User Interfaces in Dark Mode During Daytime – Improved Productivity or Just Cool-Looking?

Lasse Apalnes Pedersen[1], Svavar Skuli Einarsson[1], Fredrik Arne Rikheim[1] and Frode Eika Sandnes[1,2[0000-0001-7781-748X]]

[1] Oslo Metropolitan University, 0130 Oslo, Norway
[2] Kristiania University College. 0153 Oslo, Norway
lasseap95@gmail.com, svavareinarsson@hotmail.com, fredrik.rikheim@outlook.com, frodes@oslomet.no

Abstract. Applications are increasingly coming equipped with a so-called dark mode. Our observation is that many computer enthusiasts are under the impression that dark mode in a way is better than the traditional light mode. This study sets out to explore this belief by observing if dark mode indeed poses any improvements in terms of productivity and quantity of errors over light mode. A controlled experiment was designed involving a visually intensive text entry task using a virtual keyboard with an unfamiliar layout. The results indicate that there were no differences between dark mode and light mode in terms of productivity and quantity of errors.

Keywords: dark mode, dark UI, dark theme, productivity, error rate, text entry, preference, personalization, color theme, high contrast mode

1 Introduction

According to Google Trends the term "Dark mode" emerged suddenly around the summer of 2018. During the last year or so there have been an increase in software applications and platforms that promote their dark mode configuration. For example, the widely used IOS and iPadOS platforms got a dark mode in their version 13 update.

In short, dark mode can be understood as an inverted text background-foreground configuration where the text in the foreground is bright and the background is dark, whereas light mode involves dark text in the foreground on a bright background.

One rationale for dark mode is that it is claimed to be better for the eyes when devices are used for prolonged periods under dim lighting conditions [1, 2]. For instance, children using their smartphones at night. Another rationale for using a dark mode is to save power [3]. Given display technologies where the background light of individual pixels can be turned off, such as with organic light emitting diodes (OLED) power can be saved if most of the pixels remain in an off-state, and hence black state [4].

This is a post-peer-review, pre-copyedit version of a conference proceeding published in HCII 2020: Universal Access in Human-Computer Interaction. Design Approaches and Supporting Technologies, 14th International Conference, Held as Part of the 22nd HCI International Conference, 2020, Proceedings, Part I, which is part of the Lecture Notes in Computer Science book series (volume 12188). The final authenticated version is available online at DOI: https://doi.org/10.1007/978-3-030-49282-3_13

Several development tools such as Eclipse also offer dark mode configurations, also called dark themes. Our impressionistic experiences are that computer science students often have opinions and preferences for or against dark mode. Some argue that dark mode is “better”. The alleged benefits of dark mode in environments with low lighting does not necessarily apply to development tools when these are used during daytime in well-lit office spaces such as those found in workplaces, institutions, schools and universities. Also, the argument of power saving does not hold for mains-connected desktop computers.

There is not a shortage of opinions regarding dark mode and dark user interfaces although few opinions are based on empirical evidence documented in peer-reviewed sources. A blog post UX designers Niklos Phillips [5] identifies that dark mode is often used in interfaces related to film such as Apple TV and Netflix to achieve dramatic effect and as an convention often used in entertainment, as well as reasons of branding. Dark user interfaces are also commonly observed in gaming, probably for the similar reasons. Phillips argues that dark user interfaces work well for such entertainment contexts as content is often viewed at a distance in dimly lit rooms. He further argues that dark mode is not effective in text and data intensive applications and when there is a mix of different types of contents.

This study, therefore, was initiated to explore dark mode in the context of productivity under normal lighting conditions to determine whether dark mode during daytime leads to better productivity and fewer errors than the traditional light mode. Or, is dark mode just an esthetical gimmick that looks impressive?

The rest of this paper is organized as follows. The next section reviews related work, followed by a description of the experimental method, results and discussion. The conclusions section closes the paper.

