Use of Customized Text Can Be Beneficial to Students Who Read Online Materials Under Constrained Visual Conditions

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Abstract. The use of digital materials, such as eBooks and other online content, has become increasingly popular among diverse groups of users due to their portability, ease of access, and cost effectiveness. However, individuals with disabilities and individuals without disabilities, who access the materials under constrained conditions (e.g., dim lighting), have different user needs. The ability to customize text is a potential solution for allowing users with different needs to optimize their online reading environments. The present study examined whether the ability to customize text would improve reading performance and reduce visual fatigue associated with online reading in two experiments. In addition, subjective ratings were obtained to evaluate the perceived usability of a system that allowed for customized text. Experiment 1 provided participants with limited experience with reading text on big or small screens under customizable and non-customizable conditions, and in either normal or dim lighting. In this experiment, we did not find any performance differences, but participants indicated that the use of customized text reduced their visual fatigue and showed a slight preference for using customized over non-customized text. In Experiment 2, participants performed the reading tasks over a longer period of time in a dimly lit room using either a big or small screen. Participants were more accurate in answering reading comprehension questions in the customized text condition. They also indicated agreement with statements about the use of customized text to reduce visual fatigue, and they wanted the option to customize text. Thus, overall, this study showed that the use of customized text could help users read and comprehend information better, as well as mitigate the effects of visual fatigue under constrained viewing conditions.

Keywords: Accessibility · Web accessibility · Customization · Customized text

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1 Introduction

Originally, web accessibility was thought to be primarily important for people with disabilities because it allows this group of users to perceive, understand, navigate, and interact with online materials. However, it has been shown that improving web accessibility not only benefits people with disabilities, but also other groups of people, including older users [1] and users accessing information under constrained conditions [2]. Examples of common constrained reading conditions include reading in dimly lit environments or on devices with smaller screen sizes. Lee, Ko, Shen, and Chao [3] found that search time for target letters decreased as illumination increased from 300 to 1500 lx. Benedetto, Carbone, Drai-Zerbib, Pedrotti, and Baccino [4] also found that students produced faster reading times in conditions with higher levels of luminance compared to lower levels. In addition, Lin, Wu, and Cheng [5] found that increasing font sizes on smaller screens (i.e., 6 to 9.7 in.) resulted in better search performance by students for targeted words. Thus, having the ability to customize properties of text can be beneficial to users by allowing them to tailor display properties to meet their specific needs.

Most universities in the United States are increasingly adopting electronic components as part of their educational practices. For example, at many universities, syllabi and other course materials are made available to students online through course management systems. The use of electronic documents not only increases the portability of the material, but it also reduces the costs associated with printing the materials. Use of electronic materials also has the potential for making the content more accessible if the content can be customized to meet the users' specific needs. In 2013, the California State Legislature enacted a bill that was intended to make higher education more affordable to students through the use of online teaching materials. As a result, the California State University system established a California Digital Open Source Library (CDOSL) and a California Open Online Library for Education (COOL4ed) to help faculty find and adopt online course materials at little or no cost to students. However, the online course materials must be accessible for the students to maximize their potential use. Sun et al. [6] and Chan et al. [7] evaluated the accessibility of 140 eTextbooks available at that time on the COOL4ed website and found that only about 60% of the books passed their accessibility evaluation. Moreover, many textbooks were in fixed formats (e.g., PDF files) that could not be customized for formatting and displaying the content on different devices. Thus, there is a need to improve the accessibility of electronic contents that are intended for use by students with and without disabilities.

As noted earlier, making text customizable may be the best way to improve accessibility for a broad range of users because the text can be adjusted to meet the specific needs of the individuals, the devices used to access the materials, or environmental conditions under which tasks are performed. Unlike personalization, which allows websites to provide content intended to suit the users' needs or interests without any intervention from the users, customization gives users control over the look and feel of the website, as well as the ability to make changes to the layout, functionality, or properties of text [8]. Many typographic properties have been identified as factors that improve reading for various groups of people with low vision [9, 10], including:

1. Font size and face
2. Color foreground and background
3. Spacing between lines, words, and letters
4. Borders and spacing between and around blocks of text
5. Width of blocks of text and line length
6. Word-wrapping, hyphenation, and justification
7. Typographic differences used to distinguish between paragraphs, headings, lists, etc.

As noted earlier, these same text properties should also improve reading for users with normal vision, especially in constrained conditions [3–5].

