ORIGINAL ARTICLE

Evaluating college students’ performance of Arabic typeface style, font size, page layout and foreground/background color combinations of e-book materials

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Abstract The present study was conducted to explore students’ preference of Arabic typeface style, font size, page layout, and foreground/background color combinations of written materials. Legibility and readability guidelines described in the literature are written for Western readers; make it difficult for e-book providers to know exactly what recommendations to follow in Arabic. First, the participants completed the font style selection process from among all the Arabic font styles available in Windows. They were then asked to select the typeface style (Simplified, Traditional, Kofi, and Nassekh) and font size (10-, 12-, and 14-point) they preferred when reading e-passages. Finally, they read another group of e-passages in the typeface style and font size they had selected in one- and two-column formats with four foreground/background color combinations. To assess their reading speed and comprehension as well as their preferences, we asked questions about the information they had read. In Experiment 1, 49 participants preferred 170 font styles from a pool of 877 presented in 12-point font size. In Experiment 2, 31 participants selected 14-pt Arabic simplified as a good readable font style for next experiment. In Experiment 3, 31 participants preferred to read Arabic materials in one column with black/white for foreground/background color combination. Participants were able to read the e-materials significantly faster and with better comprehension.
1. Introduction

The use of an electronic equivalent to a conventional printed book is called an electronic-book (e-book). The advantages of reading from e-books are: reading in low light or even total darkness, requiring far less storage space with low distributed cost; and no need to visit a bookstore (Muter, 1996).

Reading information on a visual display terminal (VDT) or a liquid crystal display (LCD) by paging is similar to reading a book, but reading speed on the screen was 28.5% slower (Muter et al., 1988) and proofreading time on the screen was 20–30% slower than on a printed paper (Gould and Grischkowski, 1984). The reason why people read more slowly from VDTs than reading from a hard copy appears to be related to image quality. The higher the resolution of the screen is, the less the difference between reading from a VDT and reading from a hard copy will be (Näsiäinen et al., 2001). Harpstet al. (1989) and Kuo et al. (2007) reported that low quality (resolution) typeface styles stimulate different spatial frequency responses in the brain than do high-quality typeface styles. This difference results in poorer accommodation to low-quality typeface styles of VDTs and maybe the cause of the poorer performance associated with reading from older VDTs. With newer, higher-resolution VDTs’ monitors and LCDs, however, reading from VDTs’ monitors may be as easy as reading from a hardcopy.

Researches have demonstrated that typography plays a critical role in ensuring legibility and readability that should be put into consideration when producing written electronic educational materials (Ley, 1988; Gould et al., 1987; Brooks and DeJoy, 1998; Schenkman and Schmid, 2003; Al-Harkan and Ramadan, 2005; Lee et al., 2008; Sheedy et al., 2008; Yau et al., 2008).

Legibility affects how rapidly, easily, and accurately one character can be recognized and distinguished from another (Huang and Ma, 2007). In other words, the greater, the ease, speed, and accuracy of sensation and perception of the character is, the more legible is the typeface (Goldstein, 1984). Typeface size is designated in points and is set to specific width and depth. The point size of a font is a measure of the overall space that the typeface styles occupy not the actual size of any individual character. Because point size does not tell you everything about how big a particular typeface will actually look, selecting type size is a visually based criterion. Bernard et al. (2003) found words to be most distinguishable when character size was about 1.14 mm wide with 0.75 mm spacing.

Typeface styles on VDT screen can be dark in a light background or light in a dark background. The research evidence is mixed in the issue of which one should be considered in the text displayed design. Some studies report no effect of polarity “the contrast of the type color and the background color” (Pawlak, 1986; Huang, 2008; Kutas et al., 2008) while others find improved performance (time and accuracy) with dark typeface styles on a light background (Ling and Schai, 2002; Bodrogi, 2003; Hunag and Chiu, 2007; Wang and Tseng, 2007; Ramadan and Mohamed, 2010).

Text materials may provide more legibility with changing foreground and background colors. Murch (1985) and Marcus (1997) argued that opponent colors were the best combinations to use; although Murch felt that blue should be avoided as a text. On the contrary, Ling and Schai (2002) argued that it was best to go with the combination of a blue text on a white background.

