

An Adaptive User Interface for Walking While Reading on a Mobile Device

by

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Abstract

Smartphones are constantly being used in different use scenarios and contexts. This Thesis puts forth the notion that Adaptive User Interfaces (AUIs) can be implemented in mobile devices to help mitigate the negative usability effects associated with certain contexts. Using an auto-scroll and an auto-scroll + zoom function, two different AUIs were implemented to see if it is possible to mitigate the negative effects associated with reading while walking. Participants using these two interfaces, along with a static interface, were tested on reading comprehension tests while either sitting or walking a course with pedestrian traffic. The results indicate that the walking context had an adverse effect on reading comprehension. Participants most preferred an AUI interface while walking, with the auto-scroll AUI resulting in faster walking, faster course completion, and faster reading. It is concluded that AUIs can be used to alleviate some negative effects associated with concurrent reading and walking.

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1. Introduction

1.1 Overview and motivation

Smartphones have become an indispensable part of everyday life. Users around the world are constantly connected to vast networks of people, endless entertainment, and virtually an unlimited amount of information, all at a tap on the screen of a small device. People now have their smartphones with them nearly all the time. Ninety-one percent of people state that they never leave their homes without their mobile device (Deutsche Telekom, 2012). With smartphones in hand, users watch videos as they eat, read the news on their way to work, check the weather when they wake up, trade stocks in traffic, chat with their friends between appointments, browse potential romantic partners while in line for a cup of coffee, and play mobile phone games as they wait for their home console video games to load. The average mobile user spends 145 minutes per day on their device, while heavy users average 225 minutes per day (dscout, 2016). The different kinds of use scenarios are endless.

Despite the various use scenarios a person might find themselves in, most mobile applications are still designed with the belief that users will be sitting and fully attending to the device. One use scenario that is particularly common is the use of mobile devices while walking. The recent Pokemon Go craze speaks to how walking while using a mobile device has become an everyday activity. While ample research has shown detrimental effects associated with mobile use while driving (e.g., Caird, Johnston, Willness, Asbridge, & Steel 2014; He et al., 2014; Hosking, Young, & Regan, 2009), a lot fewer studies have looked at mobile use while walking. However, walking while using a mobile device can be dangerous too as users can easily become too distracted by

the device, and injure themselves and/or others while using the device. Indeed, in the USA, injuries related to mobile use while walking have increased six-fold from 2005 to 2010, with more than 1500 pedestrian injuries being reported in emergency rooms in 2010 (Nasar & Troyer, 2013), a number that has undoubtedly increased in proportion with the increase of mobile device users since then.

The number of injuries associated with walking and mobile use can likely be attributed to a reduction in situational awareness and distracted attention, both of which are commonly associated with mobile device use while walking (Hatfield & Murphy, 2007; Hyman, Boss, Wise, McKenzie, & Caggiano, 2010; Nasar, Hecht, & Wener, 2008; Neider, McCarley, Crowell, Kaczmariski, & Kramer, 2010; Pesic, Antic, Glavic, & Milenkovic, 2016; Schwebel et al., 2012; Stavrinos, Byington, & Schwebel, 2011). According to cognitive resource theory, every individual has a limited pool of cognitive resources that they allocate to certain tasks. Individuals are constantly surrounded by potentially useful information, but their ability to use that information is constrained by the ability to attend to and process a small amount of that information at any given time (e.g., Kahneman, 1975; Norman & Bobrow, 1975). Working Memory is one cognitive system that supports complex cognition by actively selecting, maintaining and processing information relevant to the current task through attentional mechanisms. Working Memory capacity refers to the total amount of attentional resources any one individual has (e.g., Baddeley & Hitch, 1974; Baddeley, 2000; Engle, 2002). As an individual is walking while using a mobile device, their Working Memory is strained by both the task of walking and the task being performed on the mobile device. The task on the device itself can utilize the bulk of a person's Working Memory resources, leaving less available

for walking. While walking, their attention is divided between maintaining awareness of their surroundings, avoiding obstacles, and navigating a path, all while using the device when in motion. Insofar as Working Memory is constrained by both the walking and the mobile task, performance on both activities is likely to drop in comparison to being done individually. In this situation, the context of walking has a direct effect on the usability of that device. Indeed, simply walking while using a mobile device has been shown to both interfere with working memory and affect gait patterns (Lamberg & Mutatori, 2012; Licence, Smith, McGuigan, & Earnest, 2015).

One potential way to help improve the usability of devices is to have them be aware of the context in which they are being used. Such devices are called context-aware devices, and use various sensors to assess the context in which the user finds themselves in and react based on that knowledge. A common example of this is when a smartphone is rotated from portrait to landscape, the interface rotates as well. The phone has understood that the context that the user is using the phone has changed, and thus reacts appropriately to the user's needs. Interfaces that change according to the user's needs are called Adaptive User Interfaces (AUIs), and have been shown to positively affect users experience (Findlater & McGrenere, 2008; Gajos & Weld, 2008). When considering the context of walking, an AUI may improve usability and reduce the chances of hazardous use. In particular, an AUI can be designed to take into consideration that a user may not be fully attending to the device, and appropriately adapt to the situation to help the user. In the context of the walking, an AUI may adapt to a user in a way to help lessen the amount of cognitive resources a task uses up and thereby free up more resources to be used for the physical act of walking. In theory, this could improve walking performance

and make it safer to use the mobile device on the move. There have been a few studies exploring this possibility (Chen & Lin, 2016; Kane, Wobbrock, & Smith, 2008; Schildbach & Rukzio, 2010). The present research thesis attempts to add to this literature by considering the implementation of an AUI to help facilitate reading comprehension and successful navigation while walking and using a mobile device.

1.2 Contribution

A common problem in the design of mobile apps is the lack of consideration towards the different contexts in which the mobile app will be used. One everyday use scenario is in the context of walking. Literature has shown that walking while using a mobile device is both dangerous and has a detrimental effect on walking and the task at hand (Barnard, Yi, Jacko, & Sears, 2007; Bergstrom-Lehtovirta, Oulasvirta, & Brewster, 2011; MacKay, Dearman, Inkpen, & Watters, 2005; Mustonen, Olkkonen, & Hakkinen, 2004; Schildbach & Rukzio, 2010). One potential method to help mitigate this danger and detriment is through the implementation of an AUI. The aim of this thesis is to see if it is possible to use an AUI to improve both the task of reading on a mobile device and the task of walking in ways that a non-AUI cannot. It is believed that an AUI for reading while walking can lessen the cognitive load associated with the reading task, and thus help facilitate better performance on both reading and walking. Potential performance benefits include improvements in reading comprehension, reading speed, walking speed, and navigational abilities. Showing such improvements would demonstrate the potential of benefits of AUIs as a method to counteract any negative effects associated with different mobile use contexts.

The impact of three different interfaces on concurrent reading and walking performance was assessed. The three different interfaces include two adaptive interfaces and one static interface. The first adaptive interface incorporated an auto-scrolling feature, which scrolls at a custom speed according to the user that uses it. The second adaptive interface included an additional zoom feature that increases the size of the text, along with same auto-scroll feature as the other adaptive interface. Lastly, the static interface is a typical manual scroll interface as a point of comparison. Performance on all three interfaces was evaluated in both the context of walking and sitting. Participants completed a Graduate Record Examination (GRE) reading comprehension test while either sitting or walking a course with pedestrian traffic. The time in which the participants finished the navigating the course, how long it took to read the text, their scores on the GRE test, the pace at which they walked, and their preferences for the interfaces in the different contexts served as the variables of comparison in this study.

2. Related Works

2.1 Walking While Using a Mobile Device

There are a number of detrimental effects associated with walking and mobile use. An observational survey involving 546 individuals (270 females) compared crossing behaviours of pedestrians using a mobile phone with those who were not (Hatfield & Murphy, 2007). The results indicated that pedestrians who were using their phones were more likely to cross the street slowly, less likely to check for traffic before beginning to cross, less likely to wait for traffic to stop, and less likely to look at traffic while crossing compared to those who did not use their phones. These results have been corroborated by

a more recent observational study, which looked at number of predictor variables including gender, age, number of accompanying pedestrians, the manner of mobile phone use, and the location of the intersection in a logistic regression model to determine unsafe types of behaviour (Pesic et al., 2016). Their results also indicate that those who use a mobile phone while crossing behave less safely than their counterparts who do not use mobile phones while crossing.

The degree to which mobile phone use can be distracting to pedestrians can have a shocking effect on their attentional capabilities. In two different observational studies, Hyman and colleagues (2010) demonstrated that mobile phone use while walking can lead to inattention blindness. Inattention blindness is when individuals fail to notice things for attentional reasons, such as a decrease in cognitive resources due to mobile phone use, as opposed to perceptual reasons such as vision defects or deficits. In the first study, the authors observed 317 pedestrians at a busy crossing. The results of this study indicated that those who used a mobile phone walked more slowly, changed directions more frequently, and were less likely to have noticed other people than individuals in the other conditions. These findings are of a similar vein to other observational studies discussed earlier, which also found that mobile phone use has detrimental effects on pedestrians as they walk (Hatfield & Murphy, 2007; Pesic et al., 2016). Their second study was similar to the first but this study differed in that they introduced an unlikely event (a clown on a unicycle) into the path of the pedestrians. Pedestrians were interviewed at the end of the observed path, and asked if they noticed anything unusual. If they did not specifically mention the clown, they were directly asked if they had seen the clown on the unicycle. Their results indicated that those using a cell phone were least

likely to have spontaneously informed that they had seen the clown, and were least likely to say that they had seen the clown when directly asked. Only 25% of cell phone users indicated that they had noticed the clown, meaning 75% had experienced inattentional blindness as a result of mobile use while walking. The authors conclude that even during a simple activity that requires few cognitive resources such as walking, mobile phone use may result in impairments in the form of inattentional blindness.

Detrimental effects associated with walking and mobile use have also been found in more controlled environments as well. Several studies have looked at potential negative effects associated with mobile phone use while walking in an immersive virtual reality (Neider et al., 2010; Schwebel et al., 2012; Stavrinou et al., 2011). In one study, 138 college students were randomly divided up into four different groups: crossing a virtual intersection while talking on the phone, crossing while texting, crossing while listening to music, and crossing undistracted in a virtual pedestrian environment (Schwebel et al., 2012). Their results showed that participants in the texting and listening to music groups were more likely to be hit by a vehicle when crossing than the undistracted participants. Furthermore, participants in all three of the distracted groups were more likely to look away from the street as they were crossing in comparison to the undistracted group. These results were maintained even when controlling for demographics, walking frequency, and media use frequency. Similarly, Neider and colleagues (2011) had 36 participants walk on a manual treadmill while using a mobile device in an immersive virtual environment. Their task involved navigation through a series of unsigned intersections while either engaging in a hands-free phone conversation, listening to music, or undistracted. A successful crossing of the road was considered to be

done within 30 seconds of when the signal indicated it was okay to walk. Participants in the conversation condition were less likely to successfully cross the road, and took more time to initiate their crossing, when compared to the other two conditions. The authors concluded that pedestrians that use their phones while walking are less likely recognize and act on crossing opportunities.

Similar results are found in two more experiments that looked at mobile phone use in immersive virtual reality (Stavrinos et al., 2011). One experiment looked at differences between those who engaged in a phone conversation versus those who went undistracted, while the other looked at the differences between different types of distraction, namely a phone conversation, a challenging spatial task on a mobile device, and a mental arithmetic task by phone. The results of the first experiment were in line with the other research discussed here, that conversing on mobile device is a major distraction and has a considerable impact on safety of pedestrians. They also showed that distraction affects all participants, not only those inexperienced in crossing traffic, inexperienced mobile phone users, or those with weaker attention and/or information processing abilities. The results of the second experiment also substantiated the first, indicating that all forms of distraction evoked risky behaviour in pedestrians when navigating near traffic, which included significantly less time to spare, more missed opportunities, reduced attention to traffic, and increased number of instances where they were hit or nearly hit by a vehicle.

