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# The influence of color grouping on users' visual search behavior and preferences

Rafał Michalski \*

Institute of Organization and Management (I23), Faculty of Computer Science and Management (W8), Wrocław University of Technology, 27 Wybrzeże Wyspiańskiego, 50-370 Wrocław, Poland

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## ABSTRACT

The article investigates how the various colors and color pairs used as grouping factors affect the visual search process and direct manipulation activities in the context of toolbar-like graphical panels. Red, green, and blue colors having the same perceptual distance in the CIE Lab space are used. The results demonstrate significant influence of the examined color-related factors on the speed and accuracy. The color preattentive property depends strongly on the grouping pattern: layouts with smaller colored areas were operated worse than panels divided into larger parts. Meaningful differences were also observed between panels with single and two colored backgrounds.

Preferences were examined by pairwise comparisons before and after performing the 'search and select' tasks. Subjective judgments were significantly differentiated by the toolbar background color pattern both prior to the performance tasks and after them. The initial relative weights structure changed decidedly after the performance experience being more consistent with the 'search and select' results. The location factor was irrelevant for the speed and accuracy as well as for preferences. Objective and subjective findings are compared and discussed. Linear regression models showing the preference structure change and the relationship between mean acquisition times and mean preference weights are developed and discussed.

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## 1. Introduction

Despite much technological progress in the contemporary interactive devices including various types of personal computers, laptops, palmtops, tablets or smart phones, a great portion of the communication between the human and a digital device is still based on a simple interactive styles invented many years ago. New ways of exchanging information with interactive systems are being used along with classical ones. Probably, the most widespread type of interaction currently employed in various IT solutions is the direct manipulation proposed by Shneiderman [84,85] already in the beginning of 1980s of the previous millennium. One of the crucial components of this approach is the so called 'point and click' method which requires from users to search for a desired graphical object, point it, and confirm the selection. Naturally, to apply this method in practice, various technical solutions have been developed including, for instance, light pens, digitizers, joysticks, arrow keys, track balls, touch screens and, of

course, computer mice [31]. Among some latest developments in this area there are devices used in the video game consoles, namely the Xbox 360 Kinect [58], PlayStation 3® Move Motion Controller [86], and Wii U [68] or solutions used for manipulating virtual objects in a three dimensional space [36] including special gloves (e.g. [16]), and recently developed gloveless sensors [59].

Although through years there has been a significant change in technological aspects of various pointing devices, the idea of the search and select method is always similar: find the object, select it, and approve the choice. The target objects to be searched for within the graphical user interface are very often grouped and presented together forming the so called toolbars that usually take a rectangular shape. This research concerns those kinds of graphical structures with various colored features operated by means of the 'search and confirm' interaction style technique. Taking into account recommendations included in international standards [41,42], two different perspectives were applied to investigate how a user interacts with toolbars having diverse color properties: the objective and the subjective one. The former included the efficiency and effectiveness evaluations whereas the latter regarded subjects' preferences toward stimuli.

\* Tel.: +48 71 348 50 50; fax: +48 71 320 34 32.

E-mail addresses: [Rafal.michalski@pwr.wroc.pl](mailto:Rafal.michalski@pwr.wroc.pl), [Rafal.michalski@pwr.edu.pl](mailto:Rafal.michalski@pwr.edu.pl)

URL: <http://www.RafalMichalski.com>

The next two subsections provide the concise review of research related to the subject of the present study. The first one encompasses investigations of the 'search and select' method while the other presents studies concerned with a role of a color in visual search. In the last subsection, main goals of the current investigation are specified.

### 1.1. Studies of the point and click tasks

Studies related to the graphical characteristics of a target object in the human–computer interaction field fall generally into three categories [57]. The first one deals with the movement time needed to click a given object by means of a pointing device while the target is constantly visible to the subject. This was first studied by Fitts and Peterson [23,24] and later applied by MacKenzie [50,51] in the HCI field. Plamondon and Alimi [72] together with Seow [83] provide more information and comprehensive reviews of studies in this area. In the second group, participants search the interface for a graphical target without selecting and confirming their choice by clicking on the item found. Thus, papers in this trend focus on cognitive aspects of the visual search performed in the HCI context. Probably the first attempt to do research in this field was made by Backs and colleagues [2] who examined vertically and horizontally oriented menus. In the third field, approaches from the previous two were applied simultaneously, and the experimental tasks involved both the visual search and visually controlled motor activities aimed at selecting the object searched for. The studies in this group were possibly initiated by Deininger [18], who investigated different configurations of numerical telephone keypads. The further developments in this area before 1999 were reviewed in detail by Kroemer [46]. A more detailed description of the presented trends is provided in the work of Michalski et al. [57].

