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Character size and reading to remember from small displays

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ABSTRACT

An under-addressed question regarding the usage of small devices is how information gathering from such devices is limited or changed relative to a full-size display? This study explores how factual recall from a text interacts with display size and other text characteristics. In this experiment, participants read several expository texts on either small or normal size displays, and font size was also manipulated within participants. Results indicate that while users are able to accurately diagnose different character sizes, character size does significantly interact with display size to affect remembering. Those character sizes that increased the amount of scrolling on the small device screen produced lower levels of factual recall than typesets that better condensed textual information. These results provide several interesting suggestions for the future design of small devices and mobile interfaces to protect learning.

1. Introduction

Advances in the power and availability of mobile technology, coupled with the 'on-the-go' lifestyle of many individuals, have made small screen devices nearly ubiquitous in everyday life. Professionals and non-professionals alike often carry at least one small device that is used regularly for many daily activities. For example, professionals regularly rely on mobile handheld devices (e.g., personal digital assistants (PDAs) or smartphones) to check emails, gather data, and make critical decisions while away from the home office. Non-professional uses include navigation, social networking, web surfing, and entertainment, again with the goal of collecting information and using this information in task relevant and appropriate ways. These small devices are also slowly filtering into the educational setting, and are often advocated as useful tools for collaboration and the sharing of data (Motiwalla, 2007; Reimers & Stewart, 2009; Roschelle, 2003), a process sometimes referred to as *m-learning* (Quinn, 2001)

Use of small devices is increasing rapidly, especially in the business sector, as J. Gold Associates predicts that smartphone use will increase by 200% over the 3-year period from 2008 to 2011 (Hamblen, 2008). The increase of smartphone usage across all other demographics is also rapidly increasing as annual sales of smartphones already exceed 40,000,000 units worldwide (Gartner, 2009).

However, while mobile devices enable convenient access to large amounts of information and data, literally at one's fingertips, an important question is whether information gathering from such small screens results in a cognitive trade-off in subsequent performance? These concerns are echoed by educators who have integrated small screen devices into the learning setting and remain unconvinced of their educational utility (Ng & Nicholas, 2009). Quite simply, are we sacrificing learning and understanding for this enhanced personal flexibility, and is this tradeoff acceptable?

1.1. Text on small devices

Emails, messaging, and online information gathering are all examples of the most common uses of this small screen technology (Cui & Roto, 2008). Importantly, these common uses are all text-centric, and as such, users who engage in this activity often must read large amounts of text on their small devices. However, one obvious tradeoff that occurs when reading textual information on small devices is the reduced character size utilized on these displays, which is often a direct function of the similarly reduced size of the screen (Churchill & Hedberg, 2008). Unfortunately, even with this reduction in character size, text often overflows onto multiple screens and requires a judicious amount of scrolling to read even a simple webpage or email (e.g., 'web clipping'; Albers & Kim, 2002).

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Scrolling has been shown previously to negatively impact performance on full-size displays. For example, studies by Piolat, Roussey, and Thunin (1997) and Sanchez and Wiley (2009) have found that reading text from scrolling displays does reduce comprehension of the material, likely because of the added difficulty in locating information within scrolling text. Similarly, locating information on spatial displays was likewise decreased in scrolling situations (Morrison & Duncan, 1988). Do these findings also hold true for small devices? If this is the case, given that the physical dimensions of the device itself are limited by portability and convenience factors, the only alternative would be to advocate the use of smaller and smaller character sizes to minimize the scrolling effect as much as possible. However, directly related to this suggestion, how small is too small? While text can be minimized to almost severe degrees on small devices, can a too small character size itself also negatively impact comprehension?

While current consumer technology permits the adaptive resizing of text via multi-touch gesturing, or even changing the orientation of the display (e.g., landscape viewing), these options still struggle against the limitations of the display size, and in fact might place more demand on the user to constantly resize and adapt their reading behavior to the specific device. Further, even information sources that are designed to better portray information on mobile devices (e.g., mobile webpages) still often cannot portray all information on a single screen despite the explicit redesign of layout/material. While automated text compression or summarization (Luhn, 1958) provides another option to limit the amount of information presented, however, this methodology has not been fully embraced yet in the consumer market and is not without its own challenges (Hahn & Mani, 2000). Thus it remains important to evaluate the potential interaction between display and text size, and specifically how they interact to portray textual information and affect information gathering.