There have been some experimental studies that have looked at the distracting effects of mobile phone use on walking outside of virtual reality as well. Nasar and colleagues (2008) looked at the distracting effects mobile phone use would have on

walking in two different experiments. The first study had 60 participants walking along a prescribed route, half of whom conversed on a mobile phone while the other half held a mobile phone and waited for a call that never comes. As they walked the route, participants were tasked with remembering a number of objects, photographs and signs, which the authors used to measure their participants situational awareness. The results indicated that participants that were not involved in a mobile conversation remembered significantly more objects than those who were, suggesting that mobile phone use may have a negative effect on a person's situational awareness as they are walking. The second study expanded on the first by observing 127 pedestrians as they walked through three busy crosswalks, making note of those who were walking without any distractions, while using a mobile phone, and while using an iPod music player. The results of the second study suggest that those who used a mobile phone engaged in significantly more unsafe behaviours than those who used an iPod or nothing at all. These results are in line with other observational studies, which also indicated that pedestrians that mobile use while walking results in unsafe behaviours (Hatfield & Murphy, 2007; Hyman et al., 2010; Pesic et al., 2016). Based on both of these studies, the authors conclude that mobile phone usage while walking results in reductions in situational awareness, increases in unsafe behaviour, puts pedestrians at greater risk for accidents, and endangers others around them.

In sum, research has shown that walking while using a mobile device can result in a number of unsafe behaviours. The most consistent of these unsafe behaviours involve reduced walking speed and distracted attention (Hatfield & Murphy, 2007; Hyman et al., 2010; Nasar et al., 2008; Neider et al., 2011; Stavrinos et al., 2011). Based on these

studies, it is suggested that for one to improve the safety of pedestrians, one must improve their walking speed and the attention paid to walking as they walk and use the device. It is likely that reduced walking speed is a by-product of reduced attention due to the strain on cognitive resources associated with the mobile task. Therefore, if an interface can reduce the attention required for the task at hand, pedestrians would be afforded more attention for walking and likely improve their walking speed as well. Another important take away from these studies is that a number of different kinds of mobile use have a detrimental effect on walking. In the case of reading while using a mobile device, this is compounded as walking has a detrimental effect on reading while reading has a detrimental effect on walking, as will now be discussed.

2.2 Reading While Walking

Reading comprehension while walking has been shown to deteriorate in association with walking speed. One study looked at text legibility while walking (Mustonen, Olkkonen, & Hakkinen, 2004). The study compared participants' ability to read actual and pseudo text on a mobile device, while walking down a corridor and on a treadmill at three different speeds. Pseudo text stimuli were random strings of upper and lower-case text. Participants were instructed to look for a target character ("H"), which were randomly placed with the restriction that the lines did not start or end with them. Participants indicated the presence of target characters by using a joystick-button on the device. For the real text, participants were asked two questions to make sure they had read the text thoroughly. The results indicated that the more walking speed increased, the more visual performance deteriorated in both the experimental conditions. Although

reading speed was faster for real text in comparison to pseudo text, reading speed was clearly negatively affected by walking speed, though the effect of speed was not as prominent on character detection in the pseudo text condition.

The relationship between walking speed and mobile use was also examined by Bergstrom-Lehtovirta et al. (2011) who found a trade-off between walking speed and touch performance a mobile device. The study was a within-subjects design where participants were instructed to walk on a treadmill, adjusting the speed until they found their preferred walking speed, while interacting on a mobile device. The experimental task was to select crosshair targets as they appeared on the screen as quickly and accurately as possible. Amplitudes for both hand and body oscillations were measured, along with the participants' accuracy. The authors found that all walking, even at only 20% of preferred walking speed, has an adverse effect on mobile use. However, according to their data, at 40% to 80% of participants' preferred walking speed, participants were able to maintain a stable level of performance both in hand/body oscillations and target accuracy. Of course, this study did not look at reading while walking, which is likely more complicated than just target selection. Nonetheless, it shows that there is a relationship associated with performance on mobile device with walking speed.

Bernard et al. (2007) conducted one of the first studies to look at the effects walking has on reading comprehension did so on a PDA device. Their study was a more far reaching exploration of the effects different factors have on mobile device use, including changes in motion, lighting, task type, and workload, though changes in motion was the primary motivation for the study. Participants in the study completed both a

reading comprehension test and a word search test under both high and low light conditions, while either sitting or walking a course. Of particular interest was the finding that participants had better word search scores and better reading comprehension scores in the sitting condition compared to those in the walking condition. The authors conclude that designers need to take into consideration context when designing mobile interfaces, and that future research should look at different ways in which designs can adapt to the context of use.

While it is apparent that walking has a detrimental effect on reading comprehension in the Bernard et al. (2007) study, conflicting results were reported in a different study (John, Bassett, Thompson, Fairbrother, & Baldwin, 2009). Their study evaluated the benefits of using a treadmill workstation in comparison to a typical sitting workstation. However, in comparison to Bernard et al., this study was done on a desktop computer. Participants were assessed on a battery of tests including selective attention and processing speed, typing speed, mouse clicking/drag-and-drop speed, and GRE math and reading comprehension tests. The study was set up to be within-subjects design where 20 participants (9 female) completed all of the tests while both sitting and standing, with a 2-day interval between the conditions. The results of the study indicated that those in the seated condition performed better for mouse-clicking, drag-and-drop tests, typing speed. Participants also tested significantly worse on math GRE tests in the walking condition, but did not perform any worse on the reading comprehension GRE test when compared to the sitting condition. These results are inconsistent with Bernard and colleagues' findings of negative effects being associated with walking and reading comprehension. Nonetheless, this might be an instance in which research on a desktop is

not generalizable to mobile phone research. Indeed, the authors themselves suggest this possibility as the screens on the PDAs used in Bernard and colleagues' study are much smaller than the screens they use in their study. Regardless, even though detriments in reading comprehension were not found, it is still clear that the context of walking can have negative effects on task performance.

The studies discussed above provide evidence that the context of walking seems to have an adverse effect on complex cognitive tasks, such as reading and math. Furthermore, there is an association between walking speed and task performance, with slower walking being associated with worse task performance. Due to research showing slower walking speed being an unsafe walking behaviour (Hatfield & Murphy, 2007; Hyman et al., 2010; Neider et al., 2011; Stavrinos et al., 2011), if one can improve task performance, one can likely increase walking speed, and in turn facilitate safer walking behaviour. One possible method of doing this is through the implementation of an AUI. AUIs have been shown to enhance task performance if they adapt to the user correctly. Due to their adaptive nature, they can be designed to seamlessly suit the context in which they are used.

2.3 Adaptive User Interfaces

Ideally, adaptive user interfaces (AUIs) adapt to the user based specifically on how they use the device. There have been a couple of studies that look at how the implementation of AUI can benefit users. Gajos and Weld (2008) conducted four different experiments that looked at AUI and their impact on usability. The first three experiments looked at an adaptive toolbar in Microsoft Word, with different aspects of

the toolbar being adaptive to user need depending on the study. In each study, they compared the manual version of Microsoft Word with an adaptive version. Their results showed that users preferred the adaptive version despite it being less predictable due to the ease of use afforded by the adaptive interface. The researchers also found that a number of factors affected usability, including the accuracy and predictability of the Artificial Intelligence (AI), the frequency of adaptation, the frequency of interactions the user has with the interface, the complexity of the task, and the interface's spatial stability. In the fourth study, the researchers looked at automatically generated custom interfaces for users with motor impairments. Their study compared 11 participants with motor impairments with 6 able bodied participants on an automatically generated interface using Supple ++ and to the manufacturer's default interface. The results showed that users with motor impairments were 26% faster using the generated interfaces, while making 73% fewer errors. Moreover, their users strongly preferred the generated interfaces, finding them more efficient, easier to use, and less tiring. Based on the four studies, Gajos and Weld concluded that adaptive interfaces that are predictable and accurate can benefit both motor impaired users and regular users.

There has been some conflicting evidence with regards to AUIs. At least one early study found that an adaptive menu may, in fact, hinder usability instead of facilitating it. Mitchell and Shneiderman (1989) compared static menus, in which the order of items is fixed, with adaptive menus, in which the items appeared based on the frequency of use by the user. Their study used a two group within-subjects design, where one group would use the static menu and then adaptive menu on tasks while the other group would do the opposite. They had four dependent measures, including the number of task errors,

number of operations to complete the task, time it took to complete the task, and subjective satisfaction. It should also be noted that the participants, freshman college students, had little to no computer experience. The results indicated that there was no difference between the number of operations or number of errors. However, the participants that saw the adaptive menus first took significantly more time to complete the tasks. Moreover, 81% of subjects in both groups stated that they preferred the static menus to the adaptive menus. Mitchell and Schneiderman concluded that at best the adaptive menus are as effective as the static menus, and at worst the adaptive menus hinder users in ways static menus do not. Either way, users still most preferred the static menus, so the authors concluded that static menus are likely the best option in most cases.

Findlater & McGrenere (2004) also compared the effect of adaptability on menu selection. However, the major difference with this study is that it drew a distinction between adaptable menus and adaptive menus. Here adaptive menus mean ones that are adjusted by the system in the hopes of supporting the user as has been discussed, while adaptable menus allow customization through user input. Another difference between the two studies is that this one used split menus as opposed to regular menus. Split menus are comprised of two partitions, with the top partition having the most frequent items while the bottom partition is more traditional in nature. These menus are meant to expedite access to the frequently used items in the menu. The goal of the study was to compare the efficiency of adaptable, adaptive and static split menus, thus having three conditions of comparison. In the static condition, the items in the top partition represented the four most frequently used items in the menu, while the bottom partition used traditional ordering. In the adaptive condition, an algorithm orders the items based on frequency and

recency of use (the top 2 items are frequency items while the latter two are recency items). Lastly, in the adaptable condition, the user had the option of using arrows keys to change the order of the 4 items in the top partition, as well as add from the bottom partition into the top partition (top partition is initially empty and allows a maximum of four items). They did not, however, have the option of changing the ordering of the bottom partition as it was static. This study also used a within-subjects design, and had the three conditions all perform a task on Microsoft Word, with order being counterbalanced. However, in contrast to the Mitchell and Schneiderman (1989) study, about two thirds of the 26 participants were at least intermediate level computer users. Their results suggest that the adaptive menu is slower than the static menu, but only slower than the adaptable menu if the user did not use the adaptable menu first. Similarly, the adaptable menu was not slower than the static menu unless the user used it first. The adaptable menu was also preferred over the static menu but not over the adaptive menu. Also, the static menu was not preferred over the adaptive menu. Findlater and McGrenere conclude that static split menus are more effective than adaptive split menus, but also found that it was the most preferred by 30% of users. Nonetheless, the majority of users preferred the adaptable interface, with it showing the most positive results in the tasks. Therefore, the authors suggest that combining adaptive elements with customization options for the user is the best way to go for these kinds interfaces.