Al-Harkan and Ramadan (2005) argued that larger improvements in visual identification performance can be achieved by changing task features. Consequently, page layout seems to be an important factor in reading performance and subjective preference of e-book users. To date, research investigating the optimal use of line length, multiple columns, and text justification is inconclusive. Longer line lengths typically result in faster reading times (Dyson and Kipping, 1997, 1998), but research suggests medium to short line lengths typically may result in better comprehension (Chaparro et al., 2004). In terms of text column, the research supports both long single column of text (Dyson and Kipping, 1997) and multiple short columns (Lam et al., 2000) while preference seems to be toward multiple short columns (Dyson and Kipping, 1997; Bouma, 1980; Andreyev and Martynov, 2000).

Legibility and readability guidelines, which include typography guidelines, described in the literature are written for English readers. Most of the investigating of variables concerned with information presentation on VDTs has been done within the context of Western language alphabets and convention of printing and reading. It is vague for Arabic language, making it difficult for Arabic e-books’ providers in general to know exactly what recommendations to follow when producing e-books.

Because of the many differences between Arabic and English text styles, character recognition methods differ in the way they handle texts in the two languages. For example, the Arabic text is read and written from right to left while English is read and written from left to right. Arabic text is cursive, i.e., characters are connected within each word without spaces and in this way they are treated as a block forming one word. Words are separated by spaces (Al-Mutawa, 1999).

English characters take two different forms (upper and lower case). However, Arabic characters take different forms for different reasons. When a character comes at the beginning of a word it has a special shape. When it comes in the middle of the word it has another shape and so on. Each character in Arabic language has up to seven forms depending on the font used such as “ال”, “ال”, “ال”, “ال”, “ال”, “ال”, “ال” for “Aleph”, and location of the character within a word, i.e., “ال”, “ال”, “ال”, and “ال” for “Sad”. In addition, some characters have more or fewer forms than others such as “ال”, and “ال” for “Ya”. No middle form character should be placed at the end or at the beginning of the word; no end form character should be placed anywhere other than the end of the
Experiment 1 was designed to explore which font styles do participants prefer most. There are many fonts used in the Arabic printing trade such as Kofi (164), Nasekh (65), Rikah (29), Farsi (20), MCS (10), Andulis (30), Diwany (210), Baseatt (17), Al-Wadi (39), Mofasl (36), Kateer (82), Rakamy (29), Gadeed (68), Solath (31), Baaher (17), Simplified (20), and Traditional (10) typeface styles. The numbers between brackets refer to numbers of styles included in each font. The shape of Arabic typeface differs from one font to another because Arabic calligraphy was developed as an art. Every Arabic character has a unique appearance.

3. Methods

3.1. Participants

Participation criteria included being at least 16 years of age or older, able to understand, read and speak Arabic. After the study was explained and written consent was obtained, demographic information was collected. The participants were 49 male volunteer university students whose ages ranged from 17 to 23 years. All of them passed a visual acuity test and had no ocular pathology when examined by an ophthalmologist. Each subject was paid for his participation.

3.2. Selection of font styles used in the experiment

The 17 Arabic fonts available in Microsoft Word (Version, 2003; www.microsoft.com) were selected to be used in the study. Within each Arabic font, there are several styles. For example, thirty-nine font styles are included in Al-Wadi font; and 877 represent the total number of font and style combinations available in the Word and included in the study.

Testing was done in two separate sequence stages. The first stage was to choose the best 10 of font styles from the 17 fonts. Then in the second stage, the goal was to select the top 10 of the font styles from a pool of 170 font styles that were chosen in the first stage. After the participants completed the first stage, they were asked to come back again to participate in the second stage.

3.3. Experimental design

Arabic font styles are randomly distributed to Arabic typeface styles. A complete sentence containing the majority of Arabic characters was written by the assigned Arabic typeface style. The characters were 12 points, which are widely used in Microsoft applications for displaying Arabic characters, and were presented as black on a white background. A program written in Visual Basic Studio 6.0 (msdn.microsoft.com) was used to display the typefaces in a Dell 17-inch (430 mm) LCD monitor at resolution of 1024 x 768 pixels, attached to a Pentium IV (2.66 GHz) processor PC running Microsoft Windows XP environment. All participants were tested in an ergonomics laboratory in which the light level was approximately 300 lux. To ensure both maximum clarity and reliability, the contrast was set to maximum level and the brightness to minimum level. The viewing distance was approximately 500 mm. These set-up parameters were fixed in all experiments.

3.4. Experimental procedures

Participants were asked not to engage in any other work using computers for an hour before the experiment to prevent visual fatigue. The experiment took approximately two and half hours to finish and the participants were tested individually. There was a 5-min break between typeface style treatments. In the experimental session, the participants were given instructions and two practice trials to familiarize them with their tasks.