2 Related work

As revealed by Google Trends, «Dark mode» appears to be quite a recent term. At the time of writing, we were only able to identify two academic papers that mention dark mode explicitly in the title [6, 7]. Both studies addressed dark mode in terms of transparent heads up displays and transparent augmented reality displays. Although not mentioned explicitly, the notion that negative text polarity is better with technologies relying on beam splitting such as augmented reality, teleprompters, etc., is well known [8] as the dark background is not reflected by the beam splitter (half-mirror) while the bright text is reflected and overlaid with the background image.

Although the term dark mode appears recent, the idea of dark and light modes is far from new. The effects of positive and negative text polarity have been studied extensively, where positive text polarity is analogous to light mode and negative text polarity is analogous to dark mode. Interestingly, most of the literature on text polarity recommends positive text polarity over negative text polarity [9, 10, 11], that is, the studies recommend light mode for text reading tasks. Only in some cases, involving certain types of visual impairment, is negative text polarity found to improve readability [12] and some applications and operating systems have high contrast modes as well as some digital text magnifiers [13, p 91]. For example, Microsoft Windows implements their high contrast mode using negative text polarity.

Note that these studies mostly focus on text in conjunction with extended reading tasks. Computer usage does indeed vary slightly as it involves also visual recognition tasks where user recognizes images and symbols besides reading text. Moreover, the readability studies are often based around the paper metaphor with either text in black ink on paper, or the background printed in black ink with the text as the paper-white background. In fact, modern display technologies are able to display millions of colors and hence a very large number of text-background combinations is possible. In one sense, the notion of dark mode must in such a context be understood as the brightness of the background being darker than the brightness of the foreground text. Usually, colors are adjusted according to three main parameters, namely their hue, brightness and saturation [14]. Although the brightness varies with the hue and various saturation settings, the main effect on brightness is via the brightness setting. Accessibility guidelines therefore focus on ensuring enough contrast between the background and the foreground [15, 16, 17] thereby resulting in various contrast tools [18, 19, 20]. There is comparatively little focus on negative versus positive text polarity.

Personalization is a much-studied topic [21, 22]. Personalization help accessing existing content on emerging platforms [23] and help individuals with reduced functioning to access content [24]. A study of smartphone personalization [25] revealed both gender differences in the way they are personalized and also that personalization has a positive effect on the perceived usability. Personalization has also been connected to adaptable systems [26].

3 Method

3.1 Experimental design

A controlled 2 × 2 mixed experiment was designed with two independent variables and two dependent variables. The independent variables comprised the within-groups factor mode with the levels dark and light, and the between groups factor preference with the levels preference for dark mode and preference for light mode. Productivity in terms of words per minute (wpm) and error rates were measured as dependent variables.

3.2 Participants

A total of 16 participants was recruited for the experiment of which one was female. The participants were all computer science students at the authors' university, and they were all in their twenties. The narrow cohort of computer science students is particularly relevant for this experiment as we assumed that computer science students would be more familiar with the concept of dark mode compared to the general population. Participants were screened before the experiment in which they were asked about their preference for dark mode or light mode. This allowed us to recruit a balanced set comprising 8 participants with a preference for dark mode and 8 participants with a preference for light mode. The recruiting process revealed that there were slightly more people with a preference for light mode, yet it was relatively easy to recruit a completely balanced set of participants with both preferences.

Fig. 1. A screenshot of the virtual alphabetical keyboard in dark mode.

Fig. 2. A screenshot of the virtual alphabetical keyboard in light mode.

3.3 Task

In order to measure the difference with the use of dark versus light mode a visually intensive pointing task was set up involving text copying task using a virtual onboard keyboard. Text entry is a workload intensive task that most users understand which phenomena is studied extensively [27, 28]. To make it harder for the participants alphabetically ordered keyboards were used instead of a Qwerty keyboard as it was assumed that most users would be too familiar with the Qwerty layout [29, 30]. Studies have shown that users enter text significantly slower with alphabetical layouts [31, 32]. The lack of familiarity with the alphabetical keyboard was thus expected to induce a more intense visual search for the letters. MacKenzie and Soukoreff's commonly used list of 500 phases was used in the experiment [33].

