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Exploring Button Design for Low Contrast User Interfaces

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Abstract. Mainstream display technologies have progressed towards higher resolutions and contrast levels. However, for IoT applications, where displays are embedded in the environment, there are requirements to optimize displays for lower power consumption or minimal environmental impact, potentially sacrificing contrast or switching time. We approach this issue by considering the spatial design of UI components. As a first step, we explore switch type UI components (e.g., check box, toggle switch) and evaluate the performance of 4 alternative spatial designs at low contrast levels. As a contribution, we open the issue of spatial UI design for low contrast and demonstrate an approach for its evaluation.

Keywords: Low contrast · UI components · Visibility · Design

1 Introduction

The evolution of display technologies has witnessed ever increasing performance in terms of resolution, contrast levels and refresh rates. However, for Internet of Things (IoT) applications, displays may need to sacrifice parameters such as resolution, contrast and refresh rate to achieve low power consumption.

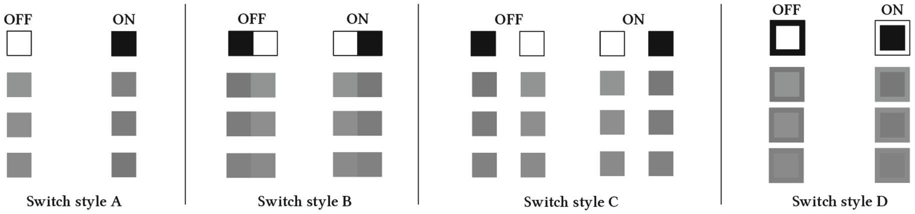

Fig. 1. The four graphical styles of switch UI component, with the 6 low contrast variants of each tested in the study

Several 'low-contrast' display technologies exist, e.g., the chemical lateral flow displays used in cheaper pregnancy tests. Other technologies such as electrochromic [5] and thermochromic displays [6,9] provide opportunities for the

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display designer to optimise the display design to minimise power consumption at the expense of e.g. switching time and contrast.

Decreased display contrast may lead to situations where the state of the display is not clear to users [2,8,10]. Similar contrast issues can also occur due to environmental factors, e.g. reduced contrast caused by reflection on smartphone screens [3]. For people with degraded visual performance, e.g. due to macular degeneration, cataracts or glaucoma, display contrast is even more critical.

We approach the issue of low-contrast visual displays from a UI design perspective by exploring the impact of visual design on the usability one of the most basic UI components, a simple switch button, when rendered at low contrast levels. Through a smartphone app based user study with 25 participants we report on the influence of 4 different switch designs when presented at low contrast levels (Fig. 1). As a contribution, we open the issue of design for low contrast user interfaces and demonstrate an experimental approach for its evaluation.

2 Concept

To explore the impact of visual design on usability at low contrast levels we created 4 alternative designs for the *on/off* switch UI component. This was selected as it is one of the most basic of UI components, common to all formats of GUI. As a design criteria, the active visual areas of each of the component designs were identical, only the spatial arrangement was changed between the cases. The evaluated switch component designs were (see Fig. 1): (A) a ‘checkbox’ style switch, with white indicating the *off* state and black the *on* state without any visual reference for comparison. This case was included as a baseline. (B) a left-right toggle switch style design. - similar in design to switch components of the Apple iOs or Google’s Material Design. (C) a variant of switch style B, but with a visual gap separating the two areas of the switch. (D) a variant of switch style B, but with one graphical areas surrounding the other. The area of the surrounding area being identical to the central area.

Six levels of greyscale were selected for the components, with the following percentages of black (k value): 44%, 46%, 48%, 52%, 54%, 56%. These levels were selected based on initial exploration to provide the right level of challenge when viewed on a smartphone screen. In components with two filled areas (styles B - D), the grayscale colors were used in pairs balanced around a k value of 50%, i.e., [44%, 56%], [46%, 54%],[48%, 52%]. To explore the effect of orientation, e.g. left-right, the grayscale color pairs were applied in both orientations, resulting in a total of 6 variations per component style (Fig. 1).

3 User Study

A test application running on Android smartphones was developed, this included a test to evaluate the contrast capabilities of the test device/participant, as well as evaluation of the four switch component styles.

3.1 Test Proceedure

To identify any issues with either the performance of the smartphones used for testing, or the participant's low contrast vision, we implemented a sine wave grating test based on the Functional Acuity Contrast Test (FACT) [4] to our test app. The test consisted of 25 sine wave gratings with between 1.5 and 18 cycles per degree (assuming a 45 cm viewing distance from a 5″ device screen) and contrasts between 0.6% and 8.3%. Each of the 25 grating patterns was presented once, and randomly inclined at an angle of either −15°, 0° or +15°. This test aimed to identify outliers due to, e.g., issues with the participant's test configuration or participants with poor low contrast vision.

As training, the test app presented an initial screen showing images of the 4 styles of switch and then one test case of each style of component was tested, the results of which were discarded. The test application then presented the 24 test cases (see Fig. 1) in random order. For each case, the model illustrating the switch in *off* and *on* states was first shown, then after a delay of 1.5 s, the test case image was shown The participant then assessed if the presented case represented the *off* state or *on* state of the component, pressing a button to indicate their selection.

Test participants, recruited through the authors' personal networks, installed the test app on their own devices, and after completing the test, sent a log file of the test data to the facilitator. Altogether 28 participants returned data in the study. After validation with the 1.5IQR rule data from 3 participants were removed as outliers. Hence data from 25 participants (14 female, $age = 27.2$, $SD = 4.6$) was further analyzed.

