and less preferable messages (3rd quarter)
- preferable, but less comprehensible messages (4th quarter).

Answers indicated that 99% of the drivers considered messages of road conditions along the roadside to be important. Two thirds of these drivers supported information on local road conditions, and one third considered information on road conditions for long distance to be important (table 6).

Table 6: *What kind the information on road conditions along roadside should be?*

Information on road conditions	N	Percentage of drivers (%)
Local information	78	60
Information for longer distance (e.g. 100 km)	41	31
Both	10	8
Information displays along roadside are useless	2	1
Total	131	100

Of the drivers surveyed, 63% would like to have in-vehicle display that would show similar messages for road conditions. According to the rest of the drivers (37%) it is unnecessary to get information inside a car. Among those who wanted in-vehicle display, 17% drive less than 15,000 km/year, 21% drive between 15,000 - 29,999 km/year, 28% drive between 30,000 - 49,999 km/year, and 34% drive more than 50,000 km/year.

Those drivers who liked to have an in-vehicle display were asked how much they would be willing to pay for the device. The driver was allowed to freely suggest a price, but if he or she was not able to choose a price, he or she was given following alternatives: FIM 100, FIM 500 and FIM 1,000. Percentage of willingness to pay is seen in table 7.

Table 7: *Percentage of drivers willing to pay to get information on road conditions by way of an in-vehicle display.*

Price of a device	N	Percentage of drivers who liked to get information on road conditions into a car (%)
FIM 100 - 499	21	25
FIM 500 - 999	22	27
FIM 1,000 -	36	43
will not buy	4	5
Total	83	100

4 EXAMINATION OF THE RESULTS

This interview study investigates the comprehension of different message signs for poor road conditions, the preference of these messages, the drivers' opinions on message signs for poor road conditions, and on in-vehicle displays that would show similar messages. The main results are examined in this chapter.

The speed display, temperatures of air and road surface, symbol for slippery road and its modifications, and symbol for crosswind were comprehended much better than other messages. The percentages of drivers who could correctly identify these messages ranged from 82% to 98%.

The different numerical temperature displays which are used in urban surroundings are familiar to many of us. Temperature displays along the roadside are similar, but they specify whether the temperature shown is that of the air or the road surface. Air temperature was comprehended easily. The temperature display with the text "ROAD SURFACE" was easiest to comprehend among the studied road surface temperature displays, for it expressly states that the temperature reading is of the road surface. The meanings of the temperature display with a word "ROAD", and the display with the picture of a road with temperature were comprehended clearly worse. Only about one third of the drivers comprehended correctly the arrow in front of the road temperature.

Speed display is only indirectly connected with information on road conditions but, it was reasonable to investigate it in this survey study because present variable message signs in Finland usually show driving speed with road temperature. The message of the speed display was easily comprehended.

The symbol representing a slippery road and its modifications as slipperiness because of snow or ice, and slipperiness because of rain were easily comprehended. This result may arise from the point that they remind drivers of similar "old" traffic signs.

The symbol representing a crosswind was better comprehended in this study (85% correct) than in the previous comprehensibility study when this sign was still being planned in Finland in 1981.

The symbol representing caution for an icy road surface, or snowfall, was poorly comprehended in light of the fact that many drivers had seen the symbol sometimes on television. Up until the winter of 1992-93, this symbol was used in TV news' weather forecasts to alert drivers to the areas having poor road conditions (e.g. "snowfall will impede roadtraffic...").

The new verbal/numerical messages, headway and friction, were not comprehended very well. "HEADWAY", and "having a headway between cars" were familiar terms to the drivers. It was said that headway is a good and necessary thing to remember in traffic, and it was admitted that one should have a certain headway between cars while driving. However the headway value's dependence on driving speed and road conditions were explained correctly only in 37% of the answers. On the other hand, the percentage of incorrect and do not know answers were only 13%.

The friction was correctly comprehended by only 15% of the drivers. And 44% of the drivers were not able to explain its meaning at all. When the drivers compared different speed/friction combinations, and they were asked what the situations in those pictures tell about slipperiness of road surface, the percentage of correct answers was 52%. The percentage of incorrect and do not know answers was 18%. Similar comparison of speed/headway combinations gave 73% correct answers and the percentage of incorrect and do not know answers was 12%.