This study finds corroborating evidence with the Gajos and Weld (2008) study that users appreciate customizability and adaptability in an interface. Nonetheless, this study also substantiates Mitchell and Shneiderman's (1989) findings that too much unpredictability in menus is not appreciated by users. The study also supports their

conclusion that static menus are more effective than adaptive menus. However, there is a difference in user preference of static over adaptive menus, as no significance was found here. One might be able to attribute this difference with the level of computer expertise in the participants, because more computer savvy participants may find the feature more useful. Moreover, because users preferred both the adaptive and adaptable menus over static menus, but not over each other, this suggests that users benefit from adaptive interfaces in some capacity.

While there have been studies showing the benefits of AUIs, there are some studies showing potential drawbacks associated with them, as has been shown. However, all of the studies that have been discussed solely looked at interfaces of desktop displays. This is because the vast majority of research done on AUIs have been done on desktop displays. Yet, these days the most commonly used interfaces are those found on mobile smart phones. It is possible that these results do not generalize to the small screens used on mobile devices. At least one study has taken a look if this is the case. Findlater and McGrenere (2008) conducted a study with 36 computer adept participants (ages 19-49) comparing an AUI for desktop screens with an AUI for mobile screens. Because adaptive accuracy can affect performance and use of adaptive predications, the researchers opted to go with two different adaptive mobile screens, one with 50% adaptive accuracy and one with 78% accuracy, as well as a static condition. Similar to most of the studies that have been discussed, the authors opted to go for a within-subjects design, meaning that there was a total of two conditions (desktop vs. mobile) that would go through three interfaces (high-accuracy adaptive, low-accuracy adaptive, and static). The task involved selecting the correct items on adaptive split menus that would adapt to user based on user

preference (or on the static split menus). The researchers measured task performance based on speed and error rate, and various other subjective measures. The results suggested that the high accuracy interface performed better than the low accuracy interface in both the mobile and desktop conditions, which both performed better than the static interfaces in both conditions. The high accuracy interface also resulted in the most subjective satisfaction, especially on the smaller screens. Reading and content retrieval were slower on smaller screens than larger screens, due to the increase in difficulty in reading smaller text and the increase in scroll time. However, the effect of adaptive accuracy was greater on smaller screens than larger screens, mostly due to decreases in scroll time.

Based on these results Findlater and McGrenere (2008) concluded that adaptive capabilities are even more beneficial in small screens than they are in larger screens. However, this also suggests that the prior work done on this topic involving adaptive menus might not effectively generalise to smaller screens. Moreover, due to the positive effects being even more pronounced on smaller screens, this indicates that AUIs might be especially suited for smaller screens. Specifically, it seems AUIs that help lessen the amount of scrolling involved on small screens directly benefit users. This study provides support for Gajos and Weld (2008) by showing that users benefit from adaptive interfaces. Interestingly, Findlater and McGrenere (2008) found evidence against their own 2004 findings that users are more effective using static menus than adaptive menus, showing once again the lack generalizability between mobile and desktop. Although conducted using different screen sizes too, it should be noted that these results are in direct contrast with Mitchell and Shneiderman's (1989) findings that users prefer static

screens over adaptive screens. It seems that Findlater and McGrenere themselves now agree that adaptive interfaces do benefit users, despite early research suggesting otherwise.

Findlater and McGrenere's (2008) study underscores the importance of conducting more research on AUIs in mobile devices so as to gain a clearer picture of the effect adaptability has on smaller screens, as this was the first of its kind. Considering that desktop users do not experience the variability in contexts that mobile users do, it makes more sense for AUIs to be implemented in mobile devices as they can adapt to a user's context. Indeed, Williams (2008) argues that the main advantage of AUIs for mobile devices compared to static interfaces is that they can take into consideration a user's context. Many of the studies done on AUI have only looked at adaptable menus as the adaptive function, including Findlater and McGrenere's mobile study (with a few exceptions – see Chen & Lin, 2016; Kane et al., 2008). This should be considered a limitation of the field there are a number of potential adaptive functions outside of adaptive menus that have yet to be explored.

2.4 An Interface for Reading While Walking

It is clear that there are potential safety risks associated with walking while using a mobile device. It is also apparent that reading comprehension is something that suffers from walking. Because of their ability to adapt to the context of walking, AUIs are potentially useful in facilitating better reading comprehension and safer walking. Next, it is important to consider what adaptations to make in the design of an AUI that can do this. There have been several different studies that have looked at the possibility of improving

mobile use while walking (Chen & Lin, 2016; Kane et al., 2008; MacKay et al., 2005; Schildbach & Rukzio, 2010; Yen & Chien, 2011). Most of these studies have looked at primarily two manipulations that can serve to lessen the cognitive load of the task while walking. These two manipulations are the size of text/buttons, and how a person is presented information, whether via different scrolling methods or display presentations.

2.4.1 Text Size

Kane et al. (2008) looked at the feasibility of using an AUI for walking to improve use performance. The authors did this by designing an adaptive interface that resizes buttons as users are walking. In their paper, Kane et al. coin the term Walking User Interface (WUI) to denote user interfaces that are specifically designed to counteract the adverse effects walking has on user performance. Their study implements a WUI for a music player that resizes text and widget size to help make use while walking easier. Participants in their study walked an open course at a set speed, with a human pace setter used to set the speed. To add to the realism of the study, evaluations were performed in public spaces with pedestrian traffic. The study had a total of 30 participants which involved participants using three different interfaces, a static small text, a static large text and an adaptive interface that changed the size of buttons and text from small to large. There were three types of experimental tasks that were considered either easy, medium or hard. Easy tasks involved tapping on a single button on the screen, such as “Play” or “Pause”. Medium tasks involved locating and selecting a track that was on a menu list that was currently visible on screen. Lastly, hard tasks required participants to scroll through a list to find the correct track. Participants completed on equal number of each of

these tasks for a total of 3 sets of 18 trials (once per interface, 54 total), with half of the total trials begin done while walking and the other while standing wherever they were along the course. Thus, the study had a 3 x 3 x 2 within-subjects design with one factor being the type of interface, the second factor being the difficulty level, and the last factor being whether they were standing or walking. The dependent measures of the study were task time, number of task errors, number of walking deviations (which were defined as falling behind the pace setter by 6ft or more, stopping along the course, or colliding with an obstacle), total button presses, and number of glances away from the device. Kane et al. found that in both task time and task errors, participants performed better when standing in comparison to walking in all conditions. Furthermore, in both task time and task errors, performance was best when using the static large text interface followed by the adaptive interface and the small text interface respectively. However, for 35% of the participants, the adaptive interface performed the best. The researchers concluded that because the adaptive interface was no slower or more error prone than the static interfaces, this indicated that there is no additive penalty for having an adaptive interface.

Research has both further corroborated past findings showing the effects walking can have on reading comprehension, and attempts to mitigate some of those effects by increasing size of text and target size. Schildbach and Rukzio (2010) evaluated one handed use on a mobile phone where the thumb is used as the interaction method, and compared participants while they were walking to standing. The study involved both a reading comprehension task and a target selection task, where the researchers increased the text size by 20 and 40 percent. Like most studies discussed throughout this review, it also was a within-subjects design, meaning the participants partook in each task and in

each mobility condition. When comparing walking and standing, the researchers found that performance was worse in the walking condition on both the target selection task and the reading comprehension task, and doing the tasks while walking resulted in significant increases to their cognitive load. Moreover, they found that for target selection, increasing the size of text by both 20 and 40 percent lead to significant increases in performance, to the point of almost completely compensating for the negative effects of walking at 40 percent. However, when looking at the reading comprehension task, the authors concluded that similar benefits were not found due to increases in the amount scrolling in the increased text size conditions. Sanchez and Goolsbee (2010) looked at the relationship between text size and memory and also found similar results. This study did not involve walking, but when assessing the retention of text at different font sizes for small screens, the authors concluded that character sizes that increased the amount of scrolling on small device screens resulted in less correct recall of the text. Taken together, these studies suggest that the increase in work load as a result of an increase in scrolling likely mitigated any benefits that would have been gained from increasing the text size.

2.4.2 Information Display

The second potential way to improve reading comprehension while walking is how the text is displayed to the user. Several studies have looked at how both the size of the text and how it is presented to the user can help facilitate reading while walking. One Chinese study explored the potential benefits of Rapid Serial Visual Presentation (RSVP) displays to be used to help reading comprehension in the context of walking (Yen & Chien, 2011). The displays used in their study presented text either word-by-word or one

line at a time, at four different display durations: 171, 213, 240 and 308 milliseconds per character. The three different contexts they looked at were sitting, walking on a treadmill, and walking a course. Thus, the study had a 3 (type of context) \times 2 (presentation unit) \times 4 (presentation duration) mixed design. Their results indicated that both word-by-word RSVP and line by line RSVP had comparable comprehension scores in both the sitting and walking conditions, the one caveat being that at the shortest display duration (171 milliseconds per character) for single line display, reading comprehension dropped across the board. Nonetheless, this study suggests that the way in which information is displayed can help bring up reading comprehension while walking to comparable levels to sitting. That being said, this study would have benefited from another control group that looked at how a typical static display type compares to an RSVP display while walking, as more can be said for the benefit of a RSVP in mobile devices if performance was better than a static control.

Another study looked at the potential of using different types of scrolling methods to help navigation while walking. MacKay et al. (2005) compared the use of three different scrolling methods on a PDA device to navigate a map in three different contexts of mobility, sitting, standing, and walking. The first method is scroll bars, which are similar to desktop scroll bars, where users tap arrows on either end of the bars to go either up and down or left and right, or anywhere along the bar to jump to that location on the page. Tap-and-drag is the second method, and involves the user placing their fingers or stylus on the screen, and dragging in any direction. The final method, which is a new interaction style that they introduce, is called touch-n-go, and involves movement of the screen in the direction a user has tapped relative to the center of the screen. The screen

continues to move as long as contact is maintained with the screen, with the speed of movement being faster the farther from the center. Participants in the study used all three scroll methods in all three mobility types, thus being a within-subjects study. With regards to mobility, the results of their study were consistent with previous research (Bernard et al., 2007; Kane et al., 2008; Schildbach & Rukzio, 2010), with performance when sitting being the fastest, followed by when standing, and while walking being the slowest. The results for the scrolling types indicated that scroll bars were the worst of the three methods, with the other two being more preferred. Between the other two techniques, most measures were similar aside from the finding that participants thought the touch-n-go technique was easier to use and preferred it while walking. While this study was not assessing reading comprehension, it still suggests that users can benefit from unique scroll techniques that they can use while walking.

Sanchez & Wiley (2009) looked at the relationship between different scrolling techniques and the effects they have on Working Memory. Although it was done on desktop as opposed to mobile, in two different studies, the researchers compared reading comprehension in an interface that involved scrolling to an interface that was non-scrolling. The non-scrolling interface used a display type called paging, which involved pages presented in full, and the navigation between pages by clicking “Next” and “Back”. The participants Working Memory capacity was recorded as another measure. The results of the two studies suggested that scrolling negatively affected the learning of the text, especially for individuals with low Working Memory capacity. These results are consistent with Sanchez and Goolsbee (2010) findings that character sizes that increased the amount of scrolling on small device screens resulted in less retention of that text.

Taken together, such results might suggest that scrolling would be even more detrimental to users in the context of walking, as their Working Memory resources might already be strained, and even more so still to those with low Working Memory capacity in the first place.