3.4 Equipment

The experiment was conducted using a laptop computer and a mouse. The text was entered into OneNote using a virtual keyboard with an alphabetical layout. This keyboard could be configured to both light and dark mode, respectively. The customizable Hot Virtual Keyboard was selected for the experiments (https://hot-virtual-keyboard.com/). The dark mode keyboard used is shown in Fig. 1 and light mode keyboard used is shown in Fig. 2. The text copying task was performed by controlling the pointer using a mouse. The text-copying task was timed using a stopwatch.

3.5 Procedure

Steps were taken to balance the experiment to avoid biases. The text phrases were divided into two sets. Half of the participants started in dark mode and finished in light mode, and vice versa. For each mode half the participants used the first set of text phrases and the other half the second set of text phrases. After the sessions the participants were briefly interviewed regarding their experiences during the session.

Participation was voluntary and anonymous. As the experiment was conducted in one session no identifying mechanisms had to be employed to link sessions. The General Data Protection Regulations (GDPR) therefore did not apply for this study.

3.6 Analysis

The results were analyzed using JASP version 0.10.0.0.

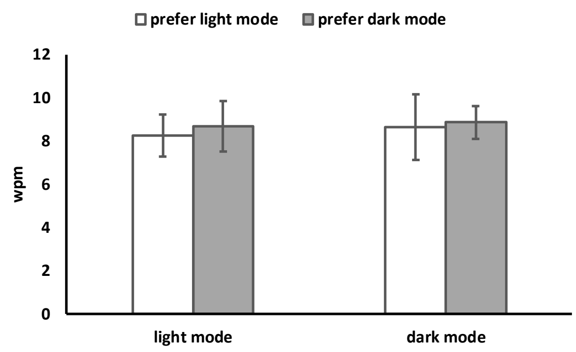

Fig. 3. Productivity in mean words per minute. Error bars show 95% confidence intervals.

4 Results

Figure 3 shows the results of the experiments in terms of productivity. Clearly, the mean words per minute for both groups under both conditions are quite similar and the 95% confidence intervals for all the point estimates overlaps. There is thus no evidence to support that there are any effects of either preference or mode of operation. A two-way mixed anova confirms the lack of significant effect both for mode of operation ($F(1, 14) = 0.680$, $p = .423$) and preference ($F(1, 14) = 0.189$, $p = .671$). The confidence intervals reveal that the participants who preferred dark mode exhibited a larger spread in the light mode condition, while similarly the participants who preferred light mode exhibited a larger spread in the dark mode.

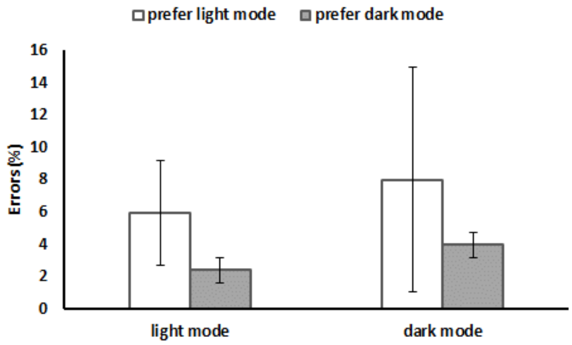

Fig. 4. Error rate in percent. Error bars show 95% confidence intervals.

Figure 4 shows the results of the error rate observations. Clearly, the error rates are similar for the light (left) and dark (right) modes. The mean point estimates for the participants who prefer light mode (white bars) is nearly twice as large as those of the participants who prefer dark mode (gray bars). However, the confidence intervals overlap, and one may therefore not conclude on any effective difference between the two groups. The participants who preferred light mode also exhibited a much larger spread than the participants who preferred dark mode. When comparing light mode with dark mode, there was a higher error rate with dark mode compared to the light mode for both groups. Again, the confidence intervals for the participants who preferred light mode overlaps too much for us to conclude that there are any significant differences. However, the confidence intervals for the participants who prefer dark mode overlap just slightly. A non-parametric Wilcoxon test confirms that there is no significant difference between light and dark mode for participants who preferred dark mode ($W = 10.5$, $p = .326$).