Prior research has shown that while users generally prefer larger over smaller character sizes (Bernard, Chaparro, Mills, & Halcomb, 2002; Chen & Chien, 2005), the impact of smaller characters on learning is mixed. While some suggest a potential detriment as a result of reading smaller character sizes on large displays (Chan & Lee, 2005; Hasegawa, Matsunuma, Omori, & Miyao, 2006; Omori, Watanabe, Takai, Takada, & Miyao, 2002), there are also several examples which find no difference in learning from smaller characters (Bernard et al., 2002; Chen & Chien, 2005). However, if it is assumed that small character size does negatively impact learning, or at least how easy it is to interact with a given interface, is there a way to attenuate these detrimental effects of small character size?

There is some suggestion that text can be made easier to read by manipulating the amount of spacing within a text (Chan & Lee, 2005). A major consequence of using small character sizes is that at these small sizes, it becomes more difficult to identify the characters that make up a word given that the distinguishing features of the letters, numbers, etc. are also so much smaller at this reduced scale. This could lead to a 'perceptual jumbling' of characters at small sizes. This jumbling might increase the processing load for users, which in turn decreases the amount of resources a reader could devote towards retaining important information. Increasing the spacing between characters could facilitate the differentiation between characters when the character size is small, thus freeing cognitive resources to comprehend the material. This intuition has been corroborated with some previous research. For example, Bernard et al. (2002) found that for smaller character sizes, users preferred fonts that contained larger inter-character distance within the typesetting. This is also similar to the results of Chan and Lee (2005) who found that both inter-character spacing and inter-line spacing also enhanced readability of online texts.

As such, it appears that one must toe a fine line between the recommendations to reduce scrolling through character size, while also ensuring that the text itself remains readable at such small levels. The current study investigates this potential interaction between character size and learning from a small device in the hopes of better understanding how interfaces might influence remembering information from small devices.

In this study, participants read several expository texts that were presented in both small and normal character sizes. In an effort to mitigate the effects of small character size, inter-character spacing was implemented at the smallest of the font sizes. Participants read these texts on either a normal desktop display or instead on a virtual small screen device. Based on previous results, it was expected that small displays, which require more scrolling and interaction with the text, would produce lower factual recall, especially in those cases where more scrolling is required (e.g., larger font sizes and more inter-character spacing). As scrolling would not normally be required in a desktop display, the inclusion of this full-size condition allows for a discrete comparison of the scrolling and character size dimensions. If character size alone reduces comprehension, the pattern of results across display conditions should be similar. However, if the need to scroll is the more important influence on remembering, then the pattern across display conditions should differ significantly.

The results of this study are important not only for consumers of this technology, but also for the developers of this hardware and software who are interested in designing interfaces which become transparent to the learner, rather than a barrier which must be overcome. These findings are also likely of great importance for educators and administrators who seek to incorporate these cheap, popular devices into the learning sector. As with other business or enterprise uses, the goal in these educational settings is to maximize and protect information gathering conducted with this technology.

2. Materials and methods

2.1. Participants

Thirty-nine ($N = 39$) undergraduates ($M(\text{age}) = 19.32$ years, SD = 1.63) from a large public university in the southwestern United States voluntarily participated for credit in an Introductory Psychology course. Overall, 17 males (44%) and 22 females (56%) participated in this experiment. All participants were native English speakers.

2.2. Design

This experiment employs a mixed design. Character size was a within subjects variable while display size was compared between groups. There were 21 participants in the full display group, and 18 in the small-display condition. Gender ratios for each display group were nearly identical to the overall distribution (43% male in the full-size condition, and 44% male in the small-display)

2.3. Materials

2.3.1. Displays

Participants read on either a normal 19" desktop display, or a virtual small screen device. The small screen display was sized at 208 × 276 pixels at 96 ppi, analogous in size to most popular small consumer electronics, and was emulated on the desktop display as a de-branded consumer device (Fig. 1). An emulated small screen device was utilized to ensure that not only was text information rendered consistently (as it was done on the same platform), but also in an effort to minimize the impact of other extraneous factors that might influence interactions with actual small devices (e.g., angle of viewing, stylus or other unfamiliar hardware requirements for navigation, etc.). In other words, this emulated display permitted us to keep all extraneous variables constant and better isolate the effects of reading on the small display alone. Further, emulated displays have been used previously with much success in other investigations involving small devices (Arning & Ziefle, 2007; Motiwalla, 2007).