One tool that is being developed that allows for customized typographic properties is a "Typometric Prescription" Style-Picker program, which is called the TRx for short [11]. The current version of the TRx allows users to adjust the font size, foreground/background colors, and the spacing between lines and between words/letters, and other features of webpages. The present study used this tool to evaluate whether the ability to customize text improves reading comprehension of online text by students under different visual conditions (dim vs. regular lighting; small vs. big screens). Two experiments were conducted that used a combination of TRx and Qualtrics, an online survey software, to present reading passages to participants and to record their responses. In Experiment 1, a mixed design was used where participants were provided with limited experience with reading text on big and small screens under customizable and non-customizable conditions. Half of the participants performed the reading tasks in a brightly lit room and half in a dimly lit room to examine whether the benefits of customization occur in standard viewing conditions or constrained conditions. Because participants were only provided limited experience with viewing customized text in Experiment 1, a complete between-subjects design was used in Experiment 2, where participants performed the reading tasks over a longer period of time in a dimly lit room using either a big or small screen. We hypothesized that the use of customized text would improve participants' reading performance and reduce their visual fatigue.

2 Experiment 1

2.1 Methods

Participants. One hundred and eleven participants were recruited from the Introductory Psychology Participant Pool at California State University Long Beach (CSULB). Participants were given experimental credits toward their course research requirement for their participation. Data from 15 participants (13.5%) were excluded due to low accuracy scores (under 60%) for the reading comprehension questions. The final data set consisted of 96 participants (70 female, 26 male; Mean Age = 18.6 years).

Participants self-identified as Hispanic/Latino (47%), White/Caucasian (12%), Asian/Asian-American (34%), Black/African American (6%) or Other (1%) as their racial/ethnic background on the demographic questionnaire.

All participants reported having normal or corrected-to-normal vision. Computer proficiency was obtained from a demographic questionnaire. Participants were asked to indicate the type(s) of device(s) they typically use to access and read online content (e.g., smartphone, tablet, laptop or desktop computer), and how many hours they spend per week on each indicated device. Most participants indicated the use of a phone/mobile device (83%) and/or laptop (85%) as their typical device for reading online content. However, some also reported using a tablet (50%) or desktop computer (17%) to perform online reading.

Of the participants who reported typical use of a phone/mobile device to read online content, 6% reported spending 5 h or less per week, 28% reported spending between 5 and 10 h per week, 24% reported spending between 10 and 15 h per week, and 42% reported spending 20 or more hours per week reading on the device. Of those who reported typical use of a laptop to read online content, 12% reported spending 5 h or less per week, 33% reported spending between 5 and 10 h per week, 40% reported spending between 10 and 15 h per week, and 15% reported spending 20 or more hours per week reading on the device.

Materials. This study was conducted on Dell desktop computers running Windows 7 as the operating system. The 24-in. (18.46 × 53.70° visual angle) LCD monitors had a 1920 × 1080-pixel resolution. For the small screen conditions, the functional screen size was scaled down to reflect viewing on a 7.5-in. display (8.58 × 17.76° visual angle) on a black background. For the big screen conditions, the full screen was used. The monitor was positioned perpendicular to the table, and the participant sat about 20 in. away from the screen.

The reading task consisted of four brief passages (M = 557 words) and two medical prescriptions (M = 204 words) obtained from online standardized practice tests for reading comprehension at the 6^{th} to 8^{th} grade level. Each reading passage was accompanied by five comprehension questions that were displayed on the same page so that participants could reference the passage when answering the questions. Visual fatigue was measured using a visual fatigue questionnaire used in previous studies [1, 4, 12]. The questionnaire asked participants to indicate their agreement to statements regarding visual fatigue symptoms on a scale that ranged from 1 (strongly disagree) to 5 (strongly agree).

Usability was assessed using the System Usability Scale (SUS) questionnaire [13]. The SUS is a 10-item questionnaire, where participants rate their agreement to statements designed to assess the usability of a system on a 5-point scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The post-experiment questionnaire consisted of questions designed to capture participants' preferences for customization in the different conditions using a 1 (prefer non-customization) to 7 (prefer customization) scale, as well as statements about customized text reducing visual fatigue in the different conditions using a 1 (strongly disagree) to 7 (strongly agree) scale.