Participants clicked ‘Start’ to display an array of assigned font styles buttons containing the same sentence presented in a random manner. Participants reviewed the sentences then clicked the buttons on which they were presented in order of preference of font styles from most preferred (e.g., easy to recognize and to read) to less preferred until 10 buttons had been selected. Once 10 sentences were selected, the screen was dismissed and the start prompt reappeared. The rest that were recognized as not easy and difficult to be read were automatically rated as zeros.

In each time, font style was clicked and automatically rated; the sentence disappeared off the viewing area. The rest stimulus array was immediately refreshed and presented on the screen. The participant searched for the next font preference in the stimulus array, then moved the mouse to the target item and pressed the mouse button. The font styles and associated rating values occurring during this process were recorded by the computer. After 10 sentences of a treatment were completed, a break was taken and the research assistant prepared the next treatment. The participants repeated the same procedures until all 17 treatments were completed. Then in the second stage, the participants followed the previous procedures to select the top 10 of the font styles from a pool of 170 font styles that were chosen from the first stage.

3.5. Results

As a result of the second stage, Table 1 presents the top 10 of the font styles with their subjective scores. According to Table 1, “Simplified”, “Nasekh”, “Traditional”, and “Kofi” were rated
with the highest scores of 287, 279, 187, and 185 points, respectively. Therefore, those font styles were selected for the next experiment. A Friedman test showed highly significant differences among font styles, \( \chi^2 \) \((169, N = 49) = 2564.6, p < 0.0001). Wilcoxon tests (two-tailed) revealed that there were no statistical differences among “Simplified”, “Standard Naskh1”, “Traditional”, and “Kofi20”. However, there were significant differences among those font styles and the rest of 170 font styles.

The four font styles that have been studied in Experiment 1: “Simplified”, “Traditional”, “Kofi”, and “Nasekh” were selected to be studied in this experiment because they were the most preferred fonts. In addition, most written materials use small fonts of 10- and 12-point Arabic character as the default font sizes in order to present an efficient amount of information. However, it was found out, in research, that reading speed tends to improve in respect of an increase in text size up till a critical point (called the maximum reading speed), after which the effect levels off (Ojanpää and Näsänen, 2003). In addition, if the display or viewing quality is extremely poor, then larger font is suggested (Lin et al., 2008). To the best of the author’s knowledge, nothing was reported about Arabic character size. Therefore, Experiment 2 was designed to study the effect of four fonts selected from Experiment 1, and the three commonly used font sizes (10, 12, and 14 points) on reading speed, reading comprehension, and subjective preference rating.

4. Experiment 2

4.1. Methods

4.1.1. Participants

After screening process, 40 male university students were recruited for these experiments. Only 31 participants completed the experiments. All were native Arabic-speakers (aged 18–33 yrs), all of whom were right handed, carried out the following two experiments. The participants included 26 undergraduate students and 5 graduate students. Participants were screened to meet the following criteria: visual acuity (corrected or uncorrected) of 20/20, normal color vision, and no ocular pathology. Those who are nearsighted were requested to wear corrective glasses when testing. All participants were tested and permitted to participate in this study by an ophthalmologist at the university hospital. The participants had experience in computer, but none of them had any speed-reading training.

4.1.2. Apparatus

Testing was done on a Pentium IV computer, with all text materials displayed on a color monitor possessing of 1024 x 768 pixels. The monitor was placed on a 75 cm high table, without any inclination, and an ambient illumination of approximately 300 lux. These set-up parameters were fixed. Also, the screen was free of glare or reflection. The distance from the center of the screen to the desktop was 23 cm; while the distance from the participants’ eyes to the center of the screen was 50 cm. Text was presented in black on a white background in order to roughly simulate the e-book on the monitor screen. The text width and the height of the display were 28 and 16.5 cm, respectively.

4.1.3. Independent variables

Four Arabic font styles (“Simplified”, “Traditional”, “Kofi”, and “Nasekh”) and three font sizes (10, 12, and 14 points) were considered as independent variables in this experiment.