Participants were run in small groups, ranging from 2 to 5 individuals in a quiet research lab which contained only computers and desks. Participants were seated at individual computers and allowed to adjust their seating position for comfort as needed/desired.

2.3.2. Texts

Participants read 3 separate expository texts about the foreign countries of Brunei, Chad and Guinea. The texts were adapted from material taken from Encarta Online Encyclopedia (Microsoft, 2008). Each text discussed the geographical location, topographical layout, climate, wildlife, economic stability, ethnic make-up, observed religion, transportation, and government for each country. All 3 texts were similar in length ($M = 528$ words, SD = 7), and organizational structure. All texts were presented in Courier New font, as all characters are uniform in width for this typeset. Texts were presented in 8-point font, 8-point font with 2 character spaces, and 12-point font (see Fig. 2 for an example). These sizes translate to 13, 10, and 9 characters per inch wide, respectively.

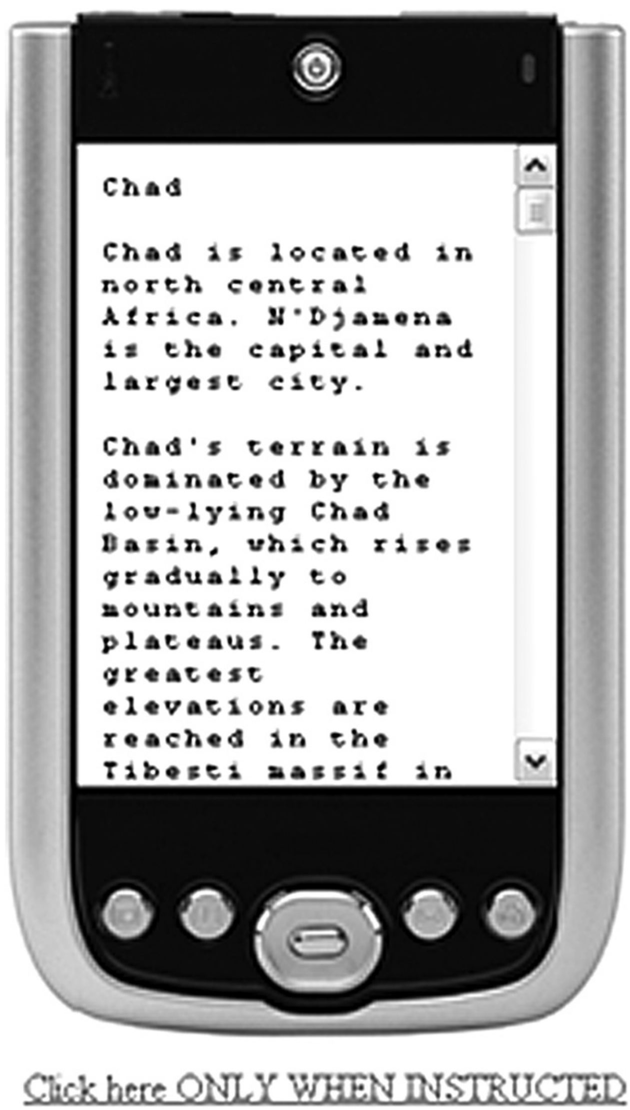

Fig. 1. Emulated small display device.

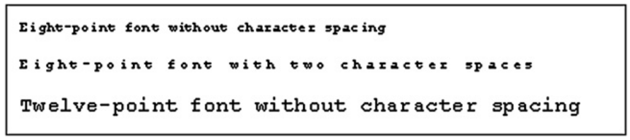

Fig. 2. Example text for character size manipulation. **Note: For illustration purposes only, may not be to exact scale based on figure resizing, and any difference should be considered relative to other text in the figure only.

As a result of these differences in font size, for the small displays (on average, based on word count), 10% of the text was visible on the first screen without having to scroll in the 8 pt. condition, while 8% was visible in the 8 pt. with spacing, and only 5% of the text was visible on the initial screen in the 12 pt. condition. None of the text sizes scrolled when presented in the full-size display.

2.3.3. Prior knowledge and demographics

To evaluate participants' prior knowledge of the material used in this experiment, participants were asked to rate their knowledge of each country on a scale from 1 to 5 (1-'I have never heard of this country', 2-'I have heard of it, but know nothing about it', 3-'I know some information about this country', 4-'I know quite a bit about this country', 5-'I know this country very well'). Participants were also queried on their gender and age in years.

