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EVALUATION OF THE USABILITY OF SYMBOLS INDICATING A MALFUNCTION OF AUTOMOBILES

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Abstract: *The research presented in this paper refers to the ability of drivers to understand the information presented by symbols, which indicate a certain vehicle malfunction. The testing included 4 symbols, three of which were ISO verified symbols. This study of the usability of symbols on a sample of respondents showed that the understanding of the information presented using symbols is relatively low and ranges between 51% and 65%. By testing statistical hypotheses, it was found that at the population level, these values are even lower. Suggestions have been given that should initiate the improvement of the usability of this type of symbol.*
Key words: *vehicle displays, symbols, usability.*

1. INTRODUCTION

Symbols are marks, signs, or words that indicate, signify, or are understood as representing an idea, object, or relationship [1]. According to [2], symbols can be defined as graphical entities with semantic meaning in a specific domain and that represent the minimum information that must be conveyed. Modern car displays are capable of displaying a wide variety of symbols. The driver's interaction with the symbol can be seen as a twostep process. Initially, the driver should recognize what the symbol represents, i.e., which entity is shown on the symbol. After that, the driver should understand the information transmitted by the symbol, in relation to the represented entity. However, the design of some symbols often does not leave the possibility for such a clear distinction, so that the process of recognizing and understanding the meaning of the symbols takes place at the same time.

Research related to the symbols used on car displays is not often and is not easy to find them in the literature. One of the research of this type that we managed to find was done in 1988 and presented in one technical paper [3]. The results of this research indicate that the understanding of the symbols from the car display was low, while their recognition was understandably at a somewhat higher level.

2. GOAL OF THE RESEARCH

Modern car displays have the ability to display a large number of different symbols, which have the task of presenting to the driver some information related to changes in vehicle condition, driving mode, or road conditions. However, it was noticed that one part of the drivers do not adequately use all that information available to them. One reason may be a misunderstanding of the information represented by the displayed symbol.

In order to check the understanding of the displayed information with the help of symbols, 4 symbols were selected that indicate a specific malfunction on the vehicle. Regardless of whether the driver is previously acquainted in any way with the meaning of these symbols, an adequately designed symbol should associate the driver with the information it presents.

3. METHOD

As previously mentioned, in order to verify the adequacy of the design solutions for the symbols used on car displays, 4 symbols indicating a vehicle malfunction were selected. The names of these symbols are:

1. Brake;
2. Engine coolant temperature (according to ISO 7000-0246 standard);
3. Engine oil (according to ISO 7000-0248 standard);
4. Battery charging condition (according to ISO 7000-0247 standard).

A concept known as usability can be applied extensively to the ergonomic design and evaluation of a variety of products and systems [4]. A variety of usability testing methods has evolved from strict experimental psychology methods to less controlled and more qualitative ones today [5].

Research methods such as classical experiments are the foundation of usability testing. Tests can take many forms, from large-scale classical experiments to very informal qualitative studies conducted with only one participant [6]. Below, we will describe a usability experiment that was used to determine the usability of 4 symbols, which are used on car displays.

The mentioned symbols are shown in the listed order in Table 1. The basic function of the first symbol is to convey information that there is a problem with the foot or parking brake. The purpose of the second symbol is to indicate the possibility of engine overheating (to indicate that the engine coolant may be overheating or falls outside the specified parameters). The function of the third symbol is to indicate low engine oil pressure (to indicate that the engine oil is low or falls outside the specified parameters). The purpose of the fourth symbol is to indicate the possibility that the battery will soon stop working (to indicate that the battery charging condition falls outside the specified parameters). As can be seen, the use of symbols 2, 3 and 4 is recommended by ISO (International Standard Organization). The first symbol is primarily used in Canada.

The survey included 31 respondents, of whom 24 were male and 7 female. The average age of the respondents was 22.67 years (st. dev. 2.49 years). The oldest respondent was 27 years old. All respondents had a valid driver's license. Of the respondents, other demographic data were also collected.

Although the younger category of drivers was selected, within that category, the sample was random. The younger category of drivers was selected because it was assumed that the instructions and information given at the training were relatively fresh, as well as because such respondents attended newer (more modern) driving courses (harmonized with newer types of vehicles). All respondents participated on a voluntary basis.

Table 1

Symbols used in the research, offered answers to their meaning (function) and correct answers.

