The Effect of Light Mode and Dark Mode Features on Tablet applications for Thai elderly users

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Abstract

As the older Thai population are increasing to use mobile applications (such as Line, Facebook and so on) for accessing online information about goods and services (Electronic Transactions Development Agency (ETDA), 2019, 2020). However, elderly people still have some issues for the use of the web such as the text and background colours that did not have sufficient contrast. Although, there are a series of recommendations for a combination of text and background colours on the websites, but it is still lack of the recommendations for colour modes on mobile application which is different presentation from the recommendations of text and background colour. To provide the empirical evidence, this work conducted the effect of light mode (black on white) and dark mode (white on black) on tablet computers on task completion time, rating of reading and preferences for older Thai subjects. Thirty older Thais (60 to 73 years) participated in the study. Subjects performed four tasks on mobile applications which were presented in different colour modes (light mode and dark mode) via tablet computers and rated ease of reading and their preference after performing the tasks. The results show that all subjects completed their tasks. The colour mode had no significant effects on task completion time measures at a statistical significance of the 0.05 level. However, participants rated the light mode was significantly easier to read than the dark mode at 0.05 level. On preference for two colour modes, subjects expressed significant trends at 0.05 level, preferring the light mode which was black text and white background. These results show that the light mode is recommended for elderly Thai users in term of ease of reading and preferences. In addition, the researcher hopes these results can assist developers or designers of business mobile applications realize the elderly user needs.

Keywords: Colour mode, Dark mode, Light mode, Elderly users, Tablet

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Introduction

According to the United Nation's reports (United Nations, 2017, 2019a) there is increasing rapidly in the number of older populations worldwide. Globally, the number of older populations is estimated to reach 1.4 billion in 2030 and it could be doubled in 2050. Moreover, in 2015 the ration of older Thai population per 100 people of working age group Thai population (15 - 64 years) will be increased from 14.8 percent to 50.0 percent in 2050 (United Nations, 2019b). As this phenomenon can be seen that older people are growingly access online information about goods and services, in particularly the Coronavirus (COVID-19) information during the COVID-19 pandemic such as Mohpromt application (https://mohpromtstation.moph.go.th/) as evidenced by their increasing the use of the internet. To do so they need to be comfortable to access and read online information via the ICT devices such as tablet computers (tablets) and mobile phones. Thai Electronics Transactions Development Agency (Electronic Transactions Development Agency (ETDA), 2018, 2019, 2020). reported that between 2018 and 2020, the number of older people (the age group of 56 to 74 years) had accessed the internet increased from 8 to 11 hours per day. Moreover, older people are increasing to access the internet on mobile devices. For example, the proportion of older people accessed the internet via tablets higher than other age groups (Electronic Transactions Development Agency (ETDA), 2015, 2016). Vision will be changed when people are aging and this characteristic have a significance for the mobile application design and doing activities in their life.

Many studies (Barnard et al., 2013; Chatrangsan & Petrie, 2017; Vaportzis et al., 2017; Werner et al., 2012; Wright, 2014) found tablet computers are easy to use for older adults. Moreover, Chatrangsan and Petrie (2017) found that older adults are interested in using the tablet computers, but some older adults still faced with using the tablets with some interacting with the device such as tapping on some controls or text presentations such as the colours presentations did not have sufficient contrast.

Although many research (Chatrangsan & Petrie, 2019; Gradisar et al., 2007; Greco et al., 2008; Kamollimsakul et al., 2014) conducted the effect of colour presentations on the web on working performance and satisfaction of younger age group and older age group and their results suggested that black text on white background is recommended for both younger and older adults but white text on black background should be avoid for all web users. However, the presentations of colour background on light and dark modes have three layers of background colour (see Figure 1. and Figure 2) which are different from the colour presentations of text and background of existing research as discussed above.

There are some studies (Eisfeld & Kristallovich, 2020; Erickson et al., 2020; Koning & Junger, 2021; Nissen & Riedl, 2021) about the effect of color mode on the users' perception and working performance for only younger people. However, there is still lack of the recommendations for colour modes on mobile application.