2.3.4. Working memory capacity

Working memory capacity represents a stable cognitive ability that has previously demonstrated high correlations with measures of reading comprehension (Daneman & Carpenter, 1980), science learning (Geiger & Litwiller, 2005; Sanchez & Wiley, 2006), attentional control (Conway & Engle, 1994), and also measures of fluid intelligence (Unsworth & Engle, 2005). Thus, in order to control for any potential differences in general cognitive ability in this experiment (Conway, Kane, & Engle, 2003), participants completed an assessment of working memory capacity (WMC). All participants completed Automated Operation Span (OSpan) which requires participants to verify simple mathematical operations while also trying to remember unrelated words (Unsworth, Heitz, Schrock, & Engle, 2005). OSpan represents a complex span task, where participants engage in the simultaneous processing and storage of information, which is fundamentally different from simple span tasks (e.g., list-learning) that only require storage of information.

In OSpan, operation–word strings (e.g., IS (8/2)-1 = 1? BEAR) were presented in sets comprised of two to seven individual strings. Three trials of each set size were presented, and set sizes were presented in a random order. In this task, participants are required to evaluate the correctness of the math equation (e.g., 'Yes' or 'No'), and then say the following word aloud and remember this word for a later test. Responses are considered correct only if the word is recalled correctly, in the correct serial position. In order to ensure that participants were attending to the processing task, an 85% accuracy criterion on the math operations was required. Administration and scoring followed the recommendations in Conway et al. (2005).

2.3.5. Character size perception task (CSPT)

This measure was designed to evaluate and compare the relative perception of different character sizes and better quantify any perceived differences in character size. In the CSPT, participants were shown a series of words, one at a time, on a computer screen for a duration of 1 s each. All words were of equal length and presented in Courier New font. Four character sizes (8 pt., 8 pt. with 2 character spaces, 10 pt., and 12 pt.) were displayed in random order three times each, for a total of 12 overall trials. After each trial was presented, participants were asked to rate the relative size of the character on a continuous scale. The scale consisted of a 130 mm long line, with a single anchor on each end ('very small' and 'very large'), and no other anchors in-between. Participants were instructed to mark a position on the line which corresponded to their judgment of the character size. Participants were allowed to mark anywhere on the scale, and given as much time as they desired to make the size judgment. After completing the size judgment, they were then shown another word and asked to provide another size judgment. This process repeated until participants had provided ratings for all 12 trials. Perceived size was calculated by measuring the distance in millimeters from the beginning of the scale (e.g., very small) to the mark made by the participant and averaging this distance across the 3 trials for each character size.

2.3.6. Text recall

To evaluate how well the text was remembered, participants completed a short recall test for each text. Participants' retention of each text was measured using 10 short answer questions for each passage. Participants were given 3 min to answer as many of the 10 questions as possible correctly. Participants were awarded 1 point for each question answered correctly, and no penalty was assigned for incorrect or no responses.

2.4. Procedure

After obtaining informed consent, participants first completed the CSPT. After completing the CSPT, participants then began the reading portion of the study. Participants first completed the demographic questionnaire, and then were asked to read the first text (content counterbalanced) for 3 min. After reading the text, participants completed a filler task for a duration of 1 min. The filler task consisted of solving a series of 8 simple math problems (e.g., $7 + 7 - 4$) in order to prevent participants from rehearsing what they had just read. After the 1 min had expired, participants were then given 3 min to answer ten short answer questions pertaining to the text. This procedure was then repeated for the two remaining texts. After completing the questions for the third text, participants then completed the OSpan task. Participants were then debriefed and dismissed. The entire experiment took no longer than 1 h.

Table 1
Prior knowledge of content areas and WMC by display group.

	WMC	Brunei	Chad	Guinea
Small-display	57.88 (8.99)	1.39 (.70)	2.17 (.86)	2.06 (.80)
Full-size	58.90 (11.47)	1.24 (.54)	1.86 (.57)	1.95 (.50)

M(sd).

3. Results

3.1. Prior knowledge and WMC across display groups

Participants in the full size and small screen conditions rated their knowledge of the 3 foreign countries used here as very low (Table 1). Importantly, there were no significant differences in prior knowledge ratings between the display conditions for any of the countries ($ts(37)<1.34$, $p > .05$). Similarly, there was no difference between the display groups in WMC ($t(37)<1$, $p > .05$).