Design. A 2 (Condition: customization or non-customization) × 2 (Screen Size: big or small) × 2 (Lighting Level: normal or dim) mixed design was implemented, with

Lighting Level being the only between-subjects factor. Participants were randomly assigned to a lighting level condition, which remained constant throughout the experiment. They were also randomly assigned to begin in either the customization or non-customization condition. Within each customization condition, participants were given two reading passages, one using the big screen and the other using the small screen. Afterwards, participants were given one of the prescription passages, performed using the big screen. The order for screen size within each condition was counter-balanced between subjects. In addition, the order of the four reading passages and two prescription passages was counterbalanced across the different experimental conditions.

Procedure. The procedures used in the present study were approved by the institutional review board (IRB) at CSULB. The experiment was conducted in a laboratory

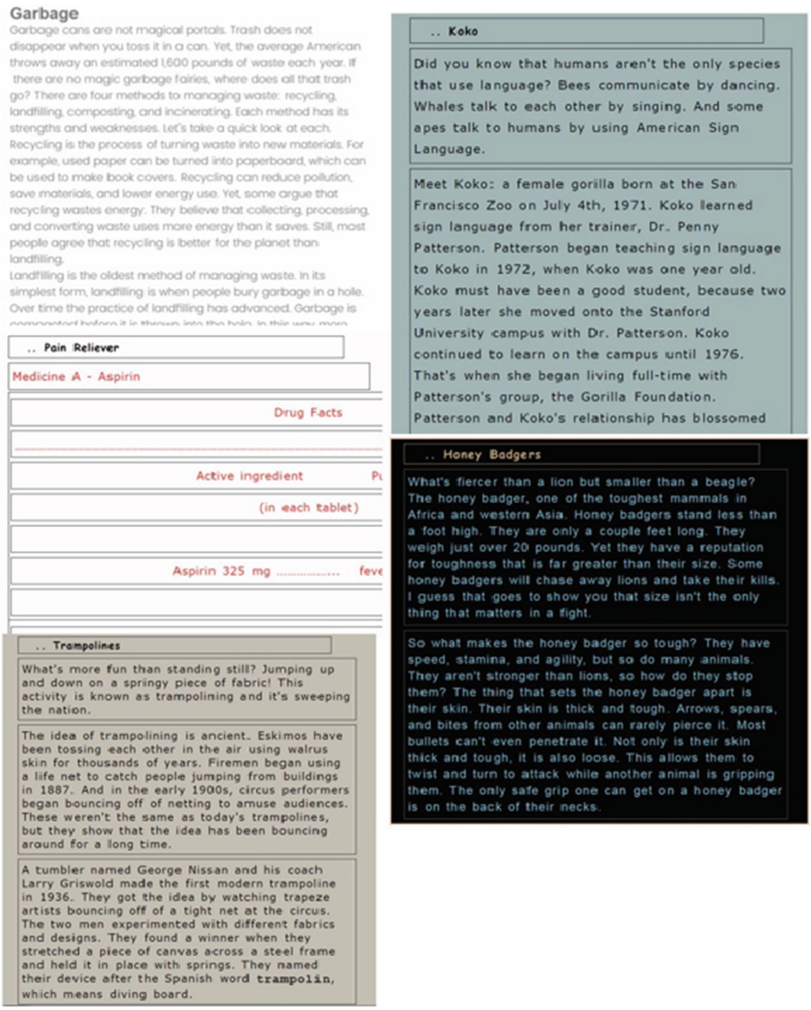

Fig. 1. Examples of customized text using TRx

environment, with each participant being tested individually. Half of the participants completed the experiment in a well-lit room and the other half completed it in a dimly-lit room. Participants began by reading and signing a consent form. Then, they were asked to complete a pre-questionnaire which consisted of demographic and computer preference and proficiency questions. Participants also filled out a pre-test visual fatigue questionnaire.

After completing the questionnaire, participants were seated approximately 20 in. from the computer screen and were presented with instructions for completing the reading tasks. In the customized condition, the experimenters assisted participants with setting their customized preferences. To do so, the experimenters used the TRx program to show the participants the different selections of font size and face, color foreground and background, as well as spacing between lines, words and letters. The selections were demonstrated one at a time, and participants made their selections for each typographic property after seeing the different options. Then, the experimenters showed the participants sample text generated by the TRx program to demonstrate the combined customized selections. Participants were given the opportunity to revise any of the customization selections at this point. Once participants were satisfied with their customization selections, the experimenters generated a stylesheet from the TRx program and inserted the settings into Qualtrics to customize the reading passages (see Fig. 1 for sample text).