Ordinal number of symbols	Symbol	Answers offered	Correct answer
1		a) Problem with any brake b) Problem with the parking brake c) Foot brake problem	Problem with any brake
2		a) Engine temperature too high b) Engine temperature too low c) Defective fuel level measurement system	Engine temperature too high
3		a) Oil is leaking b) Low oil pressure c) Add oil	Low oil pressure
4		a) The battery does not work b) The battery operates at 50% capacity c) The battery will soon stop working	The battery will soon stop working

Table 2

Percentage of the correct recognized symbols, average ad standard deviation of respondents' belief that the symbol has the meaning given in their answer.

Symbol	Percent of correct answers (%)	Average	Standard deviation
	64.52	3.97	1.079
	61.29	4.19	1.013
	51.61	3.87	1.231
	51.61	3.23	1.146

Table 3

The percentage of incorrectly recognized symbols for the first incorrectly chosen option, average and the standard deviation of the respondents' belief that the symbol has the meaning given in their response (although the answers is inaccurate).

Symbol	Percent of incorrect answers for the first incorrectly chosen option (%)	Average (for the first incorrectly chosen option)	Standard deviation (for the first incorrectly chosen option)
	22.58 (b)	4.0	1.155
	29.03 (b)	4.11	0.782
	25.8 (b)	3.37	1.302
	32.26 (a)	2.64	1.362

Table 4

The percentage of incorrectly recognized symbols for the second incorrectly chosen option, average and the standard deviation of the respondents' belief that the symbol has the meaning given in their response (even though such a response is inaccurate).

Symbol	Percent of incorrect answers for the second incorrectly chosen option (%)	Average (for the second incorrectly chosen option)	Standard deviation (for the second incorrectly chosen option)
	12.9 (c)	4.0	0.816
	9.68 (c)	3.66	0.577
	22.59 (c)	4.33	0.516
	16.13 (b)	3.5	1.732

All respondents were initially familiar with the purpose of the test. They were then given forms to fill out on their own. For each symbol offered, three answers were offered, of which only one was correct. The offered answers are given in the third column of Table 1. The correct answer is shown in the fourth column of Table 1. The task of the respondents was to circle the option (a, b, or c), which they consider to be the correct answer. In addition, for each answer given (whether correct or not), respondents were asked to circle a number on a five-point scale that corresponded to their belief that the rounded answer was correct (1 - not sure at all, 5 - completely sure).

Selecting options for offered replies was made with an additional goal. Unlike most other symbols-based research where, in addition to the exact name (meaning) of symbols, they usually offer names that have nothing to do with the symbol (or have relatively few touchpoints), this research has primarily offered those options that have to do with that symbol, but which do not correspond to the exact meaning of that symbol. The aim was to evaluate exactly how accurately a particular symbol can convey targeted information and whether the respondent can interpret a particular function of a symbol inappropriately.

4. RESULTS

Table 2 shows the percent of correct answers for each tested symbol. In this table, the column "average" refers to the average value of the respondents' answers on a scale of 1 - 5 in relation to their belief that they gave the correct answer, ie that the presented symbol has the meaning they rounded off in the test form. The standard deviation column in the table refers to the standard deviation related to the self-assessment of the respondents' that they gave the correct answer.

Table 3 shows the percent of incorrect answers for the first incorrectly chosen option. The first incorrectly chosen option, in this case, is the wrong answer with a higher percentage of errors than the percentage of errors related to the remaining incorrect option offered as a possible answer. In this table, the column "average" refers to the average value of the respondents' answers on a scale of 1 - 5 regarding their belief that they gave the correct answer (regardless of the fact that such an answer is incorrect), ie that the presented symbol has the meaning they rounded out in the test form. The standard deviation column in the table refers to the standard deviation for the assessment of the respondents' assurance that they gave the correct answer (regardless of the fact that the answer is incorrect).

Table 4 shows the percent of incorrect answers for the second incorrectly chosen option. The second incorrectly chosen option, in this case, is the wrong answer with a lower percentage of errors than the percentage of errors related to the remaining incorrect option offered as a possible answer. In this table, the column "average" refers to the average value of the respondents' answers on a scale of 1 - 5 regarding their belief that they gave the correct answer (regardless of the fact that such an answer is incorrect), ie that the presented symbol has the meaning they rounded out in the test form. The standard deviation column in the table refers to the standard deviation for the assessment of the respondents' assurance that they gave the correct answer (regardless of the fact that the answer is also incorrect).