While manual scrolling may be detrimental while walking, an auto-scrolling interface may help reading comprehension instead. Chen and Lin (2016) looked at the effects of reading comprehension, sustained attention and cognitive load in different mobile reading contexts. They did this by comparing both static and dynamic (adaptive) text display types, as well as their own mixed display type, which combined elements of both. The static display type used a paging display type, where text is displayed one page at a time and the user can tap to move on to the next page, similar to the Sanchez and Wiley (2009) study. For the dynamic display type, an auto-scrolling interface that scrolled at 355 words per minute and could not be paused was used. The last display type incorporates aspects of both the static and adaptive display type by displaying paragraphs word by word at 120 words per minute, and allows users to page through paragraphs. Additionally, the researchers used a brainwave detector, reading-comprehension tests, and cognitive-load scale to compare performance in different reading contexts, which were defined as walking, sitting and standing. The 20 participants in the study read nine peer reviewed journal articles in both English and Chinese, on each display type and in the three different contexts. After reading an article, participants were tested on their reading comprehension of that article.

The results of the study indicated that the sitting context obtained the highest sustained attention, with the mixed type interface resulting in the least. Furthermore,

reading comprehension was noticeably affected by the context in general, as is consistent with previous research (Bernard et al., 2007; Kane et al., 2008; Mackay et al., 2005; Schildbach & Rukzio, 2010), while also being somewhat affected by display type. Although it was clear that the mixed display type performed the worst, it was not clear which display type performed the best. Moreover, the results of their study also found that the different display types had a differential effect on cognitive load, with their own mixed display type having the highest load, followed by the dynamic display type, and then the static display type. This study serves as in depth look at how different display types affect cognitive load in different contexts. However, it is not apparent from their results whether or not an auto-scrolling interface is beneficial for reading on a mobile device while walking.

2.5 Current Research

The present research examined the benefit implementing an AUI to help facilitate reading comprehension while walking, adding to both the AUI and the mobile use while walking literature. This was done with development of a mobile application that takes a user's sample reading speed, and uses that speed in an auto-scroll display type that also zooms in and enlarges text. Because previous research on manual scroll displays found that they strain work memory (Sanchez & Wiley, 2009), it was anticipated that the implementation of an auto-scroll mechanism can reduce this strain, and in turn help facilitate walking. Furthermore, based on findings suggesting there are benefits associated with increasing text size, but drawbacks associated with the corresponding increase in scrolling (Kane et al., 2008; Schildbach & Rukzio, 2010; Sanchez &

Goolsbee, 2010), the present work explores the reconciliation of this problem with the combination of an auto-scroll interface with increased text size. Therefore, this study compares reading comprehension while sitting and walking on three different interfaces; a static manual scroll interface, an auto scroll interface, and an auto scroll with zoom interface. Unlike Chen and Lin (2016), this study is narrower in scope, as it solely focuses on reading and walking performance. The custom auto-scroll speed and the ability to pause and reverse, make this a more comprehensive evaluation of auto-scroll displays in the context of walking.

The experimental hypotheses for this study are as follows:

- (H1) An adaptive interface that automatically scrolls through text as the user is walking will facilitate better reading comprehension, faster reading, will result in faster walking and course completion, and will be preferred over a static interface while walking.
- (H2) Users will prefer a static interface when sitting to an adaptive one.
- (H3) Reading comprehension scores will be higher overall in the sitting condition compared to the walking condition.
- (H4) Having an adaptive interface with larger text size and automatic scroll will best facilitate the best reading comprehension, result in the best walking performance, and will be preferred over the other two conditions when walking.

3. Methods

3.1 Participants

A total of 30 (5 female) volunteers with an age range of 18 – 35 years ($\mu = 24.3$ years) participated in the study and were compensated with \$5. Participants were recruited via random selection from in and around the Carleton University campus with posters. Participants were required to be a minimum of 18 years old, attended University within the last three years, and were physically capable of walking a course. All participants were assumed to have normal or corrected-to-normal visual acuity.

3.2 Experimental Design

A 3 (Interface: Static vs. Adaptive Scrolling vs. Adaptive Zooming and Scrolling) x 2 (Movement: Sitting vs. Walking) mixed factors design was used. Interface was a within-subjects factor that was blocked and presented in a randomized order across participants. The three interface conditions included two adaptive interfaces, and one static interface. One adaptive interface auto-scrolled, while the second adaptive interface auto-scrolled and zoomed-in the text. The static interface was a typical manual scroll interface. Movement was a between-subjects factor. Context is defined as the environment in which the mobile device is being used. Therefore, the movement factor represents the different contexts in which participants used the interfaces; while either sitting or walking a course. The dependent variables of this study were the reading comprehension scores, the participant's subjective preferences, how fast the text is read, how fast participant completed the course, and how fast participants walked.

3.3 Materials

The three reading texts and their corresponding multiple-choice comprehension questions were extracted from the GRE reading comprehension practice tests. The three texts used to compare the user interfaces were selected based on having similar difficulty ratings according to the practice tests, and being of similar length (Education – 342 words, Sanctuary – 412 words, and Theatre – 425 words). An article from Psychology Today consisting of 411 words was selected for the sample text, which established each participant's reading speed.

3.4 Apparatus

A Google Pixel XL Phone was used as the mobile device in the study. The phone has a 5.5-inch AMOLED display with a pixel resolution of 1440 x 2560 pixels (534 ppi), was 15.24 x 7.37 x 0.81 cm in size, and weighed 168 g. The phone was equipped with an Operating System (OS) that used the latest version of Android Nougat 7.1.2. The study was executed on a custom-built app that was programmed in Java and loaded onto the phone. Functionality of the app included storing the time that participants required to read a sample paragraph, which it used to set the auto-scroll speed for the two adaptive interface conditions. It then randomly matched one of the three interface conditions with one of the three reading text topics (i.e., Education, Sanctuary, and Theatre) that were used in the study. Android's default of 14 Scale-independent pixels (SP) was used as the text size for the sample paragraph and in the static and adaptive scrolling interface

conditions. The text size in the adaptive zooming and scrolling condition was 28 SP (i.e., double the size of the text in the other conditions). The formula used to determine the auto-scroll speed was derived from the slope corresponding to the line of best fit from 10 different reading speeds of the sample text. The scroll speed in the adaptive scrolling condition was set such that the text would scroll at the same reading rate that was established for each participant once they read the sample paragraph. The scroll speed in the adaptive zooming and scrolling condition was approximately 50% faster than in the scrolling condition to account for the larger text size.

3.5 Procedure

Upon arrival at the testing facility, participants read and signed an informed consent form that detailed the experimental procedure. The experimenter then verbally relayed the instructions to ensure comprehension. Participants were instructed that they would read a sample paragraph to provide practice and to set the text scroll speeds in the two adaptive interface conditions. Participants were therefore instructed to read the sample text at what they considered to be a normal/comfortable pace for them.

Participants read the sample text while seated to ensure that it would be read under conditions that the participant was most familiar with.

Following completion of the sample text, participants in the sitting condition were instructed to remain seated and told that this portion of the study involved being tested on reading comprehension. Furthermore, they were informed which interface condition they would receive first, which was randomized across participants. If it was an adaptive interface condition, they were further instructed how to pause the scrolling text (i.e., tap

to pause and release to resume) and how to reverse the text (i.e., double tap). After reading the text, participants' reading comprehension was assessed using a 4-question multiple-choice test. Upon completing the test, participants began the next interface condition. After completing the final (third) interface condition, participants received a questionnaire asking them to provide subjective ratings for their preferences for the different interfaces.

The procedure for the walking condition was identical to the sitting condition except that participants walked a pre-determined course while reading in the three interface conditions. Participants were instructed to walk at whatever they thought was a comfortable pace, but to remember that their reading comprehension would be assessed so they should maintain focus on the text. As for the course itself, participants were instructed to take a left whenever they could and to follow the green markings on the floor if they needed to, which were placed every 20 feet (see Figure 1). Although it was a low traffic area, it was a public area with other potential pedestrians walking. If participants completed the course before they completed the text, they were instructed to begin a second lap and continue walking until they finished reading the text. The experimenter followed the participant around the course to ensure that they did not injure themselves or others as they were walking. Once participants finished reading the text, they were taken back to the experiment room, where they completed the corresponding reading comprehension test while seated.

on their comprehension performance scores, the content of the three texts and their accompanying questions were of similar difficulty. The three texts were therefore collapsed in subsequent analyses.

Reading comprehension scores were submitted to a 2 (Movement: Walking vs Sitting) x 3 (Auto Scroll vs Static vs Auto Scroll + Zoom) mixed factors measures ANOVA, with movement as a between-subjects factor and interface as a within-subjects factor. There was no significant main effect of interface ($F < 1$), meaning that reading comprehension did not differ across all three interfaces. As predicted, there was a significant main effect of movement $F(1, 27) = 5.19$, $MSE = 0.11$, $p = 0.031$, $d = 0.59$, indicating a medium effect size, with participants in the walking condition ($M = 34.7\%$ $SE = 0.60$) obtaining significantly lower reading comprehension scores than those in the sitting condition ($M = 51.7\%$ $SE = 0.44$; see Figure 2). There was no significant interaction between interface and movement, $F(2, 54) = 2.28$, $MSE = 0.07$, $p > 0.10$.

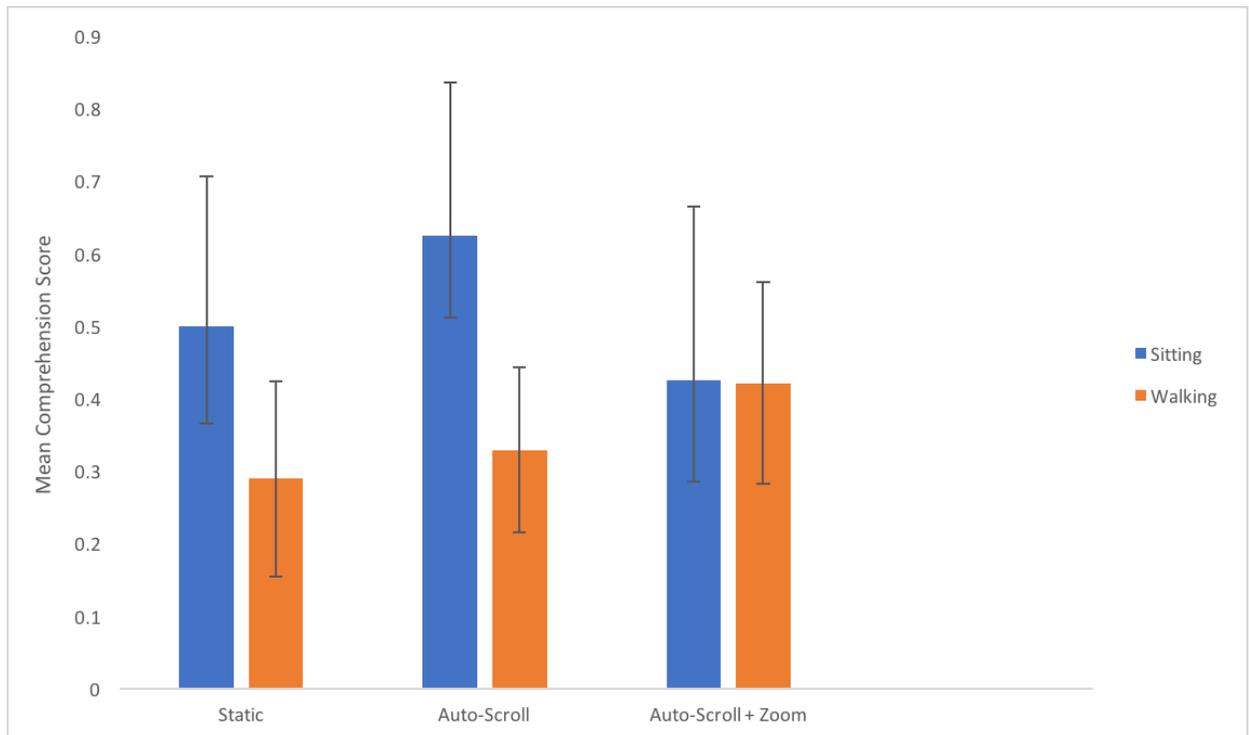


Figure 2. The mean comprehension scores for each interface while walking and sitting. Bars represent 95% confidence intervals.