4.1.4. Dependent measures and statistical analyses

The three dependent measures collected in this study were the subject’s reading speed, reading comprehension, and subjective preference rating. The subject’s reading speed and reading comprehension were the criteria of visual performance, and the rating score was the criteria of the subject’s preference. A number of words in each passage was counted prior to executing the experiment and was considered in calculating reading speeds. The reading comprehension level reflects how the subject understood the text materials. Preference score was an average of four questions about sharpness of the typeface, legibility, eye fatigue sensation related to reading a text of such font style, and font style clarity. Each one measured by a scale of a 0 (absolutely unsatisfied) to 5 (absolutely satisfied) presenting the extent of satisfaction with the treatment. In human–computer interface, preference is a component of usability, and refers to the feeling of pleasure that users are subjectively satisfied when using and like it (Fukuzumia et al., 2002).

These three measures were collected as the following: (1) reading speed was calculated by dividing total words included
in the passage and total elapsed time in reading in minutes (words/min); (2) reading comprehension was measured by dividing the total number of correct responses by the total number of questions in each trial (percent of correct answer); and (3) participants’ preferences were collected and gathered over the grades by each participant for each trial setting using a 0–5 scale.

Statistical analysis was performed using the Statistical Package for the Social Sciences software (SPSS Version 16; www.spss.com). Multiple univariate ANOVA’s were conducted to test dependent measures. Factors identified as significant were further analyzed using the Tukey’s test to differentiate between the factor levels. In addition, simple effect technique (Keppel, 1982) was employed to further analyze the interaction between factors.

4.1.5. Experimental design and procedures

Participants were asked to read 24 passages (about 1223–1289 words) presented on a computer screen (Fig. 1 displays one of the experimental trials), and were selected from an electronic book that was available in the system to represent readable materials to the participants. The content of the passage was chosen from an International Alpha series (in Arabic language). Selection criteria required that the sentences did not contain extremely rare words or technical terms or names of unusual instruments. Due to these criteria, some of the sentences were modified with a few words before they could be used in the experiment. The average tested passage was assessed at a mean reading level of grade 8 (SD = 1.5) using the Gunning’s FOG Index Readability Formula. The FOG Index (Gunning, 1968) is simple and appropriate for assessing material from fourth grade through college levels (Meade and Smith, 1991).

Since there were 12 different conditions, participants read two passages per each condition. For each passage, reading speed (word/min), percent of correct answer (i.e., reading comprehension level), and subjective preference measures were recorded. Twelve treatment sets were completed and were counterbalanced across participants and treatments. The presentation of the passages was randomly assigned for each trial. Thus, the effects of the passages were balanced. The pace of reading was under the control of the participant. The mean of the two estimates of reading speeds, reading comprehensions, and preferences for each condition were used in further analysis.

The experiment took approximately one and half hours (a total of 18 h for the whole experiment per participant) to complete, and each participant was tested individually. There was a 3-min break between reading sessions. In the experimental session, the participants were given instructions and a one-sentence practice for each treatment to familiarize them with the procedures. The participants were informed about the presentation method and instructed to initiate a trial by pressing the “Start” key and to read each sentence to the best of their abilities. Upon finishing reading each passage, a question window appeared on the screen. Comprehension tests, which were based on the passage content, consisted of 5 true/false questions per passage. To establish a baseline response rate,
17 students who had not read the passages attempted to answer the questions. The mean score was 2.9%.

In each trial, participants were instructed to use the mouse to click the correct answer. The computer does not allow the participants to change their answers, and it records their responses automatically. Immediately after the true-false question screen disappeared off the viewing area, the participants were required to report their satisfaction scales (preference ratings). The participants repeated the procedures until all 12 treatments were completed throughout 12 days. Each subject experienced 24 passages – two for each condition in random order (e.g., each subject was given a different randomized order of the 24 passages; in addition, no passage was repeated twice to the same participant). To prevent visual fatigue, participants were asked to avoid using a computer for 1 h before the experiment. All tests were executed during January to May, 2008.

4.2. Results

4.2.1. Reading speed

Both main effects were significant, font style, \( F(3, 90) = 9.48 \); and font size, \( F(2, 60) = 66.06 \). The main effects were significant at \( p < .001 \). In addition, font style by font size interaction was also significant, \( F(6, 180) = 5.67 \).

A one way-ANOVA was performed using simple effect technique (Keppel, 1982) to test the effect of font style and font size interaction on human performance in terms of reading speed. There were significant differences between font styles at font size 10 pt, \( F(3, 120) = 4.83, p < 0.003 \). Tukey’s test had been employed to compare the reading speed means for different font style levels. As shown in Table 2 and Fig. 2, participants read significantly faster at “Simplified” font style when compared to the participants read at “Kofi” font style.

