Subjective Perception of the Background Color and Layout in the Design of Typical Graphical Control Panels

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Abstract. The main goal of this research is to examine the influence of various control panel background colors and geometrical layouts on users' subjective perceptions. We investigated five different colors including red, green, blue, white and grey as well as two different arrangements of the panel's informative and controlling items. In the latter case, more vertical and more horizontal layouts were investigated. Panels included typical elements and colors were selected in such a way that their perceptual differences in the CIE Lab color space are similar. A method involving pairwise comparisons was applied to compute relative preferences towards examined conditions. The outcomes generally showed significant influence of the studied effects on the subjects' subjective assessments.

Keywords: Display design · Colors · Control panels · Layout · Ergonomics · Subjective preferences · AHP

1 Introduction

The usability of various types of graphical control panel designs has been subject to investigation for many decades. It is widely known that various factors such as complexity or panel items arrangements may influence the operation efficiency and effectiveness. Reports of empirical studies along with a review of many previous investigations in this regard may be found in the works of Tullis (1981, 1983, 1988). Generally, in the literature one may find a considerable number of papers dealing with the control panel operation efficiency or effectiveness, however significantly less interest is given to the perception of the control panel designs especially with respect to their color properties. Many studies have shown that colors influence both our psychological and physiological responses. In a more general context of visual search the outcomes are to a significant extent inconsistent. For example, the results of Christ's (1975) review of 42 studies in this field published between 1952 and 1973 suggested both positive as well as negative influence of the color usage on the search performance. On the ground of general psychology, the color preferences have also been studies multiple times e.g. Granger (1955), Guilford and Smith (1959) or Helson and Lansford (1970). Since the influence of colors is very often mediated by the context in which they are applied (Schloss et al., 2012) it is very interesting whether previous

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results regarding color preferences apply in the context of graphical control panels. The second area which seems to be worth investigating in this field is concerned with the general orientation of control panel items. This aspect of the control panel design has not received much attention though there are some studies where this feature was investigated. Michalski et al. (2006) studied, among other things, the orientation effect of a graphical panels including solely digital buttons. Shih and Goonetilleke (1998) focused on horizontally and vertically arranged menu items whereas Pearson and Schaik (2003) examined menu orientation in the context of designing web pages. In this study we focus directly on the users' subjective preferences towards control panels differing in layout type (applied configuration) and various panel background colors.

2 Method

2.1 Participants

Overall, 58 student volunteers from the Wrocław University of Technology participated in the study. The age of subjects ranged from 18 to 26 years with the mean of 20.8 years. The standard deviation amounted to 1.7. The sample included 29 females and the same number of men.

2.2 Apparatus

A specifically prepared for this research software application was used to carry out the research. An AHP based methodology (Saaty 1980) was implemented in this tool. Generally, according to this approach, the hierarchy of preferences is determined on the grounds of pairwise comparisons obtained from subjects taking part in the examination. The software was used for presenting appropriate pairs of graphical panels, performing necessary computations, storing the gathered data and, finally, exporting the results to a statistical package. The experiments took place in teaching laboratories in similar lighting conditions on identical personal computers and monitors.

2.3 Variables and Experimental Design

For the purposes of this research we developed a prototype of a relatively simple graphical control panel, which contains elements usually present in real life solutions. The mockup graphical panel consisted both of informative components as well as objects used for controlling the process. It may be treated as a very simplified version of the control panel used for testing the vehicle braking system effectiveness.

The research is focused on two factors. The first one involves five different graphical control panel background colors, while the second one deals with two geometrical layouts of panel's items. We focused on three basic colors including red, green, and blue, and additionally white and grey which are often applied in digital displays. Additionally, we controlled the perceptual differences between examined colors by selecting them in such a way that the Euclidean distance in the CIE Lab color

space are almost identical. The samples of colors used in this study along with detailed specifications in RGB, HSV as well as CIE Lab color spaces are given in Table 1.

