Revisiting Redundant Text Color Coding in User Interfaces

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Abstract. Practices for using redundant text color in user interfaces vary. Some designers have carefully incorporated redundant coding in their design, while in other instances redundant coding is not utilized. There is a vast body of research on the effects of color on visual search. In this study we wanted to corroborate earlier findings in the current context. A simple recognition experiment was configured. The results agreed with the literature in that color has a significant effect on response time when the color is known, while it has no effect on recall. The results support the use of redundant color coding in interfaces, especially for time-critical applications where the user must act rapidly.

Keywords: redundant color coding, text color, user interface

1 Introduction

Color display technology [1, 2] has become an expected low cost and widely available technology on many types of electronic devices during the last two decades from desktop computers [3] to mobile devices such as smartphones [4-6]. Many user interfaces utilize these color capabilities to achieve aesthetic qualities [7-12], establish trust [13-18], create groupings [19], and facilitate visual search [20-22]. For instance, color harmonies [23, 24] are often used to evoke various emotions and moods [25, 26]. Color is also used in interfaces to create groupings [19] where different groups of related elements such as menu items have certain colors [27]. In context of searching, color can be used to direct the users' attention such as using red color in form fields that have been completed incorrectly [28], or indicate a form submit button using a color that contrasts the other colors of the interface.

It is an established practice that hues should not be used on their own to communicate important information as users with reduced color perception might be unable to discriminate between certain colors [29]. Instead, color should be used as a redundant

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coding together with other information, most notably text and images, but also position, size, and shape, or non-visual cues such as haptics [30, 31].

There is a vast body of work that has explored the effects color can have on visual searching, that is, color can shorten the time to identify a specific target [32]. Still, many interfaces do not exploit the opportunities to use color to facilitate search. One may imagine a designer constrained by a corporate color profile of a customer, limiting the choices of colors for effective visual communication.

Seminal studies on redundant color coding (see for instance [33]) were conducted more than 50 years ago, at which time color coding only could be found on printed material. Color print was also more expensive to produce and therefore not as common as black and white printing. We wanted to verify if these observations still hold with current users highly accustomed to color display and user interfaces in color. Are current users exhibiting different traits than users of the past? We therefore conducted an experiment inspired by previous research on redundant color coding.

2 Related work

Early and often referred to work on effects on color was conducted by Stroop [33], who showed that peoples' response times were slowed down when the words of different colors do not match the color of that word. Stroop tests are commonly used as part of cognitive test batteries and one can conduct a simple experiment to experience the Stroop effect. However, the Stroop effect is not directly related to search. Green and Andersson [32] is an early study which showed that redundant color coding can speed up the time to locate a target during search. However, they also found that color did not influence recall. Similar work was conducted subsequently [34-36]. The study of Keller et al. [35] showed how color can be used to help viewers with interpreting information visualizations. Lindsey et al. [37] claim that it is not the appearance of a color that influences visual search but rather the physical color channels in the human visual system. In practical terms of facilitating visual search on the web, colors are claimed to be the most effective cue for communicating the presence of hyperlinks [38].

Research studies into color and aesthetics on the web have explored the relationship between the perception of aesthetics and visual complexity [7], and color and gender differences [8]. Especially how aesthetics can affect first impressions of web sites [10] and decisions, and online shopping have received some attention [11, 12]. Also, several studies have addressed how colors affect users' trust in websites [13-14], the products represented [15], and the organization they represent such as higher education institutions [18]. For instance, it has been found that highly saturated colors can have a negative effect on trust [14].

Visualization is yet another field where color has been studied extensively [39, 40] (see for instance the survey by Silva et al. [41]). Examples include affective use of colors [42], color scales [43], color maps [44], and color palette design [45].

Other research directions have included diverse topics such as how color coding affects learning [46], and how color use affects power consumption with certain display technologies [47].

3 Method

3.1 Experimental design

A within-groups experimental design was chosen with two independent variables, stimuli type and session, and two dependent variables, response time, recall rate (as opposed to error rate [48-50). The stimuli type had two levels, namely black and white and color, and the session variable had two levels, first and second. We also asked the participants about their preferred stimuli type.

3.2 Participants

A total of 20 participants were recruited for the experiment of which 7 were identified as female and 13 were identified as male. Most participants (70%) were in the 20-34-year age range, one person was between 35-49 years of age, and 5 participants were 50 years or older. Convenience sampling was conducted due to the covid-19 pandemic involving students at the authors' university and acquaintances of the authors. All the participants were native Norwegian speakers who had completed a minimum of lower secondary education. Participants were not questioned regarding previous reading challenges.