The same analysis procedures were employed for font styles at 12 pt and 14 pt font sizes. At 14 pt font size, participants read significantly faster at “Traditional” font style when compared to the participants who read at “Kofi” font style.

Both main effects as well as font style by font size interaction were significant at \( p < 0.001 \); font style, \( F(3, 90) = 31.53 \); font size, \( F(2, 60) = 16.47 \); font style by font size interaction, \( F(6, 180) = 8.34 \). One way ANOVA and Tukey test were performed to analyze the interaction.

As shown in Table 2 and Fig. 3, at 10 and 12-point font sizes, participants better understood at “Simplified” font style when compared to the other font styles. However, at 16 point font size, participants significantly better understood at “Simplified” font style when compared to the other font styles.

4.2.3. Preference rating

Both main effects as well as font style by font size interaction were significant at \( p < 0.001 \); font style, \( F(3, 90) = 35.73 \); font size; \( F(2, 60) = 22.92 \); font style by font size interaction, \( F(6, 180) = 43.95 \). One way ANOVA and Tukey test were performed to analyze the interaction.

As shown in Table 2 and Fig. 4, participants at 10 pt as well as at 12 pt preferred significantly to read educational materials at “Simplified” and “Traditional” font styles when compared to the participants to read at “Kofi” font style.

At 14 pt, participants preferred significantly to read educational materials at “Simplified” when compared to the participants to read at other font styles. In addition, participants preferred significantly to read educational materials at “Traditional” when compared to the participants who read at “Nasek” or “Kofi” font styles.

Obviously, there were distinguished differences in the time and accuracy by which users could read various fonts, and even stronger differences in their subjective preferences for the fonts. Examples of the different point sizes for the font styles where statistical differences were found are illustrated in Table 3. Looking at the data as a whole, a few conclusions appear warranted: (1) “Kofi” font at different sizes should generally be avoided; (2) to optimize subjective preference, use “Simplified 10”, “Simplified 12”, or “Simplified 14”; (3) to optimize reading speed and accuracy, the best choices appear to be “Simplified 10”, “Simplified 12”, “Traditional 12”, “Simplified 14”, and “Traditional 14”. From the analysis of reading speed, reading comprehension, and preference rating, “Simplified 14 pt” font style was the best font style and size combination, and was selected to run the third experiment.

5. Experiment 3

Several studies revealed that editing writing material displays with larger color differences of the text/background color-combinations resulted in higher subject reading performance and subjective preferences (Wang and Chen, 2003; Wang et al., 2004; Chen and Lin, 2004). However, Muter (1996) pointed out that there are many disadvantages and potential problems with the use of color in text presentation. Color displays in effect have lower resolution because three phosphors are required at each point. The performance is impaired because the use of color sometimes results in a contrast ratio that is so low.

In addition, two-column page layout enhances the visual performance of e-book users (Andreyev and Martynov, 2000); one column page layout improves user subjective
preferences (De Bruijn et al., 1992; Baker, 2005). Therefore, Experiment 3 was designed to test the effect of page layout as well as text/background color-combinations on reading performance and subjective preference using Experiment 2 results.

5.1. Experimental design and procedures

The method in Experiment 3 was the same as in Experiment 2, except for the following.

Table 2  Summary of one-way ANOVA and Tukey test results.

<table>
<thead>
<tr>
<th>Reading speed</th>
<th>F</th>
<th>At font size 10 pt</th>
<th>Font type</th>
<th>Nasekh</th>
<th>Traditional</th>
<th>Simplified</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kofi</td>
<td>84.59 (19)</td>
<td>92.24 (20)</td>
<td>96.72 (22.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>At type size 12 pt</td>
<td>0.775</td>
<td>Kofi</td>
<td>104.12 (15.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>At type size 14 pt</td>
<td>4.791**</td>
<td>Kofi</td>
<td>101.94 (22.5)</td>
</tr>
<tr>
<td>Reading comprehension</td>
<td>F</td>
<td>At font size 10 pt</td>
<td>Font type</td>
<td>Nasekh</td>
<td>Traditional</td>
<td>Simplified</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kofi</td>
<td>65.48 (25.1)</td>
<td>68.67 (12.8)</td>
<td>72.05 (15.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>At type size 12 pt</td>
<td>2.77*</td>
<td>Nasekh</td>
<td>75.97 (11.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>At type size 14 pt</td>
<td>29.263***</td>
<td>Nasekh</td>
<td>52.81 (26.4)</td>
</tr>
<tr>
<td>Preference rating</td>
<td>F</td>
<td>At font size 10 pt</td>
<td>Font type</td>
<td>Nasekh</td>
<td>Traditional</td>
<td>Simplified</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kofi</td>
<td>1.48 (.48)</td>
<td>2.4 (.78)</td>
<td>2.71 (.23)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>At type size 12 pt</td>
<td>28.139***</td>
<td>Kofi</td>
<td>1.26 (.25)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>At type size 14 pt</td>
<td>30.099***</td>
<td>Kofi</td>
<td>2.35 (.99)</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01, and ***p < .001. Underlining denotes that the means are not significantly different at p < 0.05. Giving mean values (SD).
5.1.1. Independent variables