The following observations were made during the post session interviews of the participants. Nearly all the participants reported that they felt they improved using the alphabetical keyboard from the first to the second session, hence confirming a perceived learning effect. However, the experiment was balanced so this should have not affected the results. Participants' subjective opinions regarding the two keyboards varied. Most of the participants did not think that the mode affected their text entry speed nor error rate. However, they reported that one mode was more comfortable than the other. When asked about whether one mode made it easier to search and find the letters several participants responded positively, especially for the dark mode. But these were mostly participants who preferred dark mode in the first place. Our impressions from the interview is that users who prefer dark mode were more conscious about the aesthetical appearance and comfort rather than speed and errors.

5 Discussion

The results quite clearly confirm that there were no significant differences between productivity using dark mode or light mode. Our results therefore do not give support to the claim that dark mode results in improved productivity. Clearly, as revealed by the participant recruitment process users are quite divided in their opinions and preferences for the visual profile of the user interfaces as it was easy to locate participants with preferences for either of the two interfaces. One may thus speculate that the choice of dark mode is more an expression of a user's identity rather than a choice founded in ergonomic rationales. In shared office it is common to peek on colleagues' desktops, and dark mode may be a means for users to express their individuality or get the focus of attention. Some users may want their setup to be visually different and fancier than what is offered by the default configurations. Moreover, one may argue that people occasionally like variation and that a switch from light to dark mode can contribute to this perception of change.

However, some differences were observed. The fact that the participants exhibited a larger spread in the least preferred condition supports a speculation that participants exhibit more consistent results in their preferred mode. More consistent results under preferred conditions is a tendency one would expect.

Although not significantly different, the results for the participants with a preference for dark mode exhibited a higher performance in all conditions, that is practically higher text entry rates and lower error rates. Thus, one may speculate whether the preference for dark mode is a predictor of someone particularly computer savvy, or particularly enthusiastic about the use of computers. To be aware of dark mode someone is likely to actively follow recent technology trends and developments.

It is interesting to observe the (non-significant) practical difference in error rates between the two modes which indicates that there may be more errors associated with dark mode. However, the low number of participants may be one explanation for why we were unable to detect any significant differences. It may thus be worthwhile to explore this further in a follow up experiment with a larger number of participants. In fact, a higher ratio of errors in dark mode would be consistent with previous studies of how text polarity affects readability [9, 10, 11].

Clearly, as documented in the literature, there may be contexts where dark mode poses benefits over light mode, for instance, when a device is used in a room with little lighting at night over prolonged times [1, 2], when an economic power plan is needed with battery powered devices [3, 4] or when if a user has reduced vision [12]. However, issues related to lighting conditions, prolonged computer use, power consumption and disability is beyond the scope of this study.

5.1 Limitations

This study only included 16 participants, with only 8 participants in each group. This is a very small sample, and it is hard to even detect large significant differences with such few data points. Future work should therefore include more participants.

This study was also limited to a very narrow cohort expected to be more enthusiastic and aware of dark mode. The results therefore provide no foundations for how the results generalize to the general population of computer users. Further work should also include non-computer science users as dark mode is present in application targeted at the general population of computer users.

6 Conclusions

This study explored the effects of dark mode commonly found in modern user interfaces on productivity. A visually intensive pointing task involving text entry on a virtual keyboard in the two modes was conducted. The results indicate that there are no significant effects of dark mode on neither productivity nor errors. Although no observed effects on productivity, one should not underestimate users' perceived enjoyment and satisfaction with their personalized user interface configurations.