The verbal messages "ICE ?" and "SLIPPERY ?" confused drivers mainly because there was a question mark after the words, therefore these messages were not comprehended perfectly. Forty-six percent of the drivers comprehended the message "ICE ?" correctly, and 33% comprehended the message "SLIPPERY ?" correctly. Nevertheless, these verbal messages were comprehended fairly well, because the proportions of incorrect and do not know answers were only 5% ("SLIPPERY ?") and 4% ("ICE ?").

The worst comprehended message of the studied messages was the symbol for hydroplaning. Only 5% of the drivers comprehended it correctly and the percentage of incorrect answers was the largest in this study, 66%. The symbol was often connected with ruts. The other studied symbol representing hydroplaning and slipperiness due to rain (an imaginary message) was clearly easier to comprehend, and it got only few incorrect answers. The background variables did not influence the message comprehension for poor road conditions.

The drivers were clearly fond of symbolic messages, as evident when they selected their own message combination for slippery road conditions. Of the sampled drivers, 84% selected a symbol for their message combination. In almost every case the selected symbol was slippery road, or its modifications. Half of the drivers selected road temperature. Clearly the most popular temperature message was the temperature message with text "ROAD SURFACE" and arrow that shows whether temperature is falling or rising. Even if the meaning of the arrow was not easily comprehended at first, this temperature message was found to give the most information. "HEADWAY" (37%), verbal messages (34%), and "YOUR SPEED" were the next most popular messages. Air temperature and friction displays were selected by 4% of the drivers in all.

Sixty-six percent of the drivers also chose a symbol as the most important message in their message combination for slippery road conditions. Twenty-five percent of the drivers chose road temperature as the most important message, and "HEADWAY" and verbal messages were both chosen by 18% of the drivers.

One could argue that opinions of road conditions vary according to the area one is from. A driver from the southern part of Finland might feel that road conditions are poor, but facing similar conditions a driver from the northern part of Finland might feel that road conditions are normal. Furthermore, authorities talk about road conditions with different 'languages'. Road users are given miscellaneous information about, for example slipperiness, braking distances and headways.

Consequently, it would be interesting and important for information on road conditions to determine whether there are significant differences between

drivers from southern and northern Finland, how they comprehend and prefer different messages for road conditions. It was not possible to compare drivers from the southern Finland and northern Finland as separate groups in this study, because only slightly more than one third of the interviewees were from the north.

Drivers from different areas considered similar messages most important. Only verbal messages made a difference. In the north, the three messages that drivers considered the most important were: symbols, road temperatures and verbal messages. And in the south the order of preference was: symbols, road temperatures and "HEADWAY".

Drivers considered messages for poor road conditions along the roadside mainly important. The reasons were as follows: they are more topical than usual traffic signs; they specifically describe about road conditions; they alert the driver to the changing of road conditions; the signs anticipate a situation, and inform the driver; during long drives one can easily go blind to speed and road conditions, which is especially dangerous since road conditions vary a lot; it draws the drivers attention to road conditions and driving.

Over half of the drivers considered local information on road conditions to be more important than information for longer drives. Information on road conditions for longer distances was considered to be easy to forget and unreliable. On the other hand, more than one fourth of the drivers that expressly wanted information for longer distances mentioned that it makes it easier to choose a route, if there are alternative routes available.

Almost all drivers considered messages for road conditions along the roadside to be important, and even 63% of the drivers would like to have in-vehicle display that would show similar messages for road conditions. Seventy-nine persons (95%) of these 83 drivers were also willing to pay for this device, and even 43% of them FIM 1,000 or more.

5 RECOMMENDATIONS

The implication of this study is that only comprehensible and preferable messages for road conditions should be used. Those messages are: slippery road, slipperiness because of snow or ice, and road temperature with text "ROAD SURFACE". The first two of these are also recommended to be used in variable message signs by the COST 30 committee (EUCCOST 30, 1981).