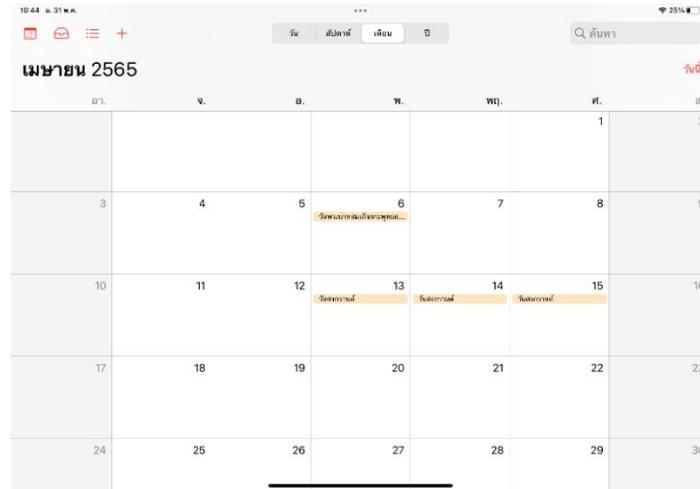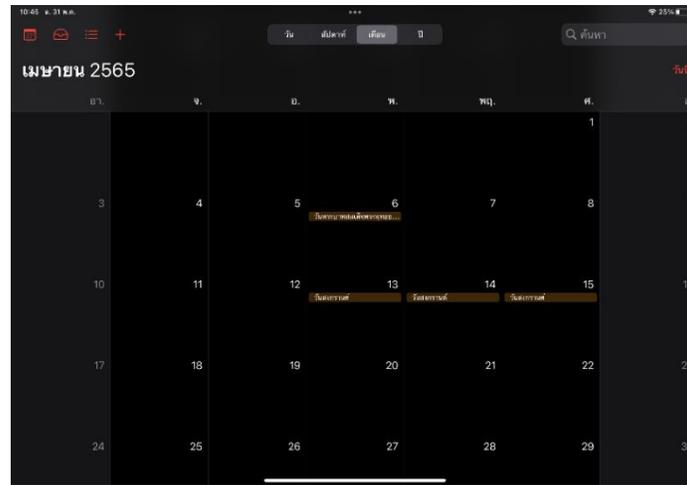**Figure 1** Example of Light Mode on an iPad

Figure 2 Example of Dark Mode on an iPad

Originally, "Light Mode" (black text on light background) is an original mode on personal ICT devices (Figure 1). In 2020 "Dark Mode" (white text and dark background) is another mode on ICT devices. "Dark Mode" which is the white text and dark controls/background was another mode to use on ICT devices (see Figure 2) and it is becoming popular mode for displaying on ICT devices as evidenced by dark mode services increasing on mobile applications such as Facebook, Instagram, and Gmail (Erickson et al., 2020; Koning & Junger, 2021; Pedersen et al., 2020). Moreover, dark mode is claimed that it easier to stay more focused at work because the text stands out whereas darkened controls into the background. In addition, using dark mode on computer screens draws less power compared when displaying a light mode (Löffler et al., 2017).

Nissen and Riedl (2021) conducted the effect of colour mode on website users' perceptions and found that colour mode have stronger effect than button shape for younger users' perceptions. In addition, some

research (Eisfeld & Kristallovich, 2020; Erickson et al., 2020; Koning & Junger, 2021) examined the effect of colour mode on younger people's visual fatigue and the researchers reported that the dark mode feature (white control on black background) reduces visual fatigue and users preferred dark mode feature to light mode feature (black control on white background). In addition, Nielsen Norman Group (2020) stated that people with normal vision perform better with light mode feature and while some people with cataract may perform with dark mode feature or long-term reading such as book readers should offer a dark mode feature. Koning and Junger (2021) also stated that dark mode made users awake when working for a longer period of time working.

The dark mode seems popular colour presentation mode for many users (Erickson et al., 2020; Koning & Junger, 2021; Pedersen et al., 2020) but no empirical evidence which colour mode is the best for online elderly users. Thus, this study will investigate the effect of light mode and dark mode of tablet computer applications on task completion time, rating of ease of reading and preference for elderly users.

Research objectives

1. To study the effect of dark mode and light mode on task completion time, rating ease of reading and subjects' preference when working on tablet computer applications

2. To compare a difference of dark mode and light mode of tablet computers toward task completion time, rating of ease of reading and subjects' preference when working on tablet computer applications

Literature Review

Definition of older adults

According to the World Health Organization or WHO (2012) and the United Nations (UN) agreed that 60 years is the threshold of old age. In addition, Chatrangsan and Petrie (2017) who calculated the appropriate minimum age of elderly people in Thailand and defined 60 years and above as older people in Thailand. Moreover, retirement is also typically at 60 years in Thailand. Thus, the minimum of age for older people in this study will be 60 years in Thailand.