Reading completion times were analyzed using the same 2 (Movement: Walking vs. Sitting) x 3 (Interface: Auto Scroll vs. Static vs. Auto Scroll + Zoom) mixed factors ANOVA used on the comprehension score data. There was a significant main effect of interface $F(2, 54) = 3.32$, $MSE = 947.77$, $p = 0.044$. A post-hoc analysis using Bonferroni pairwise comparisons was conducted to determine which differences were significant. The results indicate a significant difference ($p < 0.05$) between the Static ($M = 161.20$, $SE = 7.80$) and Auto Scroll ($M = 139.44$, $SE = 6.59$) conditions, indicating that participants were significantly faster in reading the text in the Auto Scroll condition than the Static condition. The effect size of this difference was determined to be a medium size effect, d

= 0.56. There was neither a main effect of movement nor a movement by interface interaction ($F_s < 1$; see Figure 3).

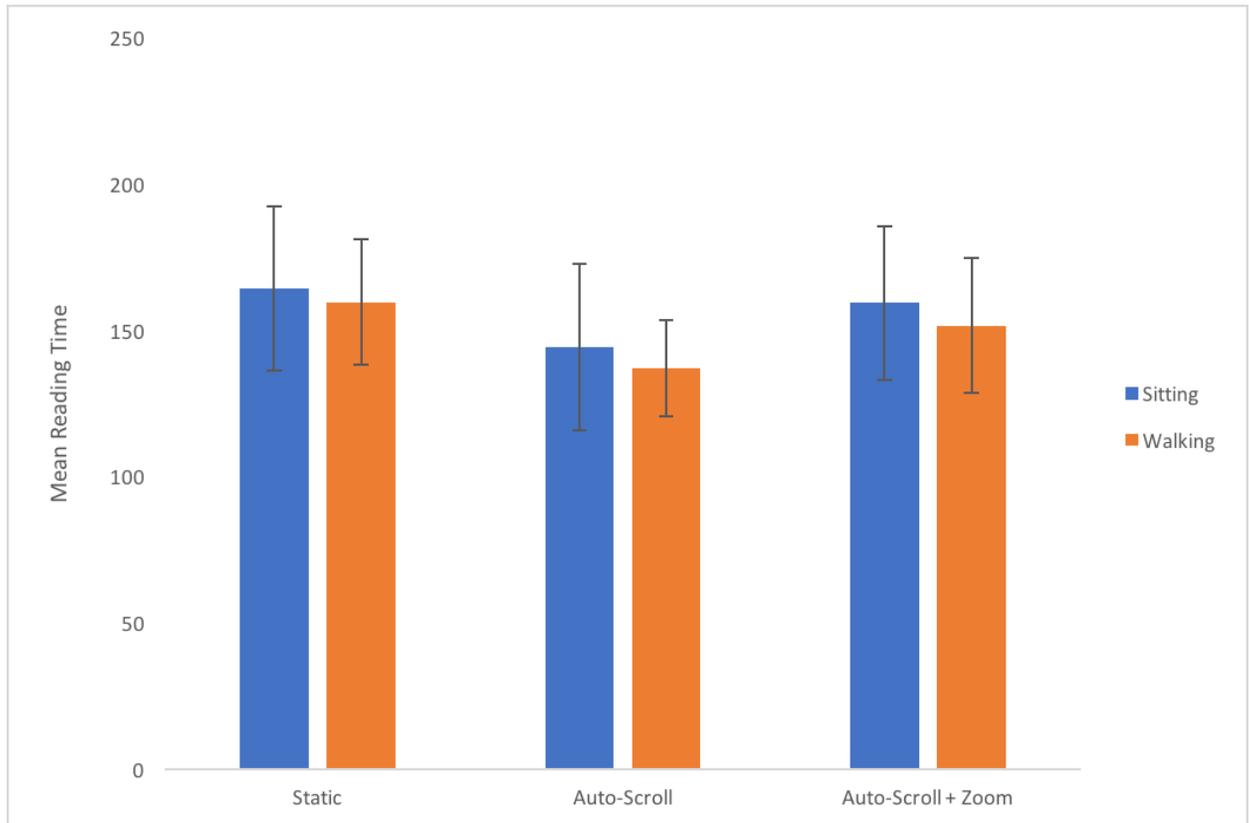


Figure 3. The mean reading times for each interface while walking and sitting. Bars represent 95% confidence intervals.

Given that only the walking group produced first lap completion times, these data were analyzed using a 1-factor (Interface: Auto Scroll vs. Static vs. Auto Scroll + Zoom) repeated measures ANOVA to determine if interface had any effect on walking speed. There was a significant main effect of interface, $F(2, 36) = 3.73$, $MSE = 81.65$, $p = 0.034$. As with the reading completion time data, a post-hoc Bonferroni pairwise comparison was conducted to determine which differences were significant. There was a

significant difference ($p < 0.001$) between the Static ($M = 98$, $SE = 5.87$) and the Auto Scroll interfaces ($M = 90$, $SE = 4.78$), with the effect size being small, $d = 0.34$. No other significant differences were found when conducting the pairwise comparisons (see Figure 4).

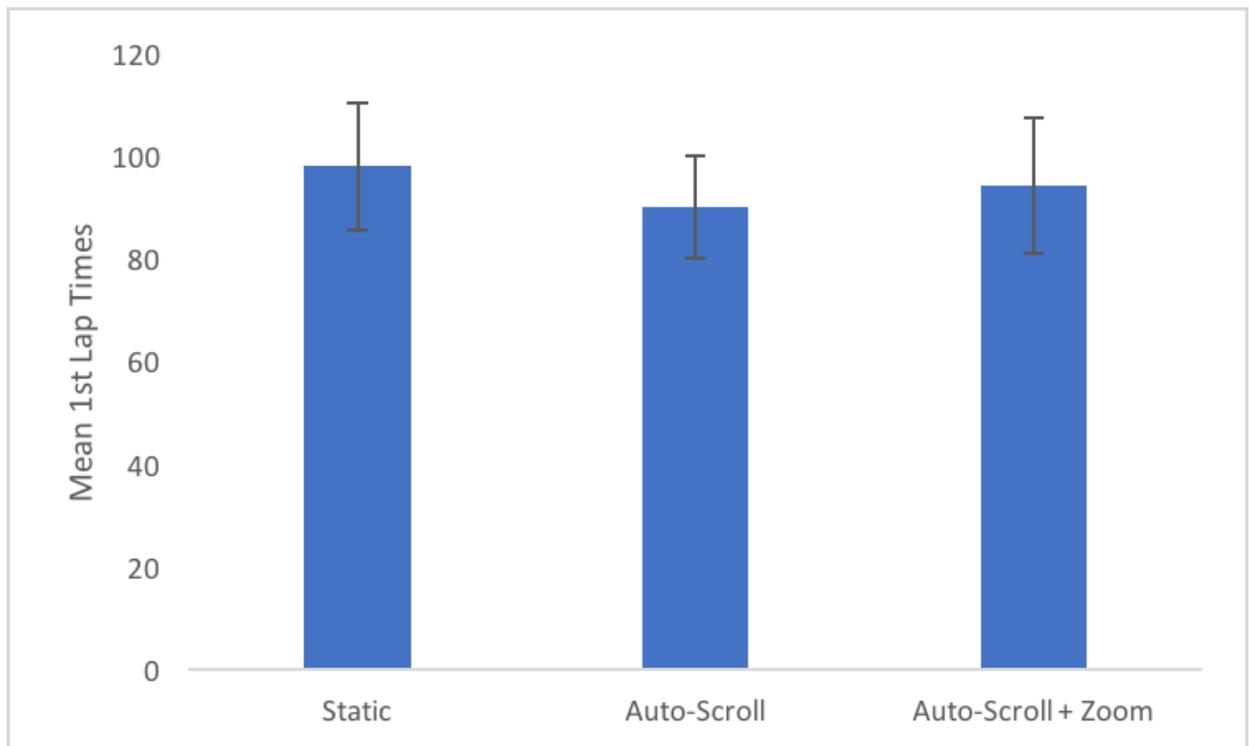


Figure 4. The mean time it took to complete 1st lap of the course for each interface. Bars represent 95% confidence intervals.

4.2 Video Analysis

A video of participants' feet was recorded for each trail with each interface in the walking condition. The video was used to count the number of steps that were taken with each interface in the first lap. The number of steps taken was divided by lap completion time so as to calculate the steps per second for each interface trail so as to get a measure of speed. The data was analyzed using 1-way (Interface: Auto Scroll vs. Static vs. Auto Scroll + Zoom) repeated measures ANOVA to compare the three interfaces. One

participant was omitted from this analysis because they held the phone in such way that their feet were not in view. There was a significant main effect of interface, $F(2, 34) = 8.43$, $MSE = 0.01$, $p = 0.001$. The post-hoc Bonferroni pairwise comparison revealed the Auto-Scroll interface ($M = 1.53$, $SE = 0.04$) to have significantly more ($p < 0.001$) steps-per-second than the Static interface ($M = 1.40$, $SE = 0.04$), with the effect size being large, $d = 0.74$. No other significant results were found (see Figure 5).

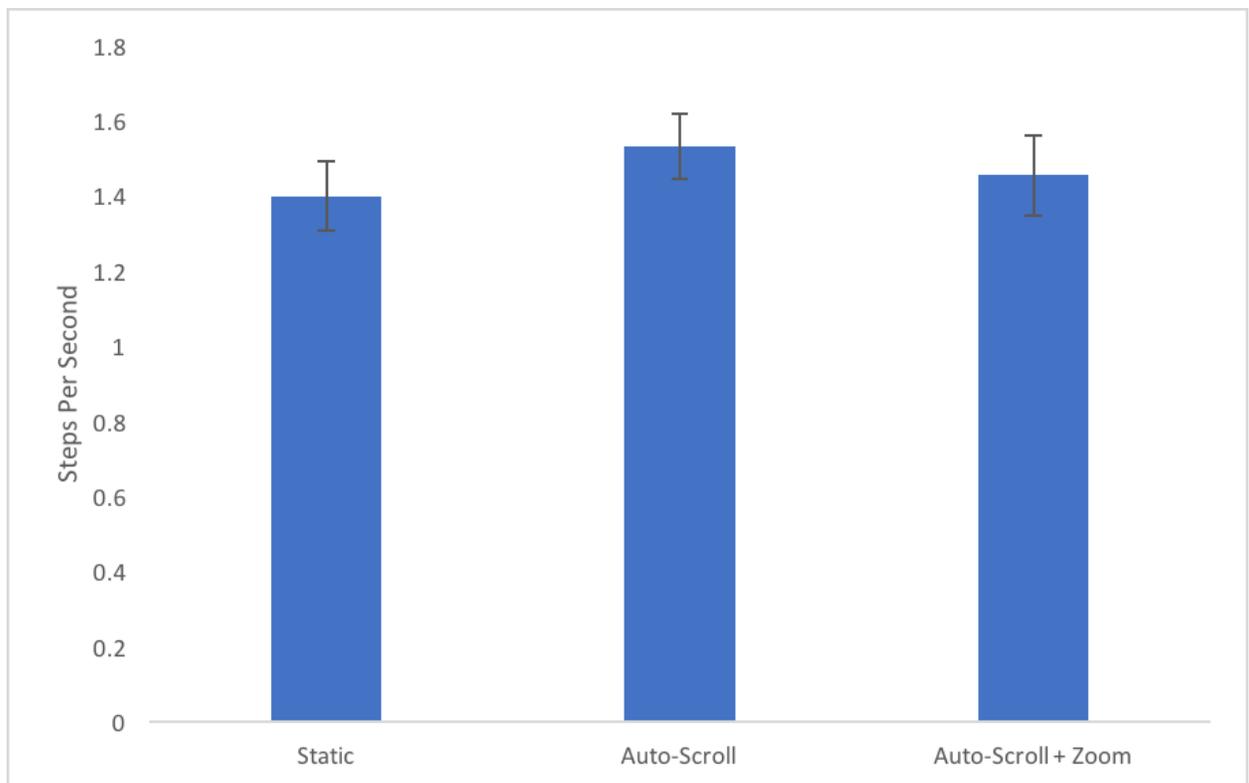


Figure 5. The mean speed that participants walked with each interface in steps per second. Bars represent 95% confidence intervals.