5.1.1.1. Page layout. Texts were delivered in a single column and two-column full-page formats. There was no scrolling. A new page was presented whenever “Continue key” on the screen was pressed similar to reading a book. The hypothesis is that the wider the pages are, more reading speed and comprehension are improved when the text is split into two columns.

5.1.1.2. Foreground/background color combinations. Four foreground/background color combinations (white/black, black/white, blue/white, white/blue) were studied in this work. The hypothesis is that the more to go with the combinations of blue/black/white texts on white/blue/black backgrounds are, the more reading speed and comprehension are improved. The RGB codes for blue, white, and black were: (0, 0, 153), (255, 255, 255), and (0, 0, 0), respectively.

Sixteen passages (two passages in each treatment) were chosen from the same electronic book that was available in electronic to represent readable materials to the participants. Then, these passages were distributed equally to those eight sessions in a random fashion. Those eight sessions represent the two main variables (two column types by four foreground/background color combinations) across all participants. Comprehension of the test passage was assessed by asking five questions based on the content. The questions were asked prior to the study to ensure content validity. Twenty-three students who had not read the passages attempted to answer the questions. The mean score was 1.8%. The same dependent variables employed in the second experiment were implemented in this experiment. Reading speed (word/min), percentage of correct answer, and subjective preference measure were dependent variables. A $2 \times 4$ within-subjects factorial design was employed in this experiment. All tests were executed during September to December, 2008.

Table 3  Examples of the different point sizes for the typefaces where statistical differences were found. Each upper sentence was significantly superior over the lower one.

<table>
<thead>
<tr>
<th>Reading speed</th>
<th>Preference rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>@ 10-pt Simplified</td>
<td>@ 10-pt Kofi</td>
</tr>
<tr>
<td>@ 10-pt Kofi</td>
<td>@ 10-pt Traditional</td>
</tr>
<tr>
<td>@ 14-pt Traditional</td>
<td>@ 14-pt Kofi</td>
</tr>
<tr>
<td>@ 14-pt Kofi</td>
<td>@ 14-pt Simplified</td>
</tr>
<tr>
<td>@ 14-pt Simplified</td>
<td>@ 14-pt Nasekh</td>
</tr>
</tbody>
</table>

5.3. Results

5.3.1. Reading speed

Only main effects were significant at $p < .001$; there were page layout and foreground/background color combinations which had significant effects on reading speed, $F(1, 30) = 411.92$, $F(3, 90) = 33.19$, respectively. Participants read significantly faster at two-column page layout ($M = 132.29$ words/min, SD = 9.2 words) when compared to the participants who read at one-column page layout ($M = 96.34$ words/min, SD = 7.8 words).

Tukey’s test was employed to compare the reading speed means of different foreground/background color combinations. As shown in Table 4 and Fig. 5, participants read significantly faster at text written in blue/white when compared to the participants who read at text written in black/white or white/black. In addition, the participants read significantly slower the text written in white/black when compared to the participants who read the text written in other color combinations.

5.3.2. Reading comprehension

Both main effects as well as page layout by foreground/background color combinations interaction were significant at $p < 0.05$; page layout, $F(1, 30) = 5.98$; foreground/background color combinations, $F(3, 90) = 20.02$; page layout by foreground/background color combinations interaction, $F(3, 90) = 79.56$. One way ANOVA and Tukey’s test were performed to analyze the interaction using simple effect techniques.

At one-column page layout, participants significantly understood better the text written in black/white as well as texts written in blue/white when compared to the participants who read the text written in white/blue or text written in blue/white. At two-column page layout, participants significantly understood better the text written in white/black or texts written in white/black when compared to the participants who read the text written in blue/white or white/black, as shown in Table 4 and Fig. 6.