Definition of tablet computers

Tablet computers or tablets are classified using the physical characteristics into three categories ((Sciarretta et al., 2015).

1. Slate tablets normally lack a physical keyboard. The term tablet is basically associated with these devices since the Apple iPad was launched in 2010.

2. Convertible tablets are similar to laptops, the difference from a standard laptop is the screen can be rotated and folded over the keyboard. In addition, the keyboard can be extracted at any time such as the Lenovo IdeaPad Yoga.

3. Hybrid tablets are similar to convertible tablets, the keyboard can be attached or detached depending on the need of users such as Microsoft surface.

However, Apple iPad is more intuitive to use for older people and a number of researchers have recommended that iPad is appropriate for older people (Jayroe & Wolfram, 2012; Waycott et al., 2012). In addition, the slate tablet is the most common device so the word "tablet computer" or "tablet" will refer to slate tablets in this study.

Research on the effect of text and background colours

Nielsen Norman Group (2020) reviewed academic research that related to the effects on contrast colours of text and background colours on reading. From their review, they recommended that people with normal vision perform better with light mode and while some people with cataract may perform with dark mode or long-term reading such as book readers should offer a dark mode feature.

Chatrangsan and Petrie (2019) investigated the effect of text and background colour on tablet computers on reading performance and preferences for older and younger readers in the UK and Thailand. There were 60 UK participants (30 older and 30 younger) and 40 Thai participants (20 older and 20 younger) in the study. Participants read five texts a tablet computer presented in different text and background colours and answer the multiple-choices questions about the texts. There were five combinations of text and background (Black on white, white on black, black on buff, sepia on buff and black on light blue). The combinations of colour had no significant effects on reading performances, however, black text on pale background is recommended for presenting the text on tablet computer for both older and younger readers.

Kamollimsakul et al. (2014) conducted the effects of text colour and background colour on the performance and preferences of younger and older people on Thai webpages. 18 younger and 18 older participants took part in this study. The three combinations of text and background colour were black text on white background, white text on black background and sepia text on buff background. Participants read the page with different colour combinations and answers the questions. The researcher found that black text on white background is recommended for younger and older people but white text on black background should be avoid for all web users.

Piepenbrock et al. (2014) investigated the effect of display polarity on visual acuity and proofreading performance for younger and older people in Germany. Participants performed a proofreading task presented in black letters on white background or white letters on black background. The researchers found that dark letters on light background should be recommended for both younger and older people.

In addition, some studies (Eisfeld & Kristallovich, 2020; Erickson et al., 2020; Koning & Junger, 2021) investigated the effect of colour mode on younger people's visual fatigue and the researchers reported that the

dark mode feature (white control on black background) reduces visual fatigue and younger users preferred dark mode feature to light mode feature (black control on white background).

However, elderly people still have some issues for the use of web such as the text and background colours that did not have sufficient contrast (Chatrangsan & Petrie, 2017). Although, there are a series of recommendations (Chatrangsan & Petrie, 2019; Kamollimsakul et al., 2014; Kurniawan & Zaphiris, 2005; Loureiro & Rodrigues, 2014; Zaphiris et al., 2006) for a combination of text and background colours on the websites but it is still lack of the recommendations for colour modes on mobile application which is different presentation from the recommendations of text and background colour.

This can be seen that there is still a lack of evidence to support which colour mode on tablet computer application will be suitable for elderly users. Thus, the study will focus on the effect of light and dark mode on tablet computer applications for older adults.

Research Methodology

Population and Sample

The inclusion criteria of Thai older people who are aged 60 years and above with living independently and have some experiences with computers, smartphones or tablet computers in Muang district, Phitsanulok, Thailand. Including, they must be able to read and write the text. However, the researcher cannot do the study with the whole of older population so a snowball recruiting technique applied in this study. At least 20 older people will be required for usability study (Nielsen, 2006). However, the optimal number of samples to test the hypothesis should be at least 30 samples (Roscoe, 1975). Thus, this study required 30 older participants.

Thirty subjects participated in this study, twenty-two females and eight males aged 60 to 73 years old (a mean of age 65.83 years). Twenty-five subjects were retired and only five subjects still working. The subjects were recruited from the Council of Cultural Affairs and older society in Muang, Phitsanulok, Thailand. There were twenty-six subjects who wore glasses for undertaking the tasks. No subject with colour vision problems. Twelve subjects had accessed the mobile applications via tablets before, but all had accessed the mobile applications via smartphones. In addition, subjects have been accessing mobile applications on average 6.03 years (Standard Deviation: SD = 2.65) and subjects access applications on average 16.63 hours per week (SD = 10.08).