4.3 Subjective Data Analysis

A post study questionnaire was administered to participants to probe their interface preference and to determine some additional information. For preference, 58% of participants most preferred one of the two adaptive interfaces when walking. In

contrast, 80% of participants most preferred the static interface to the adaptive interfaces when sitting. Most participants indicated that they use their mobile device while walking on a regular basis (3 or higher on a 5 point Likert scale), with only one participant indicating they rarely do (2 on a 5 point Likert scale) in the sitting condition. The majority of participants, indicated that the auto-scroll speed was appropriate (3 on a 5 point Likert scale) for both the auto-scroll interfaces. However, the percentage of participants indicated that the scroll speed was appropriate was higher for the Auto-Scroll interface (70%) than for the Auto-Scroll + Zoom interface (57%; see Figure 6).

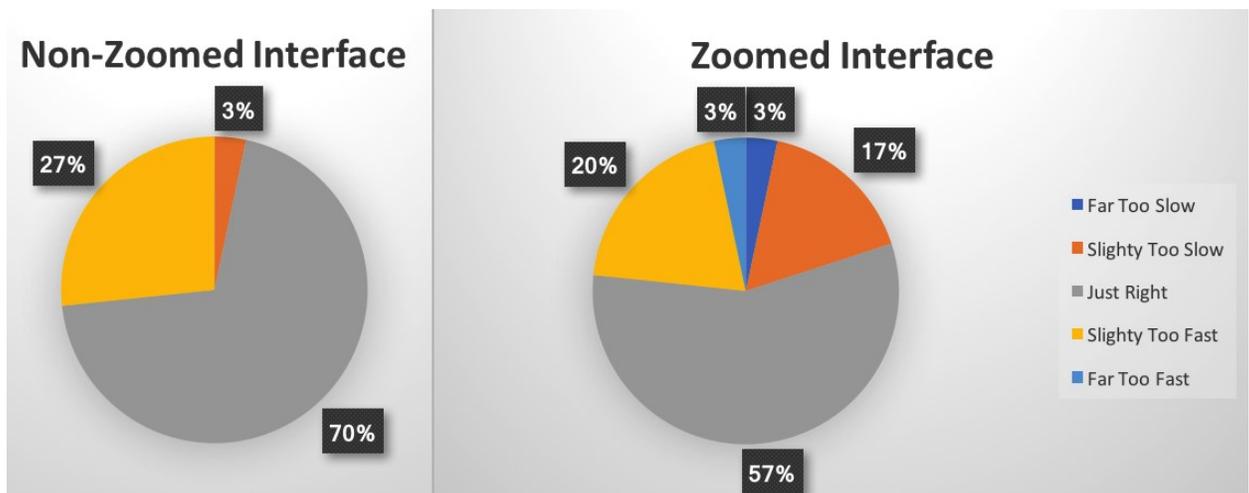


Figure 6. A distribution of participants thoughts on how accurate the auto-scroll speed was for both the adaptive interfaces.

5. Discussion

5.1 Summary of Findings

As predicted, participants in the walking condition using the auto-scroll interface were significantly faster in completing the text, walked faster, and completed the course faster than when using a static interface. This confirms most of the first hypothesis (H1),

aside from the fact that participants did not score any higher on the reading comprehension tests compared to the static interface. These results confirm the general goal of this study by showing that there can be real benefits associated with the application of an AUI in certain contexts. Indeed, it seems that the implementation of an auto-scroll feature frees up more cognitive resources to be used for the physical act of walking, resulting in both faster walking and faster reading. Moreover, participants seemed to notice a benefit themselves, as 58% of those in the walking group most preferred an adaptive interface over a static interface. The second hypothesis (H2) was also correctly predicted as 80% of participants in the sitting condition most preferred the static interface. Taken together, the present results support the notion that AUIs are best used when they correctly adapt to the context of use they are found in. In the context of walking, people benefit from an auto-scrolling interface and so prefer it, but while sitting, there are no meaningful advantages to an auto-scrolling interface, so they prefer a static interface. It is just as important to consider contexts where it would be detrimental to implement an AUI as it is contexts where it would be a benefit.

Despite the apparent benefits of increased walking speed and increased reading speed, no benefits were found in regard to reading comprehension scores. This may be because of one of two possibilities. The first is that auto-scroll simply does not facilitate reading comprehension, but only reading speed and walking speed. This would suggest that while there is no benefit to reading comprehension with implementation of an auto-scroll interface, there is no disadvantage either, as no interface stood out to be considerably better than the rest in regard to reading comprehension scores. However, because of the other benefits associated with the auto-scroll interface, it is suggested that

an auto-scroll interface would generally be useful with little to no drawback to users as they are walking.

The second possible reason that no advantages were found in any interface may be because the GRE reading comprehension tests were too difficult, and floor effects might have been present. Several of the participants mentioned that they felt that the test was too difficult, and thought it was not reflective of their actual reading comprehension. The GRE was used as it is a standardized test, and thus it was believed it would be a highly valid test of participants' reading comprehension abilities. Nonetheless, the GRE is designed to be a difficult test, and when typically done, the reader is sitting and can refer back to the text when they need to. In the current study, participants did not have the option of referring to the text, and instead had to answer all of the questions from memory. In the case of the walking group, they had the added drawback of being on the move as opposed to sitting. Indeed, the average for the walking group was far below passing ($M = 34.7\%$) and just above it for the sitting group ($M = 51.7\%$). This can be considered a limitation of the study as it is not entirely clear if no differences were found by virtue of the interfaces themselves or due to floor effects making it difficult for any to appear within the groups. Future research should look to get a more definitive answer with a reading comprehension test that can better differentiate the interfaces, and one that is generally easier.

In spite of the possible floor effects, it was still found that participants in the walking group had significantly worse reading comprehension scores than those in the sitting group. This finding is in direct contrast to previous research comparing GRE reading comprehension tests while walking and sitting, which found no differences

between the groups (John et al., 2009), although their study involved desktop computers as opposed to a mobile device. The current study seems to be more in line with research done on mobile devices showing that there is a noticeable drop off in reading comprehension when comparing sitting with walking (Bernard et al., 2007; Chen & Lin, 2016), and in general performance involved with walking (Kane et al., 2008; Mackay et al., 2005; Schildbach & Rukzio, 2010).

It was hypothesized that the addition of an auto-scroll interface would provide the benefits shown to be linked with increases in text size (e.g. Kane et al., 2008; Sanchez & Goolsbee, 2010; Schildbach & Rukzio, 2010) without the associated drawback of increases in the amount of scrolling. No notable benefits (or drawbacks) were found when comparing the auto-scroll + zoom interface with the other two interfaces. Although performance on the auto-scroll + zoom was better on almost every measure than the static interface (and worse than the non-zoomed interface), there was never a significant difference. It would make sense for the auto-scroll + zoom interface to be comparable in performance to the auto-scroll interface, but it is somewhat curious why the auto-scroll + zoom interface did not show the same performance benefits when compared to the static interface as the auto-scroll interface did. This discrepancy might be due to how the sample speed was applied to the auto-scroll speed. In the subjective measures, 70% of participants indicated that the auto-scroll speed was just right for the non-zoom interface, while 27% thought it was slightly too fast and 3% thought it was slightly too slow. In contrast, only 57% of participants said that the auto-scroll speed was just right for the zoomed interface, with other 43% having much more variable answers, ranging from far too slow to far too fast (see Figure 6). This might be because the formula for auto-scroll

speed used for the auto-scroll + zoom interface was derived from the auto-scroll interface, and would essentially multiple the value outputted for non-zoomed in interface by 50% and use that as its auto-scroll speed. It is likely that this derivation resulted in the auto-scroll speed to be less-than-optimal for the zoomed interface, and thus might be the reason why benefits were not found compared to the static interface. However, because a majority of the participants still indicated that the speed was just right, it might simply be the case that in regard to reading while walking, auto-scroll is of greater importance than text size increases. The addition of another interface that zooms in text but is manual scroll was omitted because the primary focus of this study was auto-scroll aspect of the interface. Nonetheless, the addition of this interface would have allowed for a more discernable point of comparison between the interfaces, and a better determination of the effects of text size. Therefore, this can be considered a limitation of the study, and can be better explored in future research.

The two primary adaptations in the interfaces that were explored that could have an effect on reading comprehension while walking were text size and information display. It is not clear that increasing text size had any apparent benefits to users. However, the information display method of auto-scrolling resulted in tangible benefits in the form of increased walking speed and increased reading speed. In light of these benefits, it is reasonable to think that the introduction of an auto-scroll feature reduced the total cognitive load for walking while reading, allowing these advantages to manifest. A direct measure of cognitive load was not included in the study, so only inferences of reductions based on performance benefits can be made. However, other research has shown that manual scrolling can place a large strain on Working Memory capacity (Sanchez &

Wiley, 2009). If auto-scrolling results in more positive benefits than manual scrolling, as was the case in the current study, then it should follow that auto-scrolling likely results in less working memory strain than manual scrolling. Moreover, because prior research has demonstrated a relationship between walking speed and device performance (Bergstrom-Lehtovirta, et al., 2011; Mustonen et al., 2004), the implementation of an auto-scroll display method can likely result in performance increases as a consequence of increased walking speed. Indeed, in the current study that performance increase may have been in the form of increased reading speed.

The current study had a number of similarities to Chen and Lin's (2016) study. Chen and Lin also explored the effect context has on reading comprehension, and how an auto-scrolling interface can help reading comprehension. However, the present research found results that are both consistent and inconsistent with their study. As in the current study, their results also suggested that those in the sitting group had the highest reading comprehension. On the other hand, it was difficult to determine which of the interfaces they tested performed the best. In contrast, in the current study, the auto-scroll interface performed the best on nearly all measures, and was significantly better than the static interface in reading speed, walking speed, and course completion time. The discrepancy in the findings can likely be explained by the differences in how the auto-scroll interfaces were implemented. First, in Chen and Lin the interface used the same auto-scroll speed of 355 word per minute. In contrast, the interfaces used in the current study used a customized speed based on a participant's sample time. Therefore, one would expect that the interfaces used in the current study to be more reflective of the user's reading speed, and thus more likely to show benefits. Another possible explanation is the addition of a

pause function in the present research, which Chen and Lin's study lacked. This is an important addition because if a user got distracted by the walking task in their study, they would undoubtedly have more trouble finding the location they left off at if they could not pause. Indeed, 70% of participants in the adaptive conditions used the pause feature at least once, showing that participants made use of the feature. In addition to this, the adaptive interfaces also had a reverse feature, which their interface also lacked. However, this feature was seldom used, as only 27% of the participants in adaptive conditions used the feature at least once. Regardless, it is believed that the differences in how the auto-scroll interface was implemented elucidates the differences in our results.