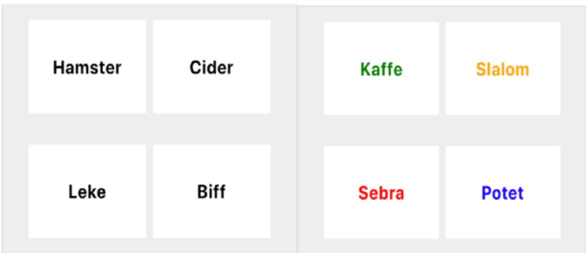

Fig. 1. Example of experiment software challenges in black and white and color, respectively. The user selects the word in a predetermined category. Black-and-white words: hamster, cider, play, and steak. Color words: Coffee, slalom, zebra, and potato.

3.3 Materials

A remote experiment platform was implemented for the browser using React. The experiment software presented words in four categories in black and white and in colors, respectively. The words were presented in Norwegian. Each category was assigned a unique color that was used consistently throughout the experiment. The four categories included animals, food, drink, and activity. A total of 10 challenges were created for each category. The participant had to click on the word belonging to a given category (a different category for each condition), and the software logged the time it took for the participants to respond.

3.4 Procedure

Due to the pandemic the experimental sessions were conducted remotely using Microsoft Teams. The participants were first briefed about the task. Next, the participants were asked to share their screen with the experiments. The session was split into four parts. The two first parts were a trial session with the color and black and white condition, and the two last parts were the second session with both the color and black and white stimuli. The user was told to recognize a specific category and then click on the word representing that category in the software. After the software session, the user was directed to an online form implemented in Google form, where they had to recall the words related to each category. The presentation orders (black-white vs color) were balanced to prevent bias. Participants were tested individually. Each session lasted approximately 10 minutes.

The experiment was conducted during a single session and participation was therefore anonymous as there was no need to link records across sessions [51].

3.5 Analysis

The successful recall rate was manually computed based on the responses in the online form. These results were combined with the time measurements obtained by the experiment software. Statistical analyses were performed using JASP version 0.13.1.0 [52].

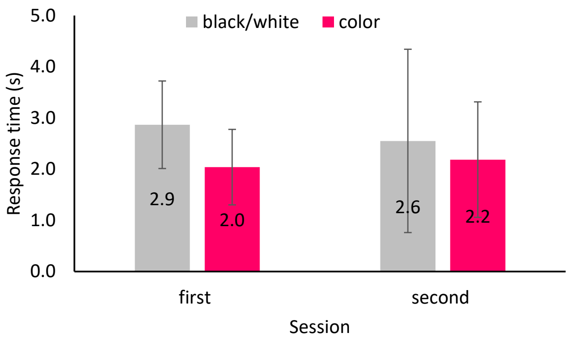

Fig. 2. Mean response times per task (in seconds) per condition. Error bars shows standard deviation.

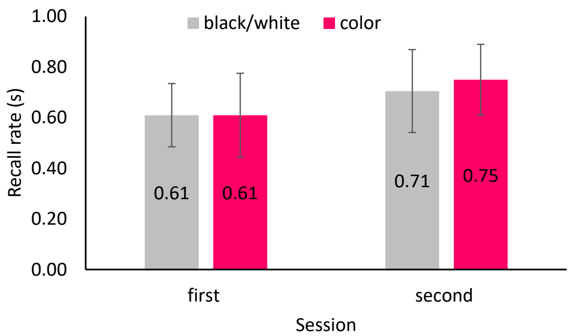

Fig. 3. Recall rates per condition. Error bars show standard deviation.

4 Results

A two-way repeated measures ANOVA shows that the observations of response times (see Fig. 2) showed a significant difference between black and white and color (F(1, 19) = 13.376, p = .002, η^2 = 0.116). The time to recognize categories with color took shorter time in seconds for the first (M = 20.4, SD = 7.4) and second (M = 21.9, SD = 11.3) session, than the first (M = 28.7, SD = 8.6) and second (M = 25.5, SD = 17.9) session with black and white. No significant difference could be found across the two sessions (F(1, 19) = 0.084, p = .775). Moreover, no interaction between the type of stimuli and the session was detected (F(1, 19) = 1.923, p = .182).