For both the customized and non-customized conditions, participants were presented with two reading passages (one on the small screen and one on the big screen) and one prescription passage (big screen only). As mentioned earlier, a counterbalance scheme was employed to control for order effects. Once the participants completed the reading and prescription tasks for each customization condition, they were asked to fill out a visual fatigue questionnaire and a SUS. After completing both customization conditions, participants were given a post-experiment questionnaire. Finally, participants were debriefed at the conclusion of the experiment.

2.2 Results

Reading Tasks. The task completion time for each passage included the time participants spent reading the passage and answering the reading comprehension questions. Accuracy for each passage was calculated as the percentage of correct responses to the reading comprehension questions. The mean time and accuracy for the reading tasks were submitted to separate 2 (Condition: customization or non-customization) × 2 (Screen Size: big or small) × 2 (Lighting Level: normal or dim) repeated measures ANOVAs. Condition and Screen Size were within-subjects factors and Lighting Level was a between-subjects factor.

For task completion time, the main effects of Condition, $F(1,94) = 5.70$ $p = .019$, and Screen Size, $F(1,94) = 15.90$, $p < .001$, were significant. Participants took longer to complete the task in the customization condition ($M = 281$ s) than in the non-customization condition ($M = 267$ s), and with the small screen size ($M = 284$ s) compared to the large screen size ($M = 265$ s). No other effects were significant.

For accuracy, there were no significant effects or interactions. The overall accuracy was acceptable, averaging 82% (see Table 1 for means by condition).

Table 1. Reading accuracy (9% of correct responses) as a function of customization condition, screen size and lighting condition

Reading accuracy				
Condition	Screen size	Lighting	Mean	Standard deviation
Customized	Big	Dim	85.4%	20.9%
		Normal	83.3%	22.0%
	Small	Dim	85.0%	19.1%
		Normal	82.1%	18.1%
Not-customized	Big	Dim	81.3%	19.5%
		Normal	81.7%	22.5%
	Small	Dim	79.6%	21.6%
		Normal	80.4%	21.6%

Visual Fatigue. Visual fatigue was measured three times: at pre-test (baseline) and after the reading tasks in both the customized and non-customized conditions. These scores were submitted to a 3 (Condition: baseline, customized, non-customized) × 2 (Lighting Level: normal or dim) repeated measures ANOVA, with Lighting Level being the between-subjects factor. The main effects of Condition, $F(2,188) = 3.49$, $p = .03$, Lighting Level, $F(1,94) = 7.79$, $p = .006$, and the interaction between the two variables, $F(2,188) = 3.27$, $p = .04$, were significant.

Visual Fatigue scores were lowest at baseline ($M = 1.87$), intermediate after reading customized text ($M = 1.93$), and highest after reading non-customized text ($M = 2.03$), see Fig. 2. Bonferroni pairwise comparisons indicate that the difference between baseline and the non-customized text conditions was significant. Visual fatigue scores were also lower in the normal lighting condition ($M = 1.79$) than in the dim lighting condition ($M = 2.10$).

Tests of the simple effects were performed to investigate the interaction between Condition and Lighting Level. They showed little difference in visual fatigue across the three conditions in normal lighting, but visual fatigue scores differed for the three conditions in dim lighting, see Fig. 3. For dim lighting, visual fatigue scores were lowest at baseline ($M = 1.96$), intermediate after reading customized text ($M = 2.08$), and highest after reading non-customized text ($M = 2.27$). Bonferroni pairwise comparisons indicate that the difference between baseline and the non-customized text conditions was significant.

Subjective Usability Ratings. SUS scores were normalized to create a percentile ranking. Scores of 68 and above are considered above average, while scores of 68 or below less than average [14]. SUS scores were analyzed using a paired *t*-test (Condition: customization or non-customization). Both conditions resulted in above average SUS scores, being 73 in the customization and 75 in the non-customization condition. The difference between the two conditions was not significant.