Although pedestrian safety was not directly looked at in the current study, the results of improved walking speed and course navigation for the auto-scroll interface do suggest that an AUI can benefit pedestrian safety. Indeed, past research has shown mobile phone use to be associated with slower walking, with this having a detrimental effect on pedestrian crossing safety (Hatfield & Murphy, 2007; Hyman et al., 2010; Neider et al., 2011; Stavrinou et al., 2011). Therefore, the implementation of an auto-scrolling AUI may help mitigate some of these potentially dangerous behaviours by increasing user walking speed and navigation abilities. Future research could more definitively explore this by comparing pedestrian crossing performance while using an auto-scroll AUI with a typical manual scroll interface.

5.2 Limitations and Future Research

The first limitation of this research is the lack of a transition between contexts. This study was designed to test the efficacy of an auto-scroll interface and as such, the

auto-scroll would trigger as soon as the participant began the study (clicked the start button). However, this is not reflective of real life, where the mobile device would have to detect that the person has started walking, and then react by activating the auto-scroll feature. Earlier prototypes of the adaptive interfaces activated the auto-scroll based on detection of movement using the phone's built in accelerometer. This was abandoned as there could be a delay in the activation of the auto-scroll and this could introduce some unforeseen confounds. Nonetheless, in actual day-to-day life, the mobile device must both understand when to trigger the auto-scroll feature (when walking) and when to stop the auto-scroll (when stopped). Future research should look to explore the transition of contexts more by looking at how and when to best implement auto-scroll and other AUI features.

Another limitation of this study is the lack of a standing condition. The addition of a standing condition would have allowed for a more comprehensive examination of the efficacy of auto-scrolling and its impact in different contexts. Indeed, in everyday life a person may transition from walking to standing several times along their destination when walking and using a mobile device. While auto-scroll may have benefits when walking, these benefits may not manifest when standing, showing again the importance of transition of context as well. Future research can look at how auto-scroll would perform in a standing condition in comparison to walking. One might even look at the value of a different type of adaptation that is better suited for standing. For example, automatic back tracking might be a useful feature when standing, as the user can reassess what they are reading. In addition to this, another limitation is the uneven number of participants in the sitting condition ($n = 10$) in comparison to the walking condition ($n =$

19). This may have resulted in one sample to have a different amount of variance compared to the other sample, potentially undermining the statistical analysis. Future research should look to remedy this problem with even sample sizes.

One final limitation is the restriction of manual scroll in the auto-scroll interface. To properly assess the efficacy of auto-scroll, participants were forced to make use of the auto-scroll feature and were not allowed to manually scroll through text. However, while a majority of the participants felt that the auto-scroll speed was appropriate, some mentioned that they would have liked to be able to manual scroll as well. This is likely for a number of reasons. One is that even though every individual has an average reading speed, the speed with which they read text is not uniform throughout the text. A user might skim through some of the parts they feel are trivial, and slow down at other more important parts. Another reason is that it is likely easier to simply manual scroll back up, instead of double tapping and waiting for the auto-scroll to go back up again. A final reason, and perhaps most importantly, is that it takes away from the users control of the device. By locking out manual scroll when auto-scroll is triggered, a user is forced to use the auto-scroll feature, and hence would relinquish some of the control they have over the device to the system. The best implementation of an auto-scroll feature would be one where it was overlaid with manual scroll. In this scenario, the user would use auto-scroll when walking, but could still manual scroll to make any adjustments they deem necessary, thus maintaining control with the user. Future research could look at the benefits of allowing manual scroll into auto-scroll interfaces, and seeing its impact on performance and user satisfaction, which one would expect to be higher in an interface that allows both.

5.3 Conclusion

The present research demonstrated how the implementation of an AUI in a mobile device can benefit a user. This was established by showing that in the context of walking, an AUI that auto-scrolls can improve navigation abilities, increase walking speed, and increase reading speed. In addition, an adaptive interface is preferred over a static interface by a majority of participants when walking. It was also found that reading comprehension shows adverse effects when walking compared to sitting, confirming once again that designers need take into consideration the context in which a user uses a mobile device. This work serves as validation towards the broader concept of developing AUIs for mobile devices that adapt to the user based on the context the user is in. As this concept becomes more developed, the importance of having “intelligence” in our systems in the form of AI and machine learning also becomes more important. Using some type of machine learning, a device can better learn when contexts change, what changes to make to the interface in response to the new context, and can evaluate if these changes help or hinder the user on an individual basis.

The present research has immediate real-world implications. The benefits in walking speed and course navigation afforded by the auto-scroll interface can have a real impact on pedestrian safety. By lessening the strain on cognitive resources, an AUI affords more resources to be available for safe navigation. Although walking while using a mobile device presents a user with potential dangers, it seems that an AUI can help mitigate some of those dangers.

References

- Baddeley, A. (2000). The episodic buffer: a new component of working memory?. *Trends in Cognitive Sciences*, 4(11), 417-423.
- Baddeley, A., & Hitch, G. (1974). Working memory. *Psychology of Learning and Motivation*, 8, 47-89.
- Barnard, L., Yi, J. S., Jacko, J. A., & Sears, A. (2007). Capturing the effects of context on human performance in mobile computing systems. *Personal and Ubiquitous Computing*, 11(2), 81-96.
- Bergstrom-Lehtovirta, J., Oulasvirta, A., & Brewster, S. (2011). The effects of walking speed on target acquisition on a touchscreen interface. In *Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services*, 143-146
- Caird, J. K., Johnston, K. A., Willness, C. R., Asbridge, M., & Steel, P. (2014). A meta-analysis of the effects of texting on driving. *Accident Analysis & Prevention*, 71, 311-318.
- Chen, C. M., & Lin, Y. J. (2016). Effects of different text display types on reading comprehension, sustained attention and cognitive load in mobile reading contexts. *Interactive Learning Environments*, 24(3), 553-571.
- Deutsche Telekom AG (2012). "Smart Payments—How the Cell Phone Becomes a Wallet". Research Report
- dscout (2016). "Mobile Touches: dscout's Inaugural Study on Humans and Their Tech," Research Report
- Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science*, 11(1), 19-23.
- Findlater, L., & McGrenere, J. (2004). A comparison of static, adaptive, and adaptable menus. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*.
- Findlater, L., & McGrenere, J. (2008). Impact of screen size on performance, awareness, and user satisfaction with adaptive graphical user interfaces. *Proceeding of the Twenty-sixth Annual CHI Conference on Human Factors in Computing Systems - CHI '08*.
- Gajos, K., & Weld, D. (2008). Usable AI: Experience and Reflections. In *Workshop on Usable Artificial Intelligence - CHI '08*.
- Hatfield, J., & Murphy, S. (2007). The effects of mobile phone use on pedestrian crossing behaviour at signalised and unsignalised intersections. *Accident Analysis & Prevention*, 39(1), 197-205.
- He, J., Chaparro, A., Nguyen, B., Burge, R. J., Crandall, J., Chaparro, B., Ni, R., & Cao, S. (2014). Texting while driving: Is speech-based text entry less risky than handheld text entry?. *Accident Analysis & Prevention*, 72, 287-295.

- Hosking, S. G., Young, K. L., & Regan, M. A. (2009). The effects of text messaging on young drivers. *Human Factors*, 51(4), 582-592.
- Hyman, I. E., Boss, S. M., Wise, B. M., McKenzie, K. E., & Caggiano, J. M. (2010). Did you see the unicycling clown? Inattention blindness while walking and talking on a cell phone. *Applied Cognitive Psychology*, 24(5), 597-607.
- John, D., Bassett, D., Thompson, D., Fairbrother, J., & Baldwin, D. (2009). Effect of using a treadmill workstation on performance of simulated office work tasks. *Journal of Physical Activity and Health*, 6(5), 617-624.
- Kahneman, D. (1973). *Attention and Effort* (Vol. 1063). Englewood Cliffs, NJ: Prentice-Hall.
- Kane, S. K., Wobbrock, J. O., & Smith, I. E. (2008). Getting off the treadmill: evaluating walking user interfaces for mobile devices in public spaces. In *Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Service*, 109-118
- Lamberg, E. M., & Muratori, L. M. (2012). Cell phones change the way we walk. *Gait & Posture*, 35(4), 688-690.
- Licence, S., Smith, R., McGuigan, M. P., & Earnest, C. P. (2015). Gait pattern alterations during walking, texting and walking and texting during cognitively distractive tasks while negotiating common pedestrian obstacles. *PLoS one*, 10(7), e0133281.
- MacKay, B., Dearman, D., Inkpen, K., & Watters, C. (2005). Walk'n scroll: a comparison of software-based navigation techniques for different levels of mobility. In *Proceedings of the 7th International Conference on Human Computer Interaction with Mobile Devices & Services*, 183 - 190.
- Mitchell, J., & Shneiderman, B. (1989). Dynamic versus static menus: an exploratory comparison. *ACM SigCHI Bulletin*, 20(4), 33-37.
- Mustonen, T., Olkkonen, M., & Hakkinen, J. (2004, April). Examining mobile phone text legibility while walking. In *CHI'04 extended abstracts on Human Factors in Computing Systems*, 1243-1246
- Nasar, J., Hecht, P., & Wener, R. (2008). Mobile telephones, distracted attention, and pedestrian safety. *Accident Analysis & Prevention*, 40(1), 69-75.
- Nasar, J., & Troyer, D. (2013). Pedestrian injuries due to mobile phone use in public places. *Accident Analysis & Prevention*, 57, 91-95.
- Neider, M. B., McCarley, J. S., Crowell, J. A., Kaczmarek, H., & Kramer, A. F. (2010). Pedestrians, vehicles, and cell phones. *Accident Analysis & Prevention*, 42(2), 589-594.
- Norman, D. A., & Bobrow, D. G. (1975). On data-limited and resource-limited processes. *Cognitive Psychology*, 7(1), 44-64.

- Pešić, D., Antić, B., Glavić, D., & Milenković, M. (2016). The effects of mobile phone use on pedestrian crossing behaviour at unsignalized intersections—Models for predicting unsafe pedestrians behaviour. *Safety Science*, 82, 1-8.
- Sanchez, C. A., & Goolsbee, J. Z. (2010). Character size and reading to remember from small displays. *Computers & Education*, 55(3), 1056-1062.
- Sanchez, C. A., & Wiley, J. (2009). To scroll or not to scroll: Scrolling, working memory capacity, and comprehending complex texts. *Human Factors*, 51(5), 730-738.
- Schildbach, B., & Rukzio, E. (2010). Investigating selection and reading performance on a mobile phone while walking. In *Proceedings of the 12th International Conference on Human computer interaction with Mobile Devices and Services*, 93-102
- Schwebel, D. C., Stavrinou, D., Byington, K. W., Davis, T., O'Neal, E. E., & De Jong, D. (2012). Distraction and pedestrian safety: how talking on the phone, texting, and listening to music impact crossing the street. *Accident Analysis & Prevention*, 45, 266-271.
- Stavrinou, D., Byington, K. W., & Schwebel, D. C. (2011). Distracted walking: cell phones increase injury risk for college pedestrians. *Journal of Safety Research*, 42(2), 101-107.
- Selst, M. V., & Jolicoeur, P. (1994). A solution to the effect of sample size on outlier elimination. *The Quarterly Journal of Experimental Psychology*, 47(3), 631-650.
- Williams, E. (2014). Predictive, adaptive mobile user interfaces: state of the art and open problems. In *Proceedings of the 2014 ACM Southeast Regional Conference*, 35-38.
- Yen, C. C., & Chien, Y. H. (2011). Rapid serial visual presentation display on a small screen: reading chinese while walking. *Perceptual and Motor Skills*, 112(3), 991-1003.