5. ANALYSIS

From table 2 it can be seen that for no symbol, the percentage of correct responses did not exceed 65 %, while for symbols 3 and 4 percent of symbol recognition is at the level of about 50 %. These are the values obtained on the selected sample. However, if we are interested in the situation on this issue at the population level, it is necessary to test certain statistical hypotheses.

For the “brake” symbol, the following null and alternative hypotheses for the population proportion need to be tested:

- H_0: $p \leq 0.5$
- H_a: $p > 0.5$

This corresponds to a right-tailed test, for which a z-test for one population proportion will be used. The significance level is $\alpha = 0.05$, and the critical value for a right-tailed test is $z_c = 1.645$. The rejection region for this right-tailed test is $R = \{z: z > 1.645\}$. The z-statistic is computed and it is $z = 1.617$. Since it is observed that $z = 1.617 \leq z_c = 1.645$, it is then concluded that the null hypothesis is not rejected. If we use the P-value approach, the p-value is $p = 0.053$, and since $p = 0.053 \geq 0.05$, it is concluded again that the null hypothesis is not rejected. The 95% confidence interval is $0.477 < p < 0.814$.

Therefore, we can conclude that there is not enough evidence to claim that the population proportion p is greater than 0.5, at the $\alpha = 0.05$ significance level.

For the “engine coolant temperature” symbol, the following null and alternative hypotheses for the population proportion need to be tested:

- H_0: $p \leq 0.47$
- H_a: $p > 0.47$

This corresponds to a right-tailed test, for which a z-test for one population proportion will be used. The significance level is $\alpha = 0.05$, and the critical value for a right-tailed test is $z_c = 1.645$. The rejection region for this right-tailed test is $R = \{z: z > 1.645\}$. The z-statistic is computed and it is $z = 1.594$. Since it is observed that $z = 1.594 \leq z_c = 1.645$, it is then concluded that the null hypothesis is not rejected. If we use the P-value approach, the p-value is $p = 0.0555$, and since $p = 0.0555 \geq 0.05$, it is concluded again that the null hypothesis is not rejected. The 95% confidence interval is $0.441 < p < 0.784$. Therefore, we can conclude that there is not enough evidence to claim that the population proportion p is greater than 0.47, at the $\alpha = 0.05$ significance level.

For the “engine oil” symbol, the following null and alternative hypotheses for the population proportion need to be tested:

- H_0: $p \leq 0.38$
- H_a: $p > 0.38$

This corresponds to a right-tailed test, for which a z-test for one population proportion will be used. The significance level is α=0.05, and the critical value for a right-tailed test is $z_c = 1.645$. The rejection region for this right-tailed test is $R = \{z: z > 1.645\}$. The z-statistic is computed and it is $z = 1.561$. Since it is observed that $z = 1.561 \leq z_c = 1.645$, it is then concluded that the null hypothesis is not rejected. If we use the P-value approach, the p-value is $p = 0.0592$, and since $p = 0.0592 \geq 0.05$, it is concluded again that the null hypothesis is not rejected. The 95% confidence interval is $0.34 < p < 0.692$. Therefore, we can conclude that there is not enough evidence to claim that the population proportion p is greater than 0.38, at the $\alpha = 0.05$ significance level.

For the "battery charging condition" symbol, the following null and alternative hypotheses for the population proportion need to be tested:

H_0: $p \leq 0.38$

H_a: $p > 0.38$

This corresponds to a right-tailed test, for which a z-test for one population proportion will be used. The significance level is α=0.05, and the critical value for a right-tailed test is $z_c = 1.645$. The rejection region for this right-tailed test is $R = \{z: z > 1.645\}$. The z-statistic is computed and it is $z = 1.561$. Since it is observed that $z = 1.561 \leq z_c = 1.645$, it is then concluded that the null hypothesis is not rejected. If we use the P-value approach, the p-value is $p = 0.0592$, and since $p = 0.0592 \geq 0.05$, it is concluded again that the null hypothesis is not rejected. The 95% confidence interval is $0.34 < p < 0.692$. Therefore, we can conclude that there is not enough evidence to claim that the population proportion p is greater than 0.38, at the $\alpha = 0.05$ significance level.

6. CONCLUSION

The research presented in this paper is a part of our broader research, which involved a bigger sample of symbols of automobile displays. However, it is interesting to compare the results presented in this paper with the results of some other research on this topic. In this regard, it is necessary to emphasize that studies of this type are extremely rare and very difficult to find.

We put a lot of effort into finding works of this type. Several index databases were searched and various keywords from this field were used for this purpose. However, as mentioned in the introduction, until this moment we were able to find only one research [3] on this topic.