Table 1. Detailed specification of colors used in the study

Color name	Color sample	RGB	HSV	CIE lab
Red		#FFC1C1	(0, 24, 100)	(84, 23, 9)
Green		#CDD796	(69, 30, 84)	(84, -11, 30)
Blue		#AFD9E2	(191, 23, 89)	(84, -12, -9)
White		#FFFFFF	(0, 0, 100)	(100, 0, 0)
Grey		#D5D1C8	(42, 6, 84)	(84, 0, 5)

The second factor differentiated the graphical panels by the way the elements were situated on the panel. We applied two arrangements: vertical and horizontal, which are illustrated in Figs. 1 and 2 respectively. Both layouts consist of the same components.

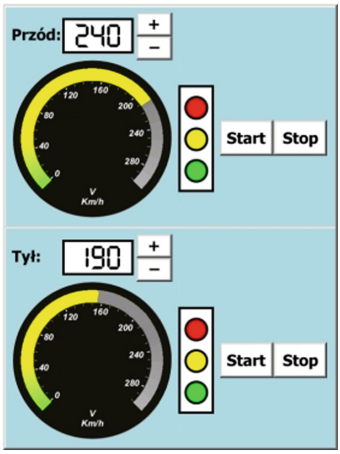

Fig. 1. Vertical version of the experimental condition with blue panel background color (Color figure online)

The combination of these two factors' levels produced ten unique experimental conditions. We employed the within subjects design, so every participant examined all of the control panel versions. Subjective perceptions of the examined graphical panel versions were measured by preference weights, determined by the AHP procedure (Saaty 1980). As a supplementary dependent variable we employed the consistency ratio which allows for assessing the inconsistency level of an individual subject's comparisons results. Details on how to compute the variables within the AHP framework are available, for instance, in the following papers Michalski (2011, 2014).

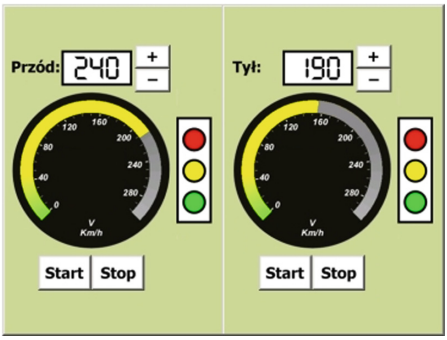

Fig. 2. Horizontal version of the control panel with blue background color (Color figure online)

2.4 Experimental Procedure

After providing the participants information about the general goal of the study and the nature of their expected contribution, they examination began. At first they entered some basic data about themselves and next the proper experiment was conducted. The subjects were to express their opinion on which version of the graphical panel would be better operated in terms of effectiveness and efficiency. Earlier, they were also informed about the possible context of use of such a panel. The control panel images were presented in pairs in random order. The left-right location of images was also determined randomly. One of the comparisons displayed by the experimental software is presented in Fig. 3.

3 Results

3.1 Basic Descriptive Statistics

The results were computed only for participants with the consistency ratio not exceeding the value of 0.25. Therefore, four subjects were excluded. Among them there were three women and one male. Basic descriptive statistical values regarding the remaining 54 persons are demonstrated in Table 2.

The results show that on average participants rated the horizontally oriented control panel with blue background color the best. On the other hand, the worst mean

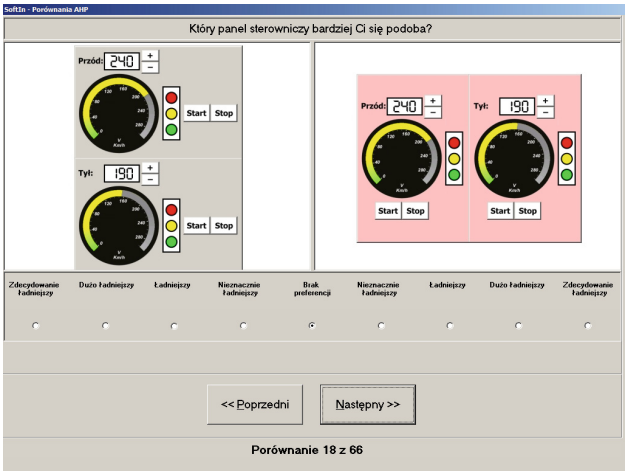

Fig. 3. An exemplary comparison presented by the experimental software

Table 2. Basic descriptive statistics for all conditions.