Moreover, subjects evaluated their experience and expertise levels for using mobile applications on a 7-point Likert scale which presented from 1 = "Not at all" to 7 = "Excellent". The study revealed that subjects' experience and expertise levels for their using mobile applications on average 3.77 and 3.20, respectively.

Research Tools

An iPad running iOS was prepared by the researcher. Materials were:

1. For pre-questionnaire, there were three parts: (1) the usage of mobile applications, including the experience and expertise with the mobile applications and (2) demographic information which is about age, gender, occupation and so on.

2. The tasks and mobile applications, the tasks in this study are based on the basic activities when accessing the internet with mobile devices. For older people, the most activities are accessing mobile applications for the social networking or information communications such as Line, Facebook, email, calendar and finding online information about goods and services (Electronic Transactions Development Agency (ETDA), 2019, 2020). Therefore, the tasks will be related to the popular activities as above. Calendar applications and Maps applications related to popular online activities were used for the study. There were four tasks:

- Calendar application:

Task 1: Make a birthday event for a closed-friend on 28th of August 2021.

Task 2: Make a marriage party for relative on 16th of February 2021 from 7.00 to 9.00 pm at Topland Plaza Hotel, Phitsanulok, Thailand.

- Maps application:

Task 3: Find a direction from a current place (Phitsanulok, Thailand) to Khao Luang (Ramkhamhaeng National Park), Sukhothai, Thailand.

Task 4: Find a direction from a current place (Phitsanulok) to Krua Nannum Restaurant & Café in Phitsanulok and also fine the opening-closing time's Krua Nannum Restaurant & Café.

3. For post-questionnaire, there were two parts: (1) ease of reading and (2) the preference of subjects for colour modes.

Research tools developments

This study was conducted in Thailand. The experimental design was used, with one within-subject was a colour mode of user interface (two levels: light mode and dark mode). The ISO 9241-11 (2018) defines usability as ensuring that interactive products are effective and efficient to use and satisfying from the users' perspective. In addition, the components of usability are defined in ISO/IEC 25022 (2016) measure of effectiveness relate to tasks completed; measure of efficiency relate to the task completion time and satisfaction of users can be measured the positive and negative comments. The rating of ease of reading and subjects' preference will be used for satisfaction measurement.

There were three dependent variables: time to complete the tasks (seconds), ease of reading rating and the subjects' preferences for two colour modes. This study is received and approved by the Naresuan University Regional Research Ethics Committee for Human Research (IRB No. P2-0003/2564). For performing four tasks on tablet computer, the order of tasks was counterbalanced to avoid practice and fatigue effect (see Table 1.). After completing the tasks, subjects evaluated ease of reading and chose their preference for light and dark modes.

For the procedure of the experiment, subjects were briefed about the study's aim and the experimental tasks in a small room with the same condition of light and temperature. Subjects read and signed an informed consent form and then completed the pre-questionnaire. If needed, subjects will brief about the fundamentals of using an iPad. Moreover, subjects can practice until they have confidence with using the iPad. Subjects then performed the four tasks with different colour modes according to their assigned (see Table 1) and time were recorded during performing the tasks. After completing the tasks, subjects completed the post-questionnaire about ease of reading and their preference for light and dark modes. Finally, subjects were debriefed and also encouraged to ask any questions about this research. To thank the subjects, the researcher offered remuneration valued at 200 baht for their participation.

Table 1 The counterbalancing of colour modes and task conditions

Conditions	Colour Modes	Tasks		Colour Modes	Tasks	
1	Light	Task 1	Task 2	Dark	Task 3	Task 4
2	Light	Task 2	Task 1	Dark	Task 4	Task 3
3	Light	Task 3	Task 4	Dark	Task 1	Task 2
4	Light	Task 4	Task 3	Dark	Task 2	Task 1
5	Dark	Task 1	Task 2	Light	Task 3	Task 4
6	Dark	Task 2	Task 1	Light	Task 4	Task 3
7	Dark	Task 3	Task 4	Light	Task 1	Task 2
8	Dark	Task 4	Task 3	Light	Task 2	Task 1

Statistical Techniques

The Parametric Statistical Test will be applied for normality distributed data. The Repeated Measures t-test will be applied to compare the time to complete the tasks, rating of ease of reading for light and dark modes by older participants. A Chi-square goodness of fit test will be applied for participants' preference. However, if the data is not normally distributed, the non-parametric test, a Wilcoxon signed-ranks test will be applied.