Appendices

Appendix A Text Material

A.1 Sanctuary Text

A sanctuary may be defined as a place where Man is passive and the rest of Nature active. Till quite recently Nature had her own sanctuaries, where man either did not go at all or only as a tool-using animal in comparatively small numbers. But now, in this machinery age, there is no place left where man cannot go with overwhelming forces at his command. He can strangle to death all the nobler wild life in the world to-day. Tomorrow he certainly will have done so, unless he exercises due foresight and self-control in the meantime.

There is not the slightest doubt that birds and mammals are now being killed off much faster than they can breed. And it is always the largest and noblest forms of life that suffer most. The whales and elephants, lions and eagles, go. The rats and flies, and all mean parasites, remain. This is inevitable in certain cases. But it is wanton killing off that I am speaking of tonight. Civilized man begins by destroying the very forms of wild life he learns to appreciate most when he becomes still more civilized. The obvious remedy is to begin conservation at an earlier stage, when it is easier and better in every way, by enforcing laws for close seasons, game preserves, the selective protection of certain species, and sanctuaries.

I have just defined a sanctuary as a place where man is passive and the rest of Nature active. But this general definition is too absolute for any special case. The mere fact that man has to protect a sanctuary does away with his purely passive attitude. Then, he can be beneficially active by destroying pests and parasites, like bot-flies or mosquitoes, and by finding antidotes for diseases like the epidemic which periodically kills off the rabbits and thus starves many of the carnivora to death. But, except in cases where experiment has proved his intervention to be beneficial, the less he upsets the balance of Nature the better, even when he tries to be an earthly Providence.

A.2 Education Text

The pioneers of the teaching of science imagined that its introduction into education would remove the conventionality, artificiality, and backward-lookingness which were characteristic; of classical studies, but they were gravely disappointed. So, too, in their time had the humanists thought that the study of the classical authors in the original would banish at once the dull pedantry and superstition of mediaeval scholasticism. The professional schoolmaster was a match for both of them, and has almost managed to make the understanding of chemical reactions as dull and as dogmatic an affair as the reading of Virgil's Aeneid.

The chief claim for the use of science in education is that it teaches a child something about the actual universe in which he is living, in making him acquainted with the results of scientific discovery, and at the same time teaches him how to think logically and inductively by studying scientific method. A certain limited success has been reached in the first of these aims, but practically none at all in the second. Those privileged members of the community who have been through a secondary or public school education may be expected to know something about the elementary physics and chemistry of a hundred years ago, but they probably know hardly more than any bright boy can pick up from an interest in wireless or scientific hobbies out of school hours. As to the learning of scientific method, the whole thing is palpably a farce. Actually, for the convenience of teachers and the requirements of the examination system, it is necessary that the pupils not only do not learn scientific method but learn precisely the reverse, that is, to believe exactly what they are told and to reproduce it when asked, whether it seems nonsense to them or not. The way in which educated people respond to such quackeries as spiritualism or astrology, not to say more dangerous ones such as racial theories or currency myths, shows that fifty years of education in the method of science in Britain or Germany has produced no visible effect whatever. The only way of learning the method of science is the long and bitter way of personal experience, and, until the educational or social systems are altered to make this possible, the best we can expect is the production of a minority of people who are able to acquire some of the techniques of science and a still smaller minority who are able to use and develop them.

A.3 Theatre Text

In traditional theater forms, the roles of performer and audience are completely separate, so that performance space can be said to encompass an actors' sphere and a spectators' sphere. Even when performers move out into the audience or when there is scripted audience interaction, spectators do not become performers. Finally, while stories may open up the imagination or excite audiences, according to Augusto Boal, they discourage political action by providing catharsis. The passive spectator follows the play's emotional arc and, once the action concludes, finds the issue closed. Boal reminds us that our theater etiquette creates a kind of culture of apathy where individuals do not act communally, despite shared space, and remain distanced from art.

Workshop theater, such as Boal's Image Theatre and Forum Theatre, is a response to that. In the workshop form, performance space is created for a select group of people, but the performers' sphere and the audience's sphere are collapsed: everyone is at once theater maker and witness. In Image Theatre, participants will come up with a theme or issue and arrange themselves into a tableau that depicts what that issue looks like in society today, versus what the ideal situation would be. They then try to transition from the current image to the ideal image in a way that seems plausible to all the participants. Forum Theatre, on the other hand, creates a narrative skit depicting a certain problem. After the actors have gone through the action of the play once, a facilitator, known as the joker (like the one in a pack of cards), encourages those who have watched the story to watch it again and to stop it at any time to take the place of the protagonist. The aim is to find a solution to the problem, realizing along the way all of the obstacles involved. In

Forum Theatre, just as in Image Theatre, there is not always a solution. The main goal of this form, then, is to engage in the action, to reflect, and to understand particular issues as being part of a larger picture, thus using art to re-cast what seem like private troubles in a public, political light.

The main reason Boal developed these workshop styles was to grant audiences agency so that they may create ways to free themselves of oppression. Because he found theater audiences to be locked into a passive role—just like he found the oppressed coerced into a subservient role in relation to their oppressors—he created the “spect-actor,” or someone who simultaneously witnesses and creates theater.

A.4 Sample Text

Memory loss is one of the more distinguishing traits of dementia and progressive loss of cognitive function as we age. But the results of a study performed at the University of Wisconsin-Milwaukee and published in the September 26, 2016 issue of the *Journal of Gerontology: Biological Sciences* suggest there may be an easy way to prevent or delay the onset of dementia-related symptoms, including memory loss, and you may already be doing it.

The researchers followed 6,467 postmenopausal women—all of whom were free of dementia at the beginning of the study—for up to 10 years, testing and assessing their cognitive function every year. The women self-reported how much coffee, tea and cola beverage they drank each day, and the researchers used this information to estimate their caffeine intake. They found that women who consumed more than 261 mg of caffeine a day—the equivalent of about three 8-ounce cups of coffee or six cups of tea—were less likely to develop symptoms of dementia or cognitive decline.

In the past, population studies and laboratory research with animal subjects have shown caffeine to have this same protective effect against dementia, but this is the first large-scale human study to confirm those findings. The researchers point out that while the results of this study cannot be generalized to men, one earlier study of European men did find that those who reportedly drank three cups of coffee a day had lower rates of cognitive decline over a 10 year period than men who drank less or no coffee.

Three or four cups of coffee a day is considered a moderate amount and likely to be perfectly safe for most healthy people. And drinking a moderate amount can provide an array of health benefits in addition to saving you from senility. But caffeine temporarily boosts blood pressure and may affect blood sugar levels, which can be a concern for those with or at risk of developing diabetes or heart disease, and can potentially cause stomach problems, interfere with bone mineral absorption, and disrupt sleep for some people. So before you self-medicate, ask your doctor if three, four, or more cups of coffee a day is a safe dose for you. At the same time, if you're drinking a lot of coffee every day, be sure you're not getting additional caffeine from sources such as “energy” drinks, or supplements, or you could be putting yourself in danger of medical complications resulting from an overdose.

Appendix B Test Questions

B.1 Sanctuary Questions

The author implies that his first definition of a sanctuary is

- A. totally wrong
- B. somewhat idealistic
- C. unhelpful
- D. indefensible
- E. immutable

Answer: B

The author's argument that destroying bot-flies and mosquitoes would be a beneficial action is most weakened by all of the **following except:**

- A. parasites have an important role to play in the regulation of populations
- B. the elimination of any species can have unpredictable effects on the balance of nature
- C. the pests themselves are part of the food chain
- D. these insects have been introduced to the area by human activities
- E. elimination of these insects would require the use of insecticides that kill a wide range of insects

Answer: D

It can be inferred that the passage is

- A. part of an article in a scientific journal
- B. extracted from the minutes of a nature club
- C. part of a speech delivered to an educated audience
- D. a speech delivered in a court of law
- E. from a polemical article published in a magazine

Answer: C

The purpose of the final paragraph is

- A. to sum up the main points of the author's argument
- B. to urge a solution to an increasingly pressing problem
- C. to qualify the author's definition of an important term
- D. to propose a program
- E. to suggest that man should not intervene in natural environments

Answer: C

B.2 Education Questions

The author implies that the professional schoolmaster has

- A. no interest in teaching science
- B. thwarted attempts to enliven education
- C. aided true learning
- D. supported the humanists
- E. been a pioneer in both science and humanities.

Answer: B

The authors apparently believes that secondary and public school education in the sciences is

- A. severely limited in its benefits
- B. worse than that in the classics
- C. grossly incompetent
- D. a stimulus to critical thinking
- E. deliberately obscurantist

Answer: A

If the author were to study current education in science to see how things have changed since he wrote the piece, he would probably be most interested in the answer to which of the following questions?

- A. Do students know more about the world about them?
- B. Do students spend more time in laboratories?
- C. Can students apply their knowledge logically?
- D. Have textbooks improved?
- E. Do they respect their teachers?

Answer: C

All of the following can be inferred from the text **except**

- A. at the time of writing, not all children received a secondary school education
- B. the author finds chemical reactions interesting
- C. science teaching has imparted some knowledge of facts to some children
- D. the author believes that many teachers are authoritarian
- E. it is relatively easy to learn scientific method

Answer: E

B.3 Theatre Questions

The author uses the word agency to mean

- A. profit
- B. organization
- C. publicity
- D. power
- E. hegemony

Answer: D

Which of the following would Boal consider a “spect-actor”?

- A. a person who engages in political action
- B. an audience member who finds catharsis in a play
- C. any person placed in a subservient role
- D. any actor
- E. a participant in an Image workshop

Answer : E

According to Boal, all of the following are disadvantage of traditional theater forms **except**:

- A. Such productions prevent the actors from going into the audience.
- B. Such productions provide catharsis.
- C. Such productions discourage communal activity.
- D. Such productions obstruct political change.
- E. Such productions distance the audience from the art.

Answer: A

All of the following would be characteristic of a Forum workshop **except**:

- A. Productions begin with a narrative script.
- B. Different people often play the protagonist.
- C. Some performances do not achieve catharsis.
- D. Participants arrange themselves into a tableau.
- E. Performances are guided by a mediator.

Answer: D

Appendix C Post Study Questionnaire

Thank you for participating in our study. Please answer following questions, and notify the experimenter when you are done.

How old are you?

What is your sex?

- Male
- Female
- Other: _____

Is English your first language?

- Yes
- No

What is your ethnic background?

- White
- Hispanic or Latino
- Black
- Native American
- Asian
- Middle Eastern
- Other: _____

What is the highest level of education you have completed?

- No schooling completed
- Elementary School
- High School

- Some College
- College
- Some University
- Bachelor's Degree
- Master's Degree
- Doctorate Degree
- Professional Degree

Would you say you often use your mobile device when walking?

Never 1 2 3 4 5 Very Often

What did you think about the auto-scrolling speed for the zoomed in interface?

Too Slow 1 2 3 4 5 Too Fast

What did you think about the auto-scrolling speed for the non-zoomed in interface?

Too Slow 1 2 3 4 5 Too Fast

At any time did the app crash on you/ have any noticeable bugs? Please Describe.

Rank order the interfaces based on preference beginning with your most preferred, and ending with least preferred. E.g., 1. Manual Scroll, 2. Auto-Scroll no Zoom, 3. Auto-

Scroll Zoom