The use of comprehensible but less preferable messages is also possible, but they must be especially justified because drivers consider them less important. Air temperature, road temperature (picture of the road with road surface temperature and road temperature with the text "ROAD"), slipperiness because of rain, crosswind, and caution for icy road surface or snowfall are that kind of messages. The latter two recommended by the COST 30 committee to be used in variable message signs. For example local use of the symbol crosswind can be reasonable.

If preferable, but less comprehensible messages ("HEADWAY" and road temperature with the arrow) are used, information of their meaning must be provided in another, more effective way. Information does influence as can be seen by the crosswind symbol. The comprehension of that message in Finland has improved considerably during the last ten years. Drivers consider familiar traffic signs better than new and different signs. Under the circumstances, however, it is not impossible to use a hydroplaning symbol either, because drivers get used to a new sign. Nevertheless, it should be examined whether preferable but less comprehensible messages could be presented in more intelligible form.

Less comprehensible and less preferable messages such as hydroplaning, "FRICTION", caution for rain or snowfall, "ICE ?" and "SLIPPERY ?" are not recommended for use. The symbol for hydroplaning that was recommended by the COST 30 committee to be used in variable message signs is often connected with ruts. It might be quite exceptional that the Finns are so strongly conscious of ruts. This may be due to strong media coverage concerning ruts and the roads where ruts cause problems.

On the basis of these interviews it seems that all drivers do not fully understand the connection between road surface temperature and road conditions. Neither do they understand that air temperature does not tell the whole truth about road conditions, especially when the temperature is around zero degrees centigrade.

The only essential temperature value in present temperature displays along the roadside might be the road surface temperature. Anyway, Finland has some displays along the roadside that show both the air and road surface temperatures.

Studies must be conducted to determine the possibility of using symbols with verbal/numerical messages in variable message signs for poor road conditions. Present temperature displays, especially those with the text, "ROAD SURFACE", could be used as a starting point for developing variable message signs for poor road conditions. On the other hand, it should be determined, how to use variable message signs for poor road conditions

during the summer. Is speed display the only suitable message to be used as a part of a road conditions display? Speed display was easily comprehended, and it was also preferred.

Variable roadside messages for poor road conditions are preferable, because these signs clearly differ from normal traffic signs and therefore also be considered easier to perceive. The message that differs from the usual helps to alert the driver, allowing him or her to react to deviating conditions. On the other hand, the economic state sets bounds to generality of variable message signs, and to technique that can be used.

Present temperature displays show temperatures year around. A question arises, why are temperatures shown along the roadside anyway? Is their function just to be an addition to speed displays? Or should temperature displays be changed so that they are more specific to road conditions? It means that temperature would be shown only when it is critical due to slipperiness, in other words when temperature ranges from +2 to -5 °C, or when it is under +2 °C. In this case, the temperature would draw drivers attention more easily. On the other hand, it is important always to show something in variable message signs so that drivers know that the system works.

There is an advance notice before present speed/temperature displays where it is explained that there is a point for speed check after a certain drive. It is not presently known whether a driver can check both his or her speed, and realise temperature display at the same moment, or whether he or she even has time to perceive it while concentrating on checking his speed. The optimal station for speed display might not be the best place to show a road's cold points, and places which will freeze first. The best station for temperature display might not be suitable for a speed check, either.

If speed and temperature are shown in the same display, it could be considered that speed would be shown only when road conditions are good, and when the temperature is not shown. Then the nature of the display would be road conditions centric, and it would not be just a speedometer check.

When drivers get information about hazards ahead, in most cases they are supposed to reduce their driving speed, lengthen headways, and generally increase their caution (e.g. Rothengatter et. al 1993). So, when they come to a critical place they should be prepared to avoid possible hazardous situations. Possible changes in driver behaviour, and the followed safety effects are not proved by empirical studies yet. Drivers behaviour must be measured, for example, speed and headway measurings should be done in different traffic and road conditions to find out possible safety effects of variable message signs for poor road conditions (Kallberg et. al 1991). On the ground of this study it is possible to plan messages to be studied.

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