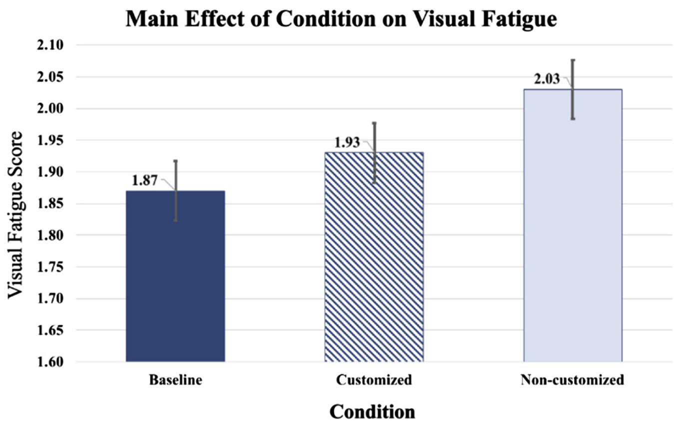

Fig. 2. Main effect of condition on visual fatigue scores. Visual fatigue scores were lowest at baseline, intermediate after reading customized text, and highest after reading non-customized text.

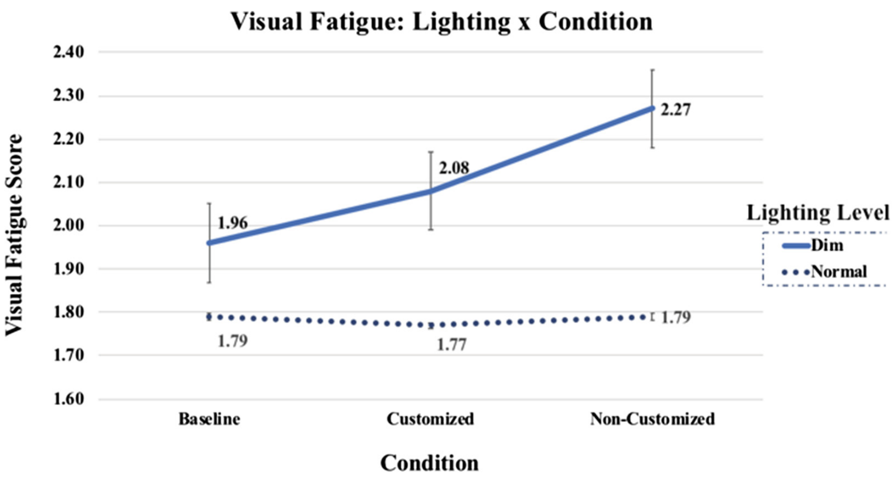

Fig. 3. Interaction between condition and lighting on visual fatigue scores. Visual fatigue scores were lowest at baseline, intermediate after reading customized text, and highest after reading non-customized text.

Post-questionnaire. Mean ratings for the questions on the post-experiment questionnaire are shown in Table 2. For the first three questions, one sample *t*-tests on the test value of 4, which indicated no preference, showed that participants preferred customization over non-customization for reading passages in both the small ($M = 4.59$), $p = .005$, and big ($M = 4.75$), $p < .001$, screen conditions. However, participants showed no preference for customization to perform the prescription task, which was only presented on the big screen.

For the three statements about whether customization decreased visual fatigue, one sample t-tests using the test value of 4, which indicated neither agree or disagree, showed that participants slightly agreed that using customization decreased their visual fatigue for the reading passages on both the small ($M = 4.64$), $p = .001$ and big ($M = 4.66$), $p < .001$, screens. However, participants neither agreed or disagreed with the statement for the prescription task, which was only presented on the big screen.

Table 2. Mean ratings given to the post experiment questionnaire

Question	Mean	Standard deviation
1 = using non-customized text, 4 = no preference, 7 = using customized text		
To perform the reading tasks using the Big screen, I preferred	4.59	2.02
To perform the reading tasks using the Small screen, I preferred	4.75	1.89
To perform the Prescription tasks, I preferred	3.63	2.05
1 = Strongly Disagree, 4 = Neither Agree or Disagree, 7 = Strongly Agree		
Using customized text decreased my visual fatigue when performing the reading tasks with the Big screen	4.64	1.84
Using customized text decreased my visual fatigue when performing the reading tasks with the Small screen	4.66	1.69
Using customized text decreased my visual fatigue when performing the Prescription tasks	3.95	1.69

2.3 Discussion

Experiment 1 showed that customization had little influence in terms of enhancing users' comprehension of the reading passages or the information in the prescription task. However, customization did help mitigate visual fatigue, especially with dim lighting, and despite the fact that participants spent a longer amount of time reading and answering questions in the customized condition. These findings indicate that there is some value in allowing users to customize text for online reading. Moreover, participants did not rate the customization condition to be lower in usability than the non-customization condition. This latter point is important because it indicates that use of customization features does not decrease the usability of a system.