7 References

1. Mantiuk, R., Rempel, A. G., Heidrich, W.: Display considerations for night and low-illumination viewing. In: Proceedings of the 6th Symposium on Applied Perception in Graphics and Visualization, pp. 53-58, ACM (2009). doi: 10.1145/1620993.1621005
2. Rempel, A. G., Mantiuk, R., Heidrich, W.: Display Considerations for Improved Night Vision Performance. In: Color and Imaging Conference 2011(1), pp. 191-194. Society for Imaging Science and Technology (2011).
3. Xu, J., Billah, S. M., Shilkrot, R., Balasubramanian, A.: DarkReader: Bridging the Gap Between Perception and Reality of Power Consumption in Smartphones for Blind Users. In: The 21st International ACM SIGACCESS Conference on Computers and Accessibility, pp. 96-104. ACM (2019). doi: 10.1145/3308561.3353806
4. Dong, M., Choi, Y. S. K., Zhong, L.: Power-saving color transformation of mobile graphical user interfaces on OLED-based displays. In: Proceedings of the 2009 ACM/IEEE international symposium on Low power electronics and design, pp. 339-342. ACM (2009). doi: 10.1145/1594233.1594317
5. Philips, M.: Dark UIs. The Good and the Bad. Dos and Don'ts. Downloaded Januar 7th, 2020. https://www.toptal.com/designers/ui/dark-ui
6. Riegler, A., Riener, A., Holzmann, C.: Adaptive Dark Mode: Investigating Text and Transparency of Windshield Display Content for Automated Driving. Mensch und Computer 2019-Workshopband (2019). doi: 10.18420/muc2019-ws-612
7. Kim, K., Erickson, A., Lambert, A., Bruder, G., Welch, G.: Effects of Dark Mode on Visual Fatigue and Acuity in Optical See-Through Head-Mounted Displays. In: Symposium on Spatial User Interaction, pp. 1-9. (2019). doi: 10.1145/3357251.3357584
8. Sandnes, F. E., Eika, E.: Head-mounted augmented reality displays on the cheap: a DIY approach to sketching and prototyping low-vision assistive technologies. In: International Conference on Universal Access in Human-Computer Interaction, pp. 167-186. Springer, Cham. (2017). doi: 10.1007/978-3-319-58703-5_13
9. Buchner, A., Mayr, S., Brandt, M.: The advantage of positive text-background polarity is due to high display luminance. Ergonomics **52**(7), 882-886 (2009). doi: 10.1080/00140130802641635

10. Piepenbrock, C., Mayr, S., Mund, I., Buchner, A.: Positive display polarity is advantageous for both younger and older adults. Ergonomics **56**(7), 1116-1124 (2013). doi: 10.1080/00140139.2013.790485
11. Tsang, S. N., Chan, A. H., Yu, R. F.: Effect of display polarity and luminance contrast on visual lobe shape characteristics. Ergonomics **55**(9), 1028-1042 (2012). doi: 10.1080/00140139.2012.688876
12. Bangor, A.: Electronic text readability issues for the visually impaired. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting **43**(23), pp. 1372-1375). Sage CA: Los Angeles, CA: SAGE Publications (1999). doi: 10.1177/154193129904302323
13. Sandnes, F. E.: Universell utforming av IKT-systemer, Oslo: Universitetsforlaget, 2nd edition (2018).
14. Brathovde, K., Farner, M. B., Brun, F. K., Sandnes, F. E.: Effectiveness of Color-Picking Interfaces among Non-Designers. In: International Conference on Cooperative Design, Visualization and Engineering, pp. 181-189. Springer, Cham. (2019). doi: 10.1007/978-3-030-30949-7_21
15. Sandnes, F. E.: On-screen colour contrast for visually impaired readers: Selecting and exploring the limits of WCAG2. 0 colours. In: Information design: research and practice (Eds: Black, A., Lund, O., & Walker, S.), pp. 405-416 (2016).
16. Sandnes, F. E.: Understanding WCAG2. 0 color contrast requirements through 3D color space visualization. Studies in health technology and informatics **229**, 366-375 (2016). doi: 10.3233/978-1-61499-684-2-366
17. Sandnes, F. E., Zhao, A.: An interactive color picker that ensures WCAG2. 0 compliant color contrast levels. Procedia Computer Science **67**, 87-94 (2015). doi: 10.1016/j.procs.2015.09.252
18. Sandnes, F. E., Zhao, A.: A contrast colour selection scheme for WCAG2. 0-compliant web designs based on HSV-half-planes. In: 2015 IEEE International Conference on Systems, Man, and Cybernetics, pp. 1233-1237. IEEE (2015). doi: 10.1109/SMC.2015.220
19. Sandnes, F. E.: An image-based visual strategy for working with color contrasts during design. In: International Conference on Computers Helping People with Special Needs, pp. 35-42. Springer, Cham (2018). doi: 10.1007/978-3-319-94277-3_7
20. Hansen, F., Krivan, J. J., Sandnes, F. E.: Still Not Readable? An Interactive Tool for Recommending Color Pairs with Sufficient Contrast based on Existing Visual Designs. In: The 21st International ACM SIGACCESS Conference on Computers and Accessibility, pp. 636-638. ACM (2019). doi: 10.1145/3308561.3354585
21. Bradley, K., Rafter, R., Smyth, B.: Case-based user profiling for content personalisation. In: International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems, pp. 62-72. Springer, Berlin, Heidelberg (2000). doi: 10.1007/3-540-44595-1_7
22. Sunar, A. S., Abdullah, N. A., White, S., Davis, H.: Personalisation in MOOCs: A critical literature review. In: International Conference on Computer Supported Education, pp. 152-168. Springer, Cham (2015). doi: 10.1007/978-3-319-29585-5_9
23. Hoh, S., Gillies, S., Gardner, M. R.: Device personalisation—where content meets device. BT Technology Journal **21**(1), 67-74 (2003). doi: 10.1023/A:1022456327773
24. Cremers, A. H., Neerincx, M. A.: Personalisation meets accessibility: towards the design of individual user interfaces for all. In: ERCIM Workshop on User Interfaces for All, pp. 119-124. Springer, Berlin, Heidelberg (2004). doi: 10.1007/978-3-540-30111-0_9
25. Tossell, C. C., Kortum, P., Shepard, C., Rahmati, A., Zhong, L.: An empirical analysis of smartphone personalisation: measurement and user variability. Behaviour & Information Technology **31**(10), 995-1010 (2012). doi: 10.1080/0144929X.2012.687773