Thus, these findings suggest that the display groups were well matched on not only their prior knowledge of the material, but also general cognitive ability.

3.2. CSPT

Participants' judgment of character size did significantly vary across different presented character sizes ($F(3, 114) = 62.86$, MSE = 52.86, $p < .01$, $\eta^2_p = .62$). Post-hoc tests using Fisher's LSD procedure indicate that there was no perceived difference ($p > .05$) in character size between the 8 pt. ($M = 15.59$, SD = 12.28) and 8 pt. with inter-character spacing ($M = 15.22$, SD = 11.05), however both 8 pt. sizes were perceived as significantly smaller ($ps<.01$) than the 10 pt. ($M = 28.51$, SD = 10.93) and 12 pt. character sizes ($M = 33.49$, SD = 13.17). Finally, the 10 pt. character size was also perceived as significantly smaller ($p < .01$) than the 12 pt. size.

These CSPT results suggests that participants were able to accurately recognize character size ranging from smaller or larger, but also suggests that for the smallest character size here, while there was only a relatively small decrease in actual size, the magnitude of the perceived difference (relative to 12 pt. size) was highly exaggerated (Fig. 3).

3.3. Text recall

Results indicate that both display type and character size did impact how well the material was remembered. The full-size display ($M = 4.22$, SD = 1.45) produced significantly better overall factual recall than the small-screen display ($M = 3.51$, SD = 1.27; $F(1, 37) = 4.26$, MSE = 3.50, $p < .05$, $\eta^2_p = .10$). Character size also did significantly impact recall ($F(2, 74) = 8.92$, MSE = 1.10, $p < .01$, $\eta^2_p = .19$). Fisher's LSD procedure indicated that the 8 pt. character size ($M = 4.39$, SD = 1.44) was remembered significantly better than both the 8 pt. with inter-character spacing ($M = 3.84$, SD = 1.47) and the 12 pt. character size ($M = 3.44$, SD = 1.39). There was no reliable difference between the 8 pt. with spacing and the 12 pt. sizes.

Finally, there was also a significant interaction between character size and display type ($F(2, 74) = 3.67$, MSE = 1.10, $p < .05$, $\eta^2_p = .09$; Fig. 4). While there was no significant difference between the display conditions for the 8 pt. ($t(37)<1$) and 8 pt. with spacing ($t(37) = 1.56$, $p > .05$), the 12 pt. size produced a significant recall deficit for the small screen device relative to a normal display ($t(37) = 3.44$, $p < .01$).

4. Discussion

The results of this study suggest some interesting patterns relative to remembering from small screen devices. To begin, CSPT results suggest that users are quite capable of diagnosing differences in character size, and can do so reliably. Participants were able to identify even

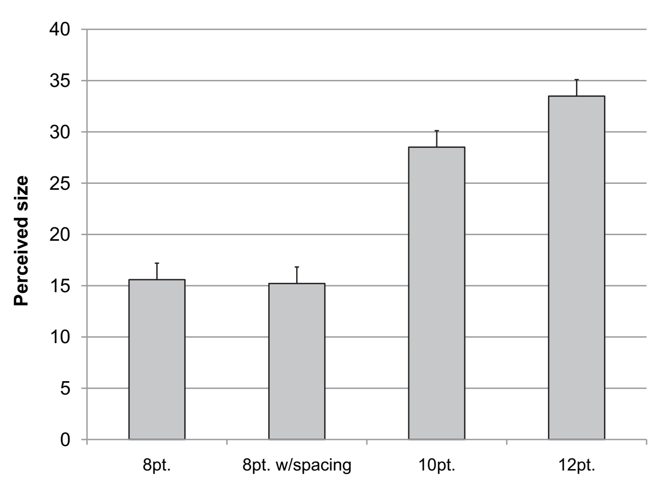

Fig. 3. CSPT results for different character sizes. Error bars represent the standard error of the mean.