3.2 Results

Of the 25 contrast test images, the mean number correctly identified participants was 23.0, $SD = 1.3$, with participants identifying between 20 and 25 correctly. Hence it was deemed that all participant/test configuration combinations provided a normal level of contrast differentiation. The mean correct response rate across the 4 test cases in each style completed by each participant was calcu-lated (Fig. 2. A within-subjects ANOVA identified a significant effect of style on correct response rate at the $p < .05$ level [F(3, 4) = 96.197, $p < .001$]. Pair-wise t-tests, with a Holm corrected p level, identified significant difference in the cor-rect response rate between Style A (correct response rate = 0.46) and the other Styles; B (0.99), C (0.96) and D (0.90) [all $p < .001$].

Task completion times were first processed using the 1.5IQR rule, by which times above 6536 ms were identified as outliers and removed from further analysis. Figure 2 shows the median and quartile distribution of the task times. A within-subjects ANOVA test identified a significant effect of style on task time at the $p < .05$ level [F(3, 4) = 8.032, $p < .001$]. Pair-wise t-tests, with a Holm corrected p level, identified significant difference in the task times between Style A (1960 ms) and the other Styles; B (2434 ms), C (2452 ms) and D (2704 ms)[all $p < .001$]. No other significant differences in task times were identified.

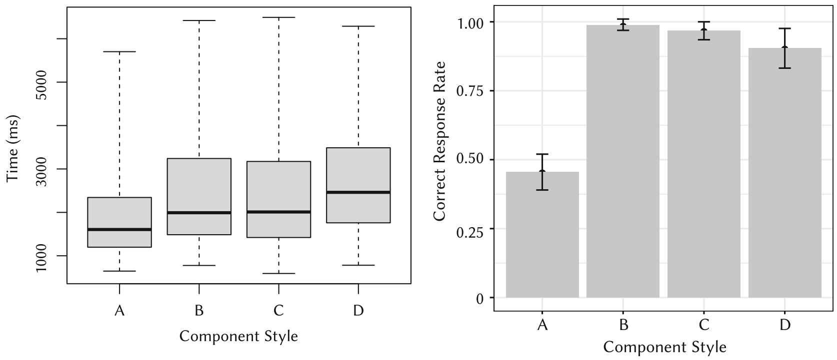

Fig. 2. Left: task time per component (Outliers removed). Right: mean percentage correct answers per component style. Error bars indicate standard error of the mean

The results were further analyzed to identify if any bias towards *on* or *off* state was present, e.g., bias in spatial perception due to left-to-right reading direction [1], or, in the case of Style D, inner-outer bias. For Styles B and C the observed differences were negligible, whilst for Style D a Chi-square tests of independence for showed that there was no significant association between component state and correct response, $\chi^2(1, N = 150) = 1.4, p = .23$. For com-ponent Style A there was a clear bias towards perception that the switch was in the *on* state, with 111/150 (74%) of answers responding in the positive sense.

4 Discussion and Conclusion

Compared to the other component styles, switch style A presented a much more challenging case to participants, requiring the absolute estimation of a grayscale shade without any reference. When displayed on a white background, participants tended to overestimate the darkness of the shade, with 74% of answers reporting the switch to be in the *on* state, rather than the expected 50%. The primary cause of this phenomena is the influence of the white background. Prior works have mitigated such issues by presenting grayscale samples on a grayscale noise pattern background [7]. However, our use of a white background is more representative of actual usage within a UI and highlights a potential problem when using this style of component.

We acknowledge that our study was limited by the number of participants. Although our study design represented a good initial approach, it lacked the sensitivity needed to identify subtle differences between the performance of the alternative UI component designs. In future this could be improved, e.g. by limiting the amount of time each component is visible.

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References

1. Afsari, Z., Ossandón, J.P., König, P.: The dynamic effect of reading direction habit on spatial asymmetry of image perception. J. Vis. **16**(11), 8 (2016)
2. Buchner, A., Baumgartner, N.: Text-background polarity affects performance irrespective of ambient illumination and colour contrast. Ergonomics **50**(7), 1036–1063 (2007)
3. Colley, A., Tikka, P., Huhtala, J., Häkkilä, J.: Investigating text legibility in mobile ui: a case study comparing automated vs. user study based evaluation. In: Proceedings of International Conference on Making Sense of Converging Media, pp. 304–306 (2013)
4. Stereo Optical Company, Inc.: Functional acuity contrast test (FACT), March 2018
5. Jensen, W., Colley, A., Häkkilä, J., Pinheiro, C., Löchtefeld, M.: TransPrint: a method for fabricating flexible transparent free-form displays. In: Advances in Human-Computer Interaction 2019 (2019)
6. Liu, L., Peng, S., Wen, W., Sheng, P.: Paperlike thermochromic display. Appl. Phys. Lett. **90**(21), 213508 (2007)
7. Matejka, J., Glueck, M., Grossman, T., Fitzmaurice, G.: The effect of visual appearance on the performance of continuous sliders and visual analogue scales. In: Proceedings of the 2016 CHI Conference on Human Factors in Computing Sys-tems, CHI 2016, pp. 5421–5432. ACM, New York (2016). https://doi.org/10.1145/2858036.2858063
8. Mayr, S., Buchner, A.: After-effects of TFT-LCD display polarity and display colour on the detection of low-contrast objects. Ergonomics **53**(7), 914–925 (2010)
9. Peiris, R.L., Nanayakkara, S.: PaperPixels: a toolkit to create paper-based displays. In: Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: The Future of Design, OzCHI 2014, pp. 498–504. ACM, New York (2014). https://doi.org/10.1145/2686612.2686691. http://doi.acm.org/10.1145/2686612.2686691
10. Wang, A.H., Chen, M.T.: Effects of polarity and luminance contrast on visual performance and VDT display quality. Int. J. Ind. Ergon. **25**(4), 415–421 (2000)