The lack of strong effects of customization in the present experiment may be due to the fact that participants were only given limited experience with the customization condition (i.e., were only provided with two passages, one on a big screen and one on a small screen). Thus, Experiment 2 examined whether any performance benefits would appear for customized text if participants performed the reading task for a longer period of time.

3 Experiment 2

3.1 Methods

Participants. Sixty-six students were recruited from the same subject pool to participate in Experiment 2. Data from two participants (3%) were excluded and replaced due to low accuracy scores (under 60%) on the reading comprehension questions. The final data set consisted of 64 participants (32 female, 32 male; Mean Age = 19.5 years). These participants self-identified as Hispanic/Latino (32%), White/Caucasian (29%), Asian/Asian-American (27%), Black/African American (9%) or Other (3%) as their racial/ethnic background on the demographic questionnaire.

Similar to Experiment 1, most participants indicated that they typically use a phone/mobile device (83%), and/or laptop (71%), as opposed to a tablet (32%) or desktop computer (18%) to view online materials. Of the participants who reported typical use of a phone/mobile device to read online content, 7% reported spending 5 h or less per week, 25% reported spending between 5 and 10 h per week, 36% reported spending between 10 and 15 h per week, and 31% reported spending 20 or more hours per week reading on the device. Of those who reported typical use of a laptop to read online content, 19% reported spending 5 h or less per week, 35% reported spending between 5 and 10 h per week, 27% reported spending between 10 and 15 h per week, and 19% reported spending 20 or more hours per week reading on the device.

Materials, Design and Procedure. The materials used in Experiment 2 were the same as those used in Experiment 1, with the exception of the post-questionnaire. In addition, participants only performed the experiment in the dim lighting condition, and with a single screen size (half with the small screen and half with the big screen). Similar to Experiment 1, participants were presented with all four reading passages. Thus, they performed the reading task over a longer period of time in their assigned condition. The prescription passage was not used in the present experiment. Thus, this experiment used a 2 (Condition: customization or non-customization) $\times$ 2 (Screen Size: big or small) between-subjects design.

Participants were randomly assigned to one of the four conditions (i.e., the customization small screen, customization big screen, non-customization small screen, or non-customization big screen condition). As noted above, participants performed all four reading passages in their assigned condition. The order of the reading passages was counterbalanced across participants. Similar to Experiment 1, the visual fatigue questionnaire was administered before the test (baseline), after reading the first two passages, and after reading all four passages. The SUS was administered at the end of the session, prior to the post-experiment questionnaire.

3.2 Results

Reading Task. The mean time and mean accuracy on the four reading passages were calculated for each participant. Mean task completion time and accuracy scores were

submitted to separate 2 (Condition: customization or non-customization) x 2 (Screen Size: big or small) ANOVAs. All factors were between subjects.
For task completion time, no effects were significant.

For accuracy, there was a main effect of Condition, $F(1,60) = 6.98$, $p = .011$, where accuracy was higher in the customization condition ($M = 88.0\%$) than in the non-customization condition ($M = 80.9\%$), as seen in Fig. 4. No other effects were significant.

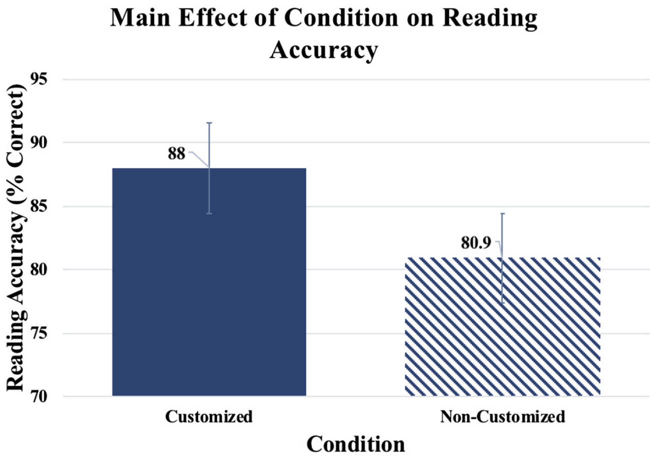

Fig. 4. Main effect of customization on reading accuracy. Accuracy was higher in the customization condition than the non-customization condition.