5.3.3. Preference rating

Both main effects as well as page layout by foreground/background color combinations interaction were significant at $p < 0.001$; page layout, $F(1, 30) = 28.65$; foreground/background color combinations, $F(3, 90) = 43.5$; page layout by foreground/background color combinations interaction, $F(3, 90) = 5.79$. One way ANOVA and Tukey’s test were performed to analyze the interaction.

At one-column page layout, participants significantly prefer to read texts written in black/white when compared to the participants who read the text written in other foreground/background color combinations, as shown in Table 4 and Fig. 7. In addition, participants significantly preferred texts written in blue/white when compared to the participants who read the text written in white/blue or white/black/foreground/background color combinations.

At two-column page layout, participants significantly prefer to read texts written in black/white as well as blue/white when compared to the participants who read the text written in white/black or white/blue, as shown in Table 4 and Fig. 7.

Looking at the data as a whole, a few conclusions appear warranted: (1) text in white letters written in a black background should generally be avoided; (2) to optimize subjective preference, use texts written in one column page layout in black on white background; (3) to optimize reading speed and accuracy,
the best choices appear to be two column page layout with either text written in white/blue or black/white; and (4) to optimize reading speed and accuracy, the best choices appear to be one column page layout with text written in black/white. Generally, from the analysis of reading speed, reading comprehension, and preference rating, one-column page layout and black/white text materials were selected as the best combinations.

6. Discussion

6.1. Font style and size

Results of the studies reported in the literature agree with the results of this study in which font style and size of e-book did significantly influence participants’ reading performance in terms of time and comprehension and on participants’ subjective preferences. For example, Bernard et al. (2003) found that participants perceived Times at both 10- and 12-point sizes as significantly more difficult to read as Arial, even though 10-point Arial and 12-point Times have approximately the same x-height. Also, they found that text at the 12-point size produced significantly greater subjective readability (perceptions of text legibility and sharpness) and had lower levels of perceived difficulty in reading a text at the 10-point size. Text at the 12-point size was also significantly preferred to those texts at the 10-point size. Boyarski et al. (1998) found that 10-point serif (Times and Georgia) and sans serif (Verdana) typefaces were equally readable (a 10-point typeface has a character

Table 4  Summary of one-way ANOVA and Tukey test results. Mean values (SD).

<table>
<thead>
<tr>
<th>Reading Speed</th>
<th>F</th>
<th>Foreground/background color</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>White/Black</td>
</tr>
<tr>
<td></td>
<td>19.501*</td>
<td>Blue/White</td>
</tr>
<tr>
<td></td>
<td>113.52 (14.5)</td>
<td>Black/White</td>
</tr>
<tr>
<td></td>
<td>120.56 (15.5)</td>
<td>White/Blue</td>
</tr>
<tr>
<td></td>
<td>127.43 (11.4)</td>
<td>Blue/Black</td>
</tr>
<tr>
<td>Reading comprehension</td>
<td>F</td>
<td>Foreground/background color</td>
</tr>
<tr>
<td>At one column page layout</td>
<td></td>
<td>White/Black</td>
</tr>
<tr>
<td>At two-column page layout</td>
<td></td>
<td>White/Blue</td>
</tr>
<tr>
<td>Preference rating</td>
<td>F</td>
<td>Foreground/background color</td>
</tr>
<tr>
<td>At one column page layout</td>
<td></td>
<td>White/Black</td>
</tr>
<tr>
<td>At two-column page layout</td>
<td></td>
<td>White/Blue</td>
</tr>
</tbody>
</table>

\( p < .001. \) Underlining denotes that the means are not significantly different at \( p < 0.05. \)

Figure 5  Reading speed (words/min) with standard error bars as a function of foreground/background color.

Figure 6  Percent correct for page layout with standard error bars as a function of foreground/background color.
height close to 4 mm at this resolution, which is similar to a 12-point size at 1024 x 768 pixels). Sanocki (1991) found that reading accuracy was predicted by both size and typeface factors related to the overall style of the letters. Bouma (1971) argued that the differences between text sizes are not often significantly apparent until the size differences become quite large. The effect of size and style on the perceptions of reading performance, did however, produce significant differences. To a certain degree, larger text sizes are considered more readable than smaller sizes (Rudnicky and Koler, 1984). This agreed with the result of Arabic “Simplified 14 pt” font style is superior to the other less point sizes.