When observing the recall rate (see Fig. 3), the situation is reversed, i.e., the two-way repeated measures ANOVA did not reveal any significant difference in recall related to the use of color (F(1, 19) = 0.951, p = 0.342). However, an effect of session on the recall rate was observed (F(1, 19) = 31.533, p < .001, η^2 = 0.322). In both conditions, the participants on average managed to recall one more item in the second session: most participants recalled 7 of the 10 items in the second, while in the first session most participants only recalled 6 out of 10 items. No interaction between the presentation type and session was identified (F(1, 19) = 1.000, p = .330).

We also combined the recall rate and response times by computing the recalls per second (Fig. 4). A two-way ANOVA shows that this combined measure gave a significant difference of both visual presentation (F(1, 19) = 23.742, p < .001, η^2 = 0.258) and session (F(1, 19) = 25.581, p < .001, η^2 = 0.199), but without any interaction between the two (F(1, 19) = 0.062, p = 0.805). Clearly, the recalls per second is higher with colors than with black and white, and higher for the second session.

When asked about their preference, a majority responded that they preferred color (60%), a minority preferred black and white (10%), while 30% expressed that they had no opinion. No correlations were found between preference and performance.

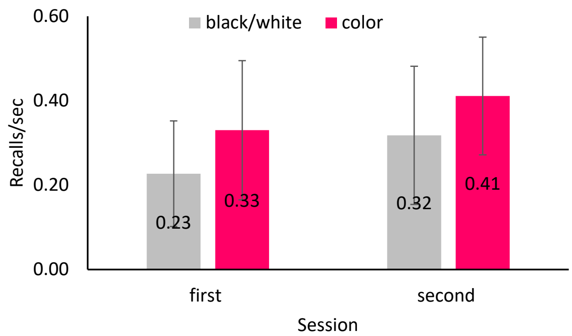

Fig. 4. Recalls per second. Error bars show standard deviation.

5 Discussion

The current study found that the use of redundant text color-coding improved words recognition performance. One possible explanation for why it took a shorter time to recognize words in color than in black and white could be that it is easier to spot a color as color is believed to facilitate search, and the results therefore agree with previous work [33]. Hence, it is easier to look for the color during the 10 trials rather than reading the content of the words, while with black and white words the participants had to read the words to discriminate between them. In other words, the participants established this strategy from the context. It is possible that the use of color speeds up the search as it adds a feature of faster visual identification to the communication interface. When comparing the two sessions it seems that the task of identifying colors of text did not improve with practice, probably because we already have developed our skills to recognize words in various contexts.

The results showed that the text color had no effect on recall. If it is the case that participants indeed recognized the color categories using color only, one may even have observed a lower recall rate for the color categories. Practice had an effect, which makes sense as the learning is strengthened through retention during the second session.

As our observations agree with similar studies conducted before color displays were commonplace it seems that how users respond to color has not changed much because of increased exposure to such color stimuli.

As redundant color coding indeed facilitated visual search one may ponder why it is not used more extensively. Is it so that corporate color schemes and visual identity trumps effective visual communication mechanisms? Another explanation could be that if redundant color coding is overused the user may be fatigued by the competing visual signals. In this sense, redundant coding should probably only be used for important interface elements in terms of urgency, frequency of use and impact.

5.1 Limitations

A shortcoming of the current experiment is the small sample size although it is within the norms of human computer interaction experiments [53]. One should therefore be careful in generalizing the findings and utilize these as indications. Another limitation of this study is that reduced color perception was not considered, as color vision would affect visual search [54-56]. It would also have been relevant to repeat the experiment with cohorts to assess the impact of low vision [57], reduced cognitive function [58], and reading disabilities [59].

Although the same words for the various categories were randomized, they were also repeated in the different conditions. It is therefore possible that there has been a learning effect as participants may have remembered words from previous rounds. However, all the participants were exposed to the same stimuli and this is thus unlikely to have caused bias. The testing was divided between four of the authors. Although the procedure was clearly specified there is also a chance that there could have been small variations in how the sessions were conducted.

6 Conclusion

A simple experiment was conducted to reassess the effects of text color-coding on recognition and recall. The results indicate that the recognition response time is significantly faster when the item to be recognized has a specific color. Color did not have any effect on subsequent recall rate. In conclusion, our findings support the established practice of facilitating visual search through redundant coding using color. The results suggest that the effect on color in information processing is similar with current day users as in the past. In time-critical applications [60] where the user must respond rapidly to changes in a user interface the time saved through such redundant coding may make a large difference.

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