Visual Fatigue. Visual fatigue scores were submitted to a 2 (Condition: customization or non-customization) × 2 (Screen Size: big or small) × 3 (Time: baseline, after reading the first two passages, and after reading all four passages) ANOVA. Only the main effect of Time was significant, $F(2,120) = 4.62$, $p = .012$, as seen in Fig. 5. Visual fatigue scores were lowest at baseline ($M = 1.78$), intermediate after the first two reading passages ($M = 1.85$), and highest after reading the last two passages ($M = 1.97$). Bonferroni pairwise comparisons indicate that the difference between baseline and the last two passages was significant.

Subjective Usability Ratings. SUS scores were submitted to a 2 (Condition: customization or non-customization) × 2 (Screen Size: big or small) ANOVA. The main effects of Condition, $F(1,60) = 4.71$, $p = .034$, and Screen Size, $F(1,60) = 6.93$, $p = .011$, were significant. Participants rated the non-customized condition as higher in usability than the customized condition ($M = 78.2$ vs 70.9, respectively) and the condition with larger screen size as higher in usability compared to smaller screen size ($M = 79.1$ vs 70.2, respectively). The interaction of Condition × Screen Size was not significant.

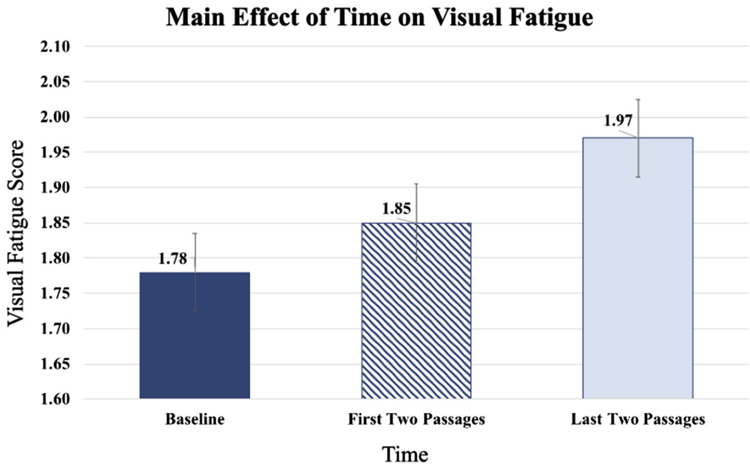

Fig. 5. Main effect of time on visual fatigue scores. Visual fatigue scores were lowest at baseline, intermediate after reading customized text, and highest after reading non-customized text.

Post-questionnaire. Because Experiment 2 used a complete between-subjects design, half of the participants did not perform the reading task using the customization features. Thus, two versions of the post-questionnaire were used, one for the participants in the customization condition and one in the non-customization condition. For the customization group, participants were asked whether they agreed with statements about using customized text to decrease visual fatigue and wanting to have the option of using customized text on a 1 (strongly disagree) to 7 (strongly agree) scale.

For the non-customization group, participants were shown the customization features at the end of the session and asked, "Now that you have seen what the customization program can do, please rate your agreement with the following statements." The statements that followed were similar to the statements shown to the participants in the customization condition. A mean perceived value of customization score was computed based on the ratings given to the 5 statements, and this mean rating was submitted to a 2 (Condition: customization or non-customization) $\times$ 2 (Screen Size: big or small) ANOVA. There were no significant effects or interactions. The average rating was 5.4, and this value was significantly different from a test value of 5 using a one-sample t-test, $p < .05$. Thus, participants agreed that the customization features were valuable through either direct experience or after demonstration of the customization features.

3.3 Discussion

Experiment 2 used only the dim lighting condition to examine the effects of reading customized text over a longer period of time. In this experiment, use of customized text did result in higher accuracy on the reading comprehension questions. However, unlike in Experiment 1, there was no evidence of customization leading to lower levels of visual fatigue. Although usability scores showed that the customization condition was in the usable range, participants rated the customization condition to be lower in usability than the non-customization condition. However, in the post-questionnaire, users agreed with statements that indicated that customized text reduces visual fatigue, and users wanted the option to customize text.

4 Conclusion

Taken together, the results of Experiment 1 and Experiment 2 show that use of customized text could be beneficial to users performing online reading tasks, even if those users do not have visual impairments. Use of customized text can also help mitigate the effects of visual fatigue under some conditions. Given that the participants in this study were young adults, the results are promising in terms of promoting the capability of providing users, especially those with visual impairments, the ability to customize text.

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