26. García-Barrios, V. M., Mödritscher, F., Gütl, C.: Personalisation versus adaptation? a user-centred model approach and its application. In: Proceedings of the International Conference on Knowledge Management (I-KNOW), pp. 120-127 (2005).
27. Aschim, T. B., Gjerstad, J. L., Lien, L. V., Tahsin, R., Sandnes, F. E.: Are Split Tablet Keyboards Better? A Study of Soft Keyboard Layout and Hand Posture. In: IFIP Conference on Human-Computer Interaction, pp. 647-655. Springer, Cham. (2019). doi: 10.1007/978-3-030-29387-1_37
28. Sandnes, F. E.: Evaluating mobile text entry strategies with finite state automata. In: Proceedings of the 7th international conference on Human computer interaction with mobile devices & services, pp. 115-121. ACM (2005). doi: 10.1145/1085777.1085797
29. Sandnes, F. E., Aubert, A.: Bimanual text entry using game controllers: relying on users' spatial familiarity with QWERTY. Interacting with Computers **19**(2), 140-150 (2006). doi: 10.1016/j.intcom.2006.08.003
30. Ye, L., Sandnes, F. E, MacKenzie, I. S.: QB-Gest: Qwerty Bimanual Gestural Input for Eye-free Smartphone Text Input, In: International Conference on Universal Access in Human-Computer Interaction. Springer, Cham. (2020).
31. Norman, D. A., Fisher, D.: Why alphabetic keyboards are not easy to use: Keyboard layout doesn't much matter. Human Factors **24**(5), 509-519, (1982). doi: 10.1177/001872088202400502
32. Sandnes, F. E.: Effects of common keyboard layouts on physical effort: Implications for kiosks and Internet banking. In: The proceedings of Unitech2010: International Conference on Universal Technologies, pp. 91-100. (2010).
33. MacKenzie, I. S., Soukoreff, R. W.: Phrase sets for evaluating text entry techniques. In: CHI'03 extended abstracts on Human factors in computing systems, pp. 754-755. ACM (2003). doi: 10.1145/765891.765971