### 1.2. Research regarding the color in visual search

The vision process is extremely important in our day-to-day life since about 80% of information retrieved from the surrounding world comes through our eyeballs [65]. Therefore, it is not surprising that the nature of a human being visual system has been extensively studied in various fields of science including biology, physiology, neurophysiology or psychology. The comprehensive review of the achievements made in this domain was prepared for instance by Findlay and Gilchrist [22].

The search for different objects is one of the most important visual tasks people are performing uncountable number of times during their usual activities. The scientists have developed various models describing how the process of finding target items in the visual field is being carried out. Among the most popular approaches are the *spotlight* proposal provided by Posner and colleagues [73] and the *zoom lens* model introduced by Eriksen and St. James [19]. According to Posner et al. [73] the visual activity during the objects search resembles a moving spotlight which covers only relatively small portion of the whole visual field at a given time. While the area is being processed, the next saccade is prepared to transfer the attention and the foveal vision to a different location. After jumping to a next spot, the whole process repeats. The competitive model of Eriksen and St. James [19] assumes different behavior. In this case, the visual search is conducted by gradually narrowing down the analyzed region similarly to zooming the pictures in cameras and cam-coders. The theory was later supported experimentally by Zelinsky and others [101].

The presented models were complemented by ideas put forward in the *Feature Integration Theory* [88,89] and *Guided Search* [95,92,94]. Both of the approaches integrate to some extent the *spotlight* and *zoom lens* hypotheses. They assume that at first the field of view is explored generally. The process has a parallel nature

thanks to some graphical features which can be processed almost at the same time. After this phase, the objects identified in the first step are investigated sequentially. The first stage is often called preattentive because it is believed that the process does not involve attention. Much effort and research has been devoted to identify attributes that facilitate the search process and make it more efficient. The results undoubtedly show that among the most important factors successfully used in the preattentive phase is a color. The detailed and comprehensive summary of the findings concerned with other preattentive features were presented by Wolfe and Horowitz [93]. Recent studies confirmed the existence of the preattentive mechanisms on a neurophysiological level. Bichot and colleagues [3,4] examined a macaque monkey which visual system is very similar to human and registered the activation of different neuron layers in the primary visual cortex. They identified two separate phases assumed by the theoretical models.

In the domain of Human–Computer Interaction (HCI) the visual search along with the role of preattentive features are of great importance. Although there were very few studies related explicitly to the role of various preattentive features, there were some papers dealing with the factors that are considered to facilitate the preattentive procedure. For instance, the screen design recommendations proposed within well known Gestalt Theory [7,6,11] such as proximity, similarity or closure are possibly connected with the objects' attributes used in the early vision processing. A brief description of the studies pertaining to the role of color as an important aspect influencing the visual search behavior in various kinds of display is presented in next subsections.

#### 1.2.1. Color related research pertaining to graphical displays

The color was identified as an important factor in the quality of the graphical information presentation already in the beginning of the 20th century [48]. The research on the effect of color on visual search efficiency in the context of the display design started as early as in the 1950s of the previous century. Christ [12] reviewed 42 studies on the color role in the visual display search tasks published between 1952 and 1973. The results led to ambiguous conclusions showing a significant positive influence of the color usage in some circumstances and negative effect on visual search performance in some others. The importance of the various aspects of color usage was examined later under diverse conditions. For example, the work of Murch [61] who specified good and bad combinations of the text and background colors or Matthews et al. [52] who reported decidedly longer search times for green on black displays as compared to the red on black. Among the researches employing more modern displays one can also find numerous papers. For example, Bodrogi [5] investigated the effect of a chromaticity contrast displayed on the multi-color graphical user interface, Wu and Yuan [98] studied the influence of highlighting and text color on visual search performance while Buchner and Baumgartner [8] analyzed the impact of text-background polarity, ambient illumination and color contrast. Recently, Wu and Chen [96] examined 18 various graphical user interfaces containing many color attributes used for choosing the desired sofa appearance. They showed, among other things, that the color grouping is one of the most important factors influencing the subjects' performance and satisfaction. Similar results confirming the importance of color grouping were obtained in the research of Wu et al. [97] who analyzed a user's behavior in the context of choosing color properties of a mobile phone. The preattentive color features were also integrated into the most famous models of visual search, namely ACT-R [26] and EPIC [35].

#### 1.2.2. Color properties in web site usability

Apart from the studies related with color properties for general displays there were many investigations devoted specifically for the visual search of the web pages. For instance, Schaik and Ling

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