Condition	Min	Max	Mean	*MSE	**SD
1. H_Red	0.021	0.31	0.0994	0.0086	0.064
2. H_Green	0.029	0.29	0.1117	0.0080	0.059
3. H_Blue	0.031	0.31	0.1335	0.0093	0.068
4. H_White	0.028	0.31	0.1159	0.0097	0.071
5. H_Grey	0.027	0.25	0.1245	0.0077	0.057
6. V_Red	0.023	0.29	0.0709	0.0074	0.054
7. V_Green	0.028	0.28	0.0802	0.0073	0.054
8. V_Blue	0.025	0.27	0.0955	0.0080	0.058
9. V_White	0.020	0.22	0.0804	0.0068	0.050
10. V_Grey	0.030	0.29	0.0881	0.0071	0.052

* MSE – Mean Standard Error, ** SD – Standard Deviation, H – horizontal layout, V – vertical layout

preference weights were obtained for the vertical version with the red background color. Analyzing the data from Table 2 and Fig. 4 one may easily notice that subjects generally better perceived horizontal layouts than their vertical counterparts. Even the worst horizontal condition with the red background color was still better than the best vertical one with the blue background color. It can also be observed that results for horizontal and vertical control panel versions exhibit a similar pattern. In other words, the perception of colors in both types of layouts seems to be comparable. The red background is the least preferred option while the blue versions are the most desired conditions both in horizontal and vertical control panel arrangements. The same situation is for the remaining colors.

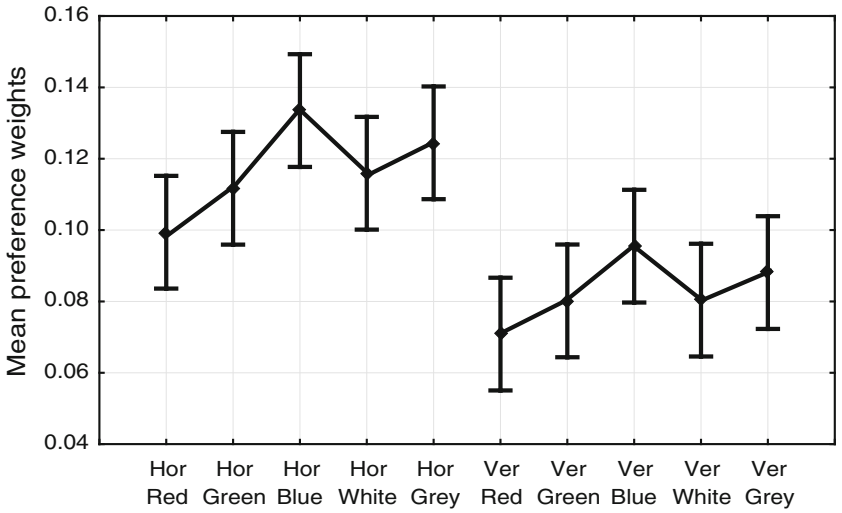

Fig. 4. Average preference weights for all experimental conditions. Vertical bars denote 0.95 confidence intervals.

3.2 Analysis of Variance

A standard two way analysis of variance was employed to formally verify if the investigated effects are statistically meaningful and whether there exists an interaction between them. The obtained ANOVA results are summarized in Table 2. They revealed that both examined factors, that is color and control panel layout significantly differentiate mean preference weights: $F(4, 530) = 3.8$, $p = 0.0047$ and $F(1, 530) = 44.7$, $p < 0.0001$ respectively. The interaction between color and layout effects occurred to be irrelevant. The mean relative preference weights for both factors are illustrated in Figs. 5 and 6.

The Fig. 5 clearly indicates that horizontal versions of the examined panels are decidedly more preferred than vertical ones. This formally supports the outcomes of the descriptive statistics analysis (Table 3).