Other references we were able to find treated this issue from a design perspective, without testing symbols on test subjects or ergonomic considerations. Certainly, it can be assumed that some other research has been published in the world on this topic, but certainly, there are few of them. Even in reference [3], which was published in cooperation with the well-known institution SAE (Society of Automotive Engineers), there is no mention of a paper on this topic, which was previously published in a journal or conference proceedings.

Based on the results of this research, it can be concluded that the percentage of correctly understood symbols is surprisingly low, especially if we take into account that these are symbols traditionally used in vehicles (primarily symbols marked with ordinal numbers 2, 3 and 4). The symbol that was best understood is the brake symbol. However, this was probably due to the textual inscription (brake), which the other symbols did not have. The least understood symbols were engine oil and battery charging condition (equal performance of understanding).

In the mentioned research [3], a slightly different methodological approach was used than in this research. The authors of the mentioned paper divided the research into two parts. Part 1 tested a driver's ability to understand a symbol by asking participants to write the meaning of each symbol next to its icon. Part 2 tested the driver's ability to recognize a symbol by asking participants to match the symbols with 25 offered functions. In [3], symbols 2, 3, and 4, which were considered in this research, were also tested. However, the offered names for these symbols contained only one word associated with the object or function they perform. Thus, symbol 2 was named "temperature" without specifying what part of the vehicle it refers to. For symbol 3, only the name "oil" was used, without providing details about the part of the vehicle that uses that oil. For symbol 4, the term "battery" was used, also without providing any other details. The percentage of errors when registering symbols differed in the first and second part of the experiment. The percentage of errors in the first part of the experiment for symbols 2, 3 and 4 were 38%, 23.2% and 6.3%, respectively. For the same sequence of symbols, in the second part of the experiment, the error percentages were 24.8%, 14.3% and 5.4%. As can be noticed, the error percentages in [3] are lower than those obtained in this research. The reason for this can be found in the difficulty of the task, considering that in this research the respondents had a somewhat more difficult task, because in addition to the name of the entity, they also had to guess its exact function (among 3 offered similar functions). It should be mentioned that symbol 1 (brake) was not used in [3].

It is important to emphasize how the values for p_0 were chosen when testing statistical hypotheses. The stated values for the proportion p_0 (0.5, 0.47, 0.38 and 0.38) were obtained for each symbol individually based on the calculation. This means that the z-test for one population proportion was applied iteratively, until a limit value of p_0 was reached for each symbol, at which the set null hypothesis cannot be rejected. In other words, it means that in the population the percentage of correct understanding for the symbol "brake" cannot be expected to be higher than 50%, as well as that the percentage of correct understanding in the population for the symbols "engine coolant temperature", "engine oil" and "battery charging condition" cannot be expected to be greater than 47%, 38% and 38% respectively. For all calculations connected with the applications of the Z-test for one population proportion, it has been satisfied conditions for sample size that $np > 5$ and $n(1-p) \geq 5$ ($n \geq 30$). This means that the predictions given on the level of the population can be considered statistically valid.

The results obtained cannot be considered satisfactory. If drivers clearly do not understand symbols on their displays, or if they do not make clear distinctions between them, they will not receive important warning information. This can result in car damage and possibly this can cause unsafe traffic situations with possible consequences. For this reason, it is necessary to take the necessary actions to improve the understanding and recognition by users of symbols shown on car displays. This is possible in two ways, through education and redesign. Driving schools when training future drivers should pay additional attention to the need for this aspect of education. In addition, new design solutions for symbols that indicate vehicle failure could further improve the ability to recognize this type of symbol, which is of great importance in order to prevent accidents.

7. REFERENCES

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Evaluarea uzabilitate simbolurilor indicând o defecţiune a unui automobil

Cercetarea prezentată în această lucrare se referă la capacitatea şoferilor de a înțelege informațiile prezentate prin simbolurile ce indică o anumită defecțiune a vehiculului. Testarea a inclus partru simboluri, dintre care trei au fost simboluri verificate ISO. Acest studiu al utilizabilității simbolurilor pe un eșantion de respondenți a arătat că înțelegerea informațiilor prezentate cu ajutorul simbolurilor este relativ scăzută și variază între 51% și 65%. Prin testarea ipotezelor statistice s-a constatat că la nivel de populație, aceste valori sunt și mai mici. Au fost date sugestii care ar trebui să inițieze îmbunătățirea gradului de utilizare a acestui tip de simbol.

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