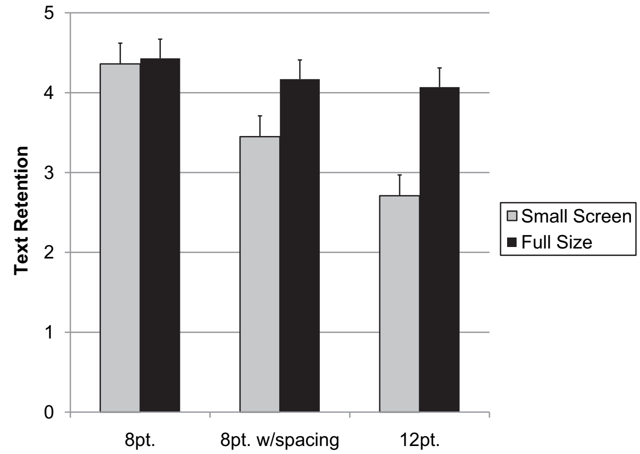

Fig. 4. Text retention by display size and character manipulation. Error bars represent the standard error of the mean.

2 pt. differences in font size, and their estimations of size were consistent in directionality (e.g., larger sizes were always estimated as larger). However, an additional interesting finding is that as character size continues to shrink, the magnitude of the perceived difference in font size judgments appears to inflate disproportionately. For example, while there was a reliable difference between the 12 pt. and 10 pt. character sizes, the same relative difference between the 10 pt. and 8 pt. sizes was estimated at nearly 3x the size. This suggests that users do not have a simple linear representation of character size when using technology, and instead there appear to be clear boundaries where fonts become much smaller (or larger) than their predecessors.

Further, character size also seems to interact with display characteristics during reading. While it appears that reading from small devices reduces factual recall overall, upon closer inspection, this effect is indeed driven by the interaction between screen size and the characters used to portray the text. Similarly, while font size also did seem to impact remembering overall, this main effect too was driven by the interaction with display size. Compared to a full-size display, reading normal size fonts (e.g., 12 pt.) or smaller fonts with character spacing on small devices produces lower levels of recall, however the smallest size used here did not reduce the amount of information remembered from the small display. Further, for full-size displays, factual recall did not vary across the different character sizes. Taken together, this pattern of results suggests that screen size or character size alone are not driving the learning differences here. Instead, this suggests that the interaction of the two, which ultimately impact the available horizontal space on a display, is truly the bottleneck for information recall. As users were forced to engage in more scrolling to read the text, unfortunately their ability to remember information from the text also subsequently decreased. The negative impact of scrolling was evidenced even when character size was kept consistent, and more scrolling was required due to the insertion of inter-character spacing. However, when scrolling was kept to a minimum on the small display (e.g., 8 pt.), factual recall was equivalent to that of the full-size display.

5. Conclusion

This study has found that on small displays, text size can indeed impact how well information is remembered. Specifically, text sizes which increase the need to scroll on small devices negatively impact how well the information is recalled. These results are consistent with previous findings which have suggested that the need to scroll does negatively impact learning (Morrison & Duncan, 1988; Piolat et al., 1997; Sanchez & Wiley, 2009). The results of this study also corroborate previous findings that did not demonstrate a difference in performance simply due to character size (Bernard et al., 2002; Chen & Chien, 2005), and in fact suggest that for small devices the opposite is indeed true.

These findings are important not only for consumers who utilize these small devices for critical daily or business functions, but also for those designers who are constantly refining or improving the software/hardware of these technologies, and would like to increase the ultimate usability of their products. These results suggest that once again; *how* technology delivers information (text in this case) can unfortunately impact end-users' interaction and successful use of said technology. On a practical note, this suggests that users should modify the displayed text size of their devices to minimize scrolling whenever possible. A perhaps less-attractive alternative would be to suggest that users might instead want to only read long segments of text on large displays. Unfortunately, this severely undercuts the utility of the small device, as the portable access to information is intrinsically tied to its worth as a viable technology. For designers, these results suggest that incorporating the option to adjust text size, either through adaptive zooming or navigation behaviors, or perhaps even hardware options, would provide users an option to tailor their devices as necessary to protect remembering of the information they are reading.

Future directions should continue to explore the character size boundary for small devices. For example, is there indeed a point when font becomes so small that it is almost unreadable? While 8 pt. character sizing was used here, hi-resolution displays can accurately portray even smaller fonts without loss of detail or 'jumbling'. It is of interest whether this boundary can be assessed reliably, as it would provide some closure to the discussion on whether character size alone does impact learning. Finally, future research should also explore other potential means of reducing scrolling or the need to scroll, utilizing novel presentation or navigation techniques which may alleviate this scrolling deficit. Until it is possible to provide large amounts of information on small mobile screens in a manner that preserves successful information gathering, we will continue to struggle to match the conveniences of portability to the tradeoffs of understanding.

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