Table 3. Two-way analysis of variance results

Effect	SS	df	MS	F	p
Color (C)	0.053	4	0.013	3.8	*0.0047
Layout (L)	0.16	1	0.16	44.7	*<0.0001
C × L	0.0016	4	0.0004	0.12	0.98
Error	1.85	530	0.0035		

*$p < 0.05$; df–degeers of freedom; SS–sum of squares; MS–mean sum of squares

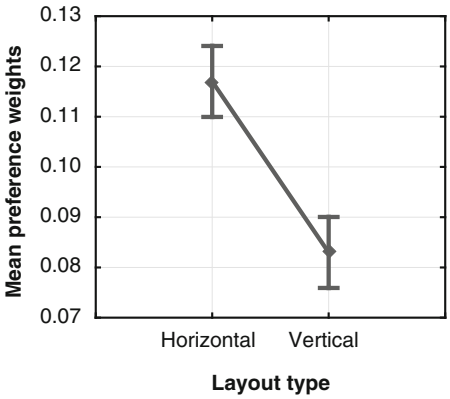

Fig. 5. Average preference weights for the layout factor. $F(1, 530) = 44.7$, $p < 0.0001$. Vertical bars denote 0.95 confidence intervals.

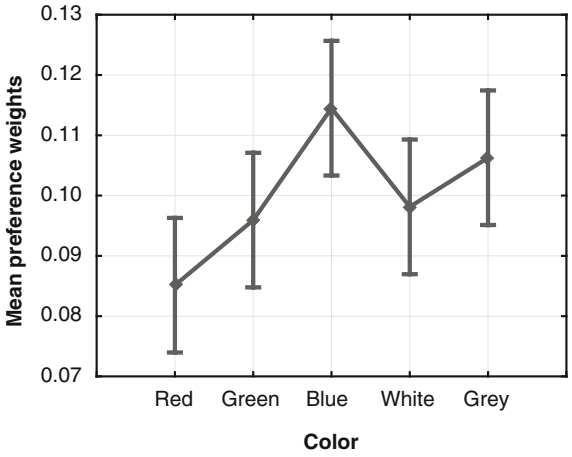

Fig. 6. Average preference weights for the Color factor. $F(4, 530) = 3.8$, $p = 0.0047$. Vertical bars denote 0.95 confidence intervals.

The Fig. 6 also confirms the observations drawn from the basic statistics presented in the previous section. The determined hierarchy of preferences towards examined control panel background colors is as follows: the best perceived is the blue then grey, white, green and finally red as the least liked color in this context.

The post hoc analysis of the color effect conducted according to LSD Fischer approach was used to further explore differences between this factor's levels. The obtained results are given in Table 4 and revealed that there were four statistically significant discrepancies between the following control panel background colors: (1) red and blue, (2) red and grey, (3) green and blue, (4) blue and white.

Table 4. LSD Fischer post hoc analysis for the Roundedness degree factor

	Red	Green	Blue	White	Grey
Red	×	0.18	*0.0003	0.11	*0.0088
Green		×	*0.021	0.78	0.20
Blue			×	*0.042	0.31
White				×	0.31
Grey					×

* $p < 0.05$

4 Discussion and Conclusions

The demonstrated in this study research clearly shows the significance of such factors as background color and layout on subjective users' preferences. Both investigated factors considerably differentiated relative preference weights. Horizontal arrangements were markedly better rated than vertical variants. Such results were observed in other studies dealing with the orientation factor such as Shih and Goonetilleke (1998), Pearson and Schaik (2003) or Michalski et al. (2006). Although these outcomes concerned users' performance but this study preferences might have reflected the subjects' experiences gained previously in similar situations.The color preference structures occurred to be almost identical for both types of arrangements indicating the dominance of colors having connotations with neutrality over others. The obtained structure of color preferences is in correspondence with some early studies conducted in the area of general psychology by Granger (1955), Guilford and Smith (1959) as well as Helson and Lansford (1970). In all these papers the blue color was perceived much better than the green one and the green one better than the red color which is exactly the case in our study. This outcome also indicates that unlike suggested by Schloss et al. (2012) the studied context did not change the general color preferences.

While interpreting the results of this research one should be aware of a number of limitations. The study was based on a relatively small sample of young subjects so generalizations should be made cautiously.

There may be also differences in perceiving colors by males and females, which was not verified in this paper. It future studies it would be beneficial to extend this investigation by including other colors and arrangements. It would also be interesting to compare the participants' subjective feelings with efficiency and effectiveness in operating various versions of graphical control panels.

Nevertheless the presented in this study results may be useful while designing graphical control panels and gives some insights into the nature of users preferences towards different factors of graphical control panels.

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