6.2. Text/background color combination of e-book

Color combination had an effect on both reading speed and comprehension. In addition, combination had an effect on preference and perceived display quality. More detailed analysis of the performance data showed that the Black/White combination was relatively better in terms of accuracy. Black/White was relatively the best in terms of speed, comprehension, and preference and perceived display quality, followed by White/Blue.

This study found that participants’ reading performance and subjective preferences varied markedly according to text/background color-combinations. Experimental results revealed that e-book displays with larger color differences of the text/background, color-combinations resulted in higher subject performance and subjective preferences, which were similar to the conclusions of other studies (Shieh and Chen, 1997a,b; Shien and Lin, 2000; Wang and Chen, 2003; Wang et al., 2004; Chen and Lin, 2004; Garcia and Caldera, 1996; Ramadan and Mohamed, 2010).

Murch (1985) and Marcus (1997) argued that contrasting colors were the best combinations to use, although Murch felt that blue should be avoided as a text. In contrast, Ling and Schaik (2002) argued that the best to go with is the combination of blue text on a white background. Our findings appear to give support to both researchers: Black/White and Blue/White led to the best performance resulting in the fastest reading speed. These findings agreed with recent research by Greco et al. (2008). However, our results contrast with those of Matthews et al. (1989) and Pastoor (1990) in which they observed no effect of using red or blue stimuli. However, in the present study, the use of blue led to some of good performances. This study found a clear effect of color combination on human performances.

The following patterns between different measures were observed in the results. Almost the same pattern of differences was found in both reading speed and comprehension measures which show that overall the Black/White combination led to high performance compared to the other combinations. Similarly, almost the same pattern of significant differences was found in preference measure showing that overall the Black/White combination resulted in high rated subjective measures compared to the other color combinations. In brief, in terms of producing the best performance, preference and perceived quality, it was found that Black/White led to the fastest reading speeds and the most preferred and was rated most highly in terms of characters’ appearance. In the present study, we found that combinations of colors that had dark characters on a light background generally led to better performance than combinations of light characters on a dark background.

6.3. Page layout

The page layout research on reading texts comes from a number of writers and researchers. The most notable are Priestly (1991), Dyson and Kipping (1997, 1998), Piolat et al. (1997), Lam et al. (2000), Andrevey and Martynov (2000), and Baker (2005). The recommendations from their researches in the area of page layout are inconclusive. Although two-column page layout enhances the visual performance of e-book users (Andrevey and Martynov, 2000), one column page layout improves user subjective preferences (Baker, 2005). Dyson and Kipping (1997) found that a single column paged was read faster than either three columns paged or one column scrolled, while there was no significant difference between three columns paged and one column scrolled. Those results agreed with the results of the present study. At the same time, the researchers did not find a significant difference in comprehension rates among the participants.

7. Conclusions

Numerous factors contribute to the ease of e-book reading. As more types of Arabic documents become digital, and more people read from online sources, finding the optimal presentation of these materials will become critical in the near future. Reading speed, comprehension, and preference tests are moving into the digital domain and studies such as this one can help researchers and designers know which font style and size, multiple columns, and foreground/background color combinations are best for their users.

It is believed that the participants’ visual performance is better, when the typography is chosen well. Consequently, some of the factors that are essential for making electronic texts feasible are: font style, font size, page layout, and foreground/background color combinations. This work studied those factors which affected electronic text’s legibility and
readability. Three experiments were carried out to determine the best combinations of those factors when combined.

The first experiment was to propose some of good Arabic font styles that were available in the Microsoft Windows. The second experiment was to determine the best font style and font size. The result revealed that “Simplified” font style and 14 pt font size were the best combination among different Arabic font styles and sizes. Therefore, they were selected to run the third experiment. The third experiment was to determine the best combination of page layout and background/text color combinations. The result revealed that one-column page layout and black/white background color were the best combination for the third experiment. This suggests that users should have the option to customize e-book pages to suit their reading needs. To date, there is no study related to Arabic characters that allows users to tailor information displays in terms of multiple columns, background/text color combinations, font styles, or font sizes. This study presented spots on those options to the users to help them increase their text reading speeds, and eventually may lead to a more optimal online reading experience.

Future studies could extend this research by examining a greater number of typefaces or sizes in both positive and negative polarity formats. In addition, as with all studies that examine reading performance with different typefaces. Many factors should be taken into account, such as the line and character spacing, actual size of characters, visual angle of characters, characters per line, lines per page, words per page, margins, contrast ratio between characters and background, ambient illumination, reader’s familiarity with the medium, the computer settings and the user’s characteristics, such as age and reading ability.

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References