Results and Discussion

Results

A test of normality presented that the time to complete the tasks show a positive skew but were not normally distributed ($p < .05$). Winsorizing process was applied to reduce the effects of outliers so a dependent t-test for paired samples was applied. For rating of ease of reading was not normally distributed, this variable is not appropriate to use the winsorizing process. Thus, to compare ease of reading rating, the non-parametric test (Wilcoxon Signed-Ranks) was applied.

Task completion time

Subjects performed four tasks on two applications with different colour modes. Time were recorded during performing the tasks. Subjects took time to complete tasks on average 233.57 seconds (SD = 97.78) for the light mode while they took time on average 243.82 seconds (SD =89.68) for dark mode (see Table 2). However, a dependent t-test show that the difference was no significant at 0.05 level ($t (29) = -0.36$, $p > .05$). This can be concluded that the colour mode had no effect on time to complete the tasks.

Table 2 A dependent t-test results comparing light and dark modes on task completion time

| conditions	Samples (persons)	Mean (seconds)	SD	t-value	p-value
Light mode	30	233.57	97.78	-0.36	0.724
Dark mode	30	243.82	89.68		

Ease of reading of subjects

Subjects evaluated ease of reading for each colour mode (light mode and dark mode) on a 7-point Likert scale (1: "very easy" to 7: "very difficult"). To compare ease of reading rating between two colour mode, the Wilcoxon Signed Ranks test illustrated that there was a significant difference ($Z = -3.25$, $p < .05$, $r = .59$) at .05 level. The median of ease of reading for two colour modes are presented in Figure 3. Light mode (Median (Mdn) = 2.00, Interquartile range (IQR) = 1.75) easier to read than dark mode (Mdn = 4.00, IQR = 2.75) were found by subjects at 0.05 level.

Figure 3 Median evaluation of ease of reading of Subjects for light and dark modes
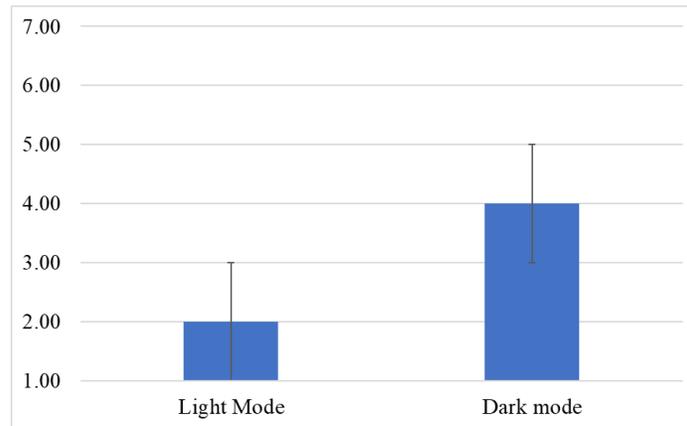
Subjects' preferences

Subjects chose which of the two presentation modes they preferred. Overall, more than half of subjects preferred the light mode (80.00%, 24 out of 30) and the others (20.00%) preferred dark mode (see Figure **4**). In addition, Chi-square Goodness of Fit Test revealed the different preference of subjects was a significant between light mode and dark mode ($\chi2$ = 10.80, df =1, p < .01). Subjects expressed significant trend, preferring the light mode.

Apart from time to complete tasks and ease of reading rating, subjects chose the preference for light and dark modes. In addition, some subjects provided the reasons why they chose that mode on post-questionnaire.

Figure 4 Subjects' preference for two colour modes
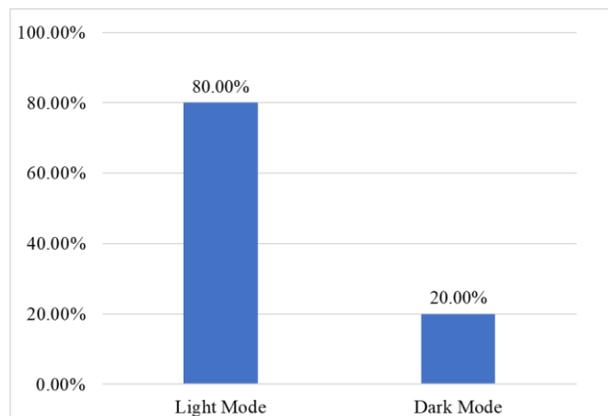
For subjects who chose the light mode, they mentioned that they felt familiar with the light mode for working on computer screen. Moreover, they stated that the light mode is easy to read whereas the dark mode is difficult to read, straining their eyes. In contrast, those who chose the dark mode mentioned that dark mode is clear for their reading. In addition, one of them said that he could focus on the text clear, without strain his eyes.

Discussion

This study examined the effects of light mode and dark mode on task completion time and subjective measures of the use of mobile application for older subjects. All subjects can complete their tasks. The colour mode had no effect on time to complete the tasks. This result agrees with the studies (Chatrangsan & Petrie, 2019; Kamollimsakul et al., 2014) who reported the colour presentations on the web had no impact on older people's performance for reading. In addition, the result similar to study of Pedersen et al. (2020) who found that there were no differences between dark mode and light mode in term of productivity and performance for text entry task via a virtual keyboard.

For ease of reading, subjects found light mode (black text with white background) easier to read than dark mode (white text with black background). Similarity to Piepenbrock et al. (2014; 2013) who stated that better visual acuity with black text on white background for older people. In addition, that agrees with Chatrangsan and Petrie (2019) who found that the combination of white text on black background was the most difficult to read for elderly people. However, that contrast with study of Pedersen et al. (2020) who reported that younger participants had mentioned the dark mode is easier to find the letters on a virtual keyboard for text entry and the participants' visual fatigue was significantly lower when working with dark mode than light mode.

In term of subjects' preferences, subjects showed a significant pattern preference, favoring light mode (black text with white background). This result is contrast with some studies (Kurniawan & Zaphiris, 2005; Loureiro & Rodrigues, 2014; Zaphiris et al., 2006) which found that pure white background should be avoided for elderly people. This is because elderly people may get used to with black text and white background for their reading. However, this result is similar to Kamollimsakul (2014) et al.'s study and Chatrangsan and Petrie's study (2019) which found that black text on white background is the most popular for younger age group and older age group in Thailand.

Contributions

Theoretical Contribution

This study contributes to the Human Computer Interaction (HCI) literature and has many practical implications for future research. In addition, this study also developed recommendations for the colour mode features for elderly people on mobile applications.

Managerial Contribution

This study can be used for mobile design or developers to understand the effect of colour modes for older tablet users. Moreover, the results can be used for the guiding to select the appropriate colour presentations to provide information about goods and services for elderly customers. This study also reflects the elderly customer needs to the business owners who need to have a mobile application to support their business.

Conclusion

The study focused on the effect of light mode and dark mode on task completion time, ease of reading rating and subjects' preferences on tablet applications for older Thai users. The colour mode had no effect on task completion time. This result agrees with study of Chatransan and Petrie (2019) and Kamollimsakul (2014) who found that the combination of text and background had no effect on reading time on mobile devices for elderly people.

For ease of reading, the clearest result, light mode is easier to read than dark mode. This result agrees with Piepenbrock et al. (2014; 2013) and Chatrangsan and Petrie (2019) who found that the combination of black text on white background was the easiest to read for elderly people. However, the result contrast with study of Pedersen et al. (2020) who reported that younger participants had mentioned the dark mode is easier and less fatigue to find the letters on a virtual keyboard than light mode.

Moreover, all participants preferred light mode over dark mode. This result agrees with previous research (Chatrangsan & Petrie, 2019; Kamollimsakul et al., 2014) which found black text on white background is the popular choice for elderly people while it is contrast with study of Kurniawan and Zaphiris (2005) and Zaphiris et al. (2006) who recommend avoiding white background for elderly people. This study contributes to the HCI literature as discussed above. In addition, new applications keep on increasing in order to serve business needs and this can be affected to elderly users who would like to buy products/services via applications or access an online information so the researcher hopes this can assist developers or designer of business mobile applications for older user needs.

Limitations and Future Research Direction

Nevertheless, the study had limitations as the experiment was performed the tasks with participants on applications and this may show different results if users were observed in their natural environment where more variables could have been identified. In addition, this study did not control the distance between the subjects viewing and the tablet's screen, as the researcher would like to create a natural environment. However, the researcher did ask subjects to put the tablet on the table when doing the tasks. Furthermore, this study focuses on only elderly users so users with different characteristics such as normal users or vision impaired users (as blindness colours, dyslexia) should be further investigated to make the findings are more generalizable.

